AIM

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Architecture Specification

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Abstract

This deliverable provides a detailed description of the AIM architecture. The appliances that are within the scope of the AIM project are white goods, audiovisual equipment, and communications devices. First, an overview of related projects is provided and then the AIM system architecture is introduced. Subsequently, important use cases that motivate the need for uniform residential energy management architecture like AIM are discussed. At the core of this document is an analysis of the AIM architecture that is explained in terms of the functional components needed, while their interactions are also described in detail. Finally an account of functionalities mapping on actual AIM components, is given.

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Architecture requirements specification

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Executive summary

The AIM project aims to foster a massively used technology for profiling and optimizing the energy consumption patterns of home appliances, and it has to deal with two major challenges: pursuing energy saving through concrete examples related to three application areas (white goods, audio/video equipment and communication equipment) and achieving results compatible with long-term proof for sustained impact needs. To do this, a proper architecture allowing real-time energy consumption monitoring and management - plus virtualisation of energy control - is proposed. This document describes in detail the AIM architecture that consists of six basic components namely the gateway, the EMD, the home network, the users, and the appliances.

The energy consumers are controlled by an Energy Management Device (EMD) that works as the local hub of the AIM energy control. EMD communicates, through proper communication channels called "Interfaces" with all the energy consumption actors using one (or more) physical communication media and associated protocols. The implicated communication technologies are based on wireless, Power Line or Ethernet connectivity. The interfaces are specified for communications channels among appliances (white goods, audiovisual and communications equipment) on one side and users (home users, utilities and network operators) on the other side.

EMD is in its turn controlled by an AIM Gateway through a bus interface ensuring access to multiple EMD's from a single access-point, either locally ('domestic' users) or offers a single access-point for controlling the full system remotely. The access point can be a TCP/IP or a web service port to an extranet. The Gateway is capable to become the "transfer node" between the Smart Home and the Smart Grid. The main assets of this node from the utility point of view are the exchange and provisioning of information between utility and the customer that allow implementation of services for energy saving, flexible tariffs, reliable power consumption forecasts and the possibility to store energy if required.

Requirements on AIM architecture in respect to users, utilities and network operators are divided into functional requirements on one side and technical and architectural on the other side. Requirements concerning end users are further classified in functional and non-functional requirements. Technical requirements related to white goods, including all possible internal appliance functions, network and control functionalities have been specified, considering also possibility to utilize power metering function. On the audio visual side, energy management requirements have been established, where high level connection states between EMD and the devices have been defined. Furthermore, requirements on the logical interfaces have been specified in order to complete definition of overall needs for the AIM architecture. The requirements are specified to make sure that future needs, possibly posed by the need of integrating additional appliances will be embedded without jeopardising viability of the overall architecture.

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Table of Contents

List of figures and/or list of tables

Abbreviations

A list of abbreviations is strongly recommended

ADSL	Asymmetric Digital Subscriber Line
AIM	FP7 Project number ICT- 224621 acronym
API	Application Programming Interface
A/V	Audio / Video
CPU	Central Processing Unit
DECT	Digital Enhanced Cordless Telecommunications
DSL	Digital Subscriber Line
DSL Forum TR 69	Broadband Forum Technical Report 069, a remote management protocol
DVD	Digital Versatile Disc
DVE	Device Virtualization Environment
EM	Energy Management
EMD	Energy Management Device
EnOcean	Enocean Alliance
ESTIA	FP6 Project number IST- 27191 acronym
FCC	Federal Communication Commission
GSM	Global System for Mobile Communications
Hi-Fi	High Fidelity
HTTP	Hyper-Text Transfer Protocol
HTTPS	Hyper-Text Transfer Protocol Secure
ICT	Information and Communication Technologies
IEC	International Electrotechnical Commission
IP	Internet Protocol
IPV4	Internet Protocol Version 4
IPV6	Internet Protocol Version 6
LAN	Local Area Network
M2M	Machine-To-Machine
MAC	Multiple Access Control
MID	Mobile Intelligent Device
MMI	Man Machine Interface
MUC	Multi Utility Communication
NAT	Network Address Translation
OSGi	Open Service Gateway Initiative
OSI	Open Systems Interconnection
OWL-DL	Web Ontology Language – Description Logic
PC	Personal Computer
PCF	Power Factor Correction
PDA	Portable Digital Assistant
PHY	Physical Layer
PLC	Power Line Communication
PoC	Push to Talk over Cellular
RDF	Resource Description Framework

RF	Radio Frequency
RG	Residential Gateway
RFID	Radio Frequency Identification
SIP	Session Initiation Protocol
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SSDP	Simple Service Discovery Protocol
SSL	Secure Sockets Layer
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol / Internet Protocol
UDP	User Data Protocol
UMPC	Ultra-Mobile Personal Computer
UPnP	Universal Plug and Play
WiFi	Wireless Fidelity (wireless networking)
WLAN	Wireless Local Area Network
XML	Extensive Mark-Up Language
Z-Wave	Interoperable Wireless Communication Protocol

Definitions

Use case: is a generic description of system functionality that may lead to a whole group of user applications through subsequent development. For example, the energy monitoring is a distinct function which can be exploited in building up energy monitoring applications for mobile phones, PCs, etc. It must be noted that not all use cases defined in D2.2 will be implemented in the context of the AIM project but will be solely identified in form of platform capabilities in order to become available to actors wishing to implement them on individual basis using the AIM technology.

Demonstration scenario: Is a use case that has been selected for demonstration in the WP5. This particular use case will be designed in the context of WP3&4. A demonstration scenario has to be more specific than a use case, which is the general behavioural description of a functionality: a demo scenario will correspond to a detailed step by step "walk-through" of a particular use case, with all parameters being fixed; not all actors of the corresponding use case being will necessarily be involved and not all potential branches will be taken.

Gateway maintenance: Is the process of a) updating the software of the AIM gateway, e.g. uploading new bundles, b) managing its communication interfaces, or c) modifying basic configuration settings, e.g. modification of IP addresses, configuration of NAT, etc.

Gateway management: Is the process of defining new energy saving services by means of using the AIM virtualisation environment. As for the distinction between maintenance and management, maintenance may be construed as either correction of internal faults or adaption to changes in the environment of the system, whereas management may rather correspond to evolution of the system for the introduction of added functionality. In both cases, not only the gateways are involved, but all parts of the system for which software may be remotely maintained & managed.

Personalisation: Is the process of personalising the energy saving services defined in the gateway to fit to personal usability requirements. For example John has the habit of forgetting the lights of the living room switched on. He then personalises the monitoring service of the gateway so that when the network detects that John leaves the home, it switches off the lights at the living room.

A distinction should be made between ***personalization*** and ***self-adaptation*** of the system: explicit personalization is the result of direct control from the part of the user and will usually correspond to preferences (e.g. in the cost vs. comfort trade off, or in interface settings) whereas self-adaptation will correspond to an automatic process of learning on the part of the system, taking into account feedback from the environment acquired by the system itself. This learning process may entail explicit reinforcement on the part of the user, but not necessarily so. In the example of a person forgetting to turn off the lights, personalisation could occur both ways.

1 General description of the AIM architecture

1.1 Main conceptual model

The main concept of the AIM architecture is to offer a harmonised technology for managing in real time the energy consumption of appliances at home, interworking this information to communication devices over the home network and virtualising it with the final aim of making it available to users through home communication networks in the form of standalone or network operator services.

Figure 1 illustrates the initial conceptual model that appears in the technical annex of the project to serve the logical basis for underpinning the detailed AIM architecture.

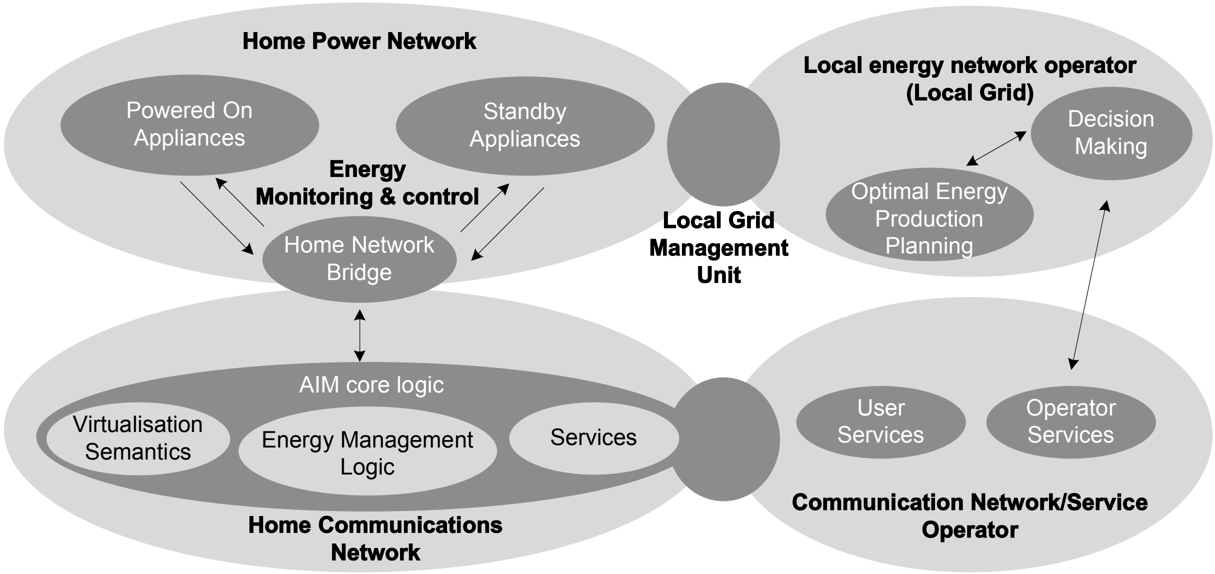

Home Power Network
Powered On Appliances
Standby Appliances
Energy Monitoring & control
Home Network Bridge
Local Grid Management Unit
Local energy network operator (Local Grid)
Decision Making
Optimal Energy Production Planning
AIM core logic
Virtualisation Semantics
Energy Management Logic
Services
Home Communications Network
User Services
Operator Services
Communication Network/Service Operator

Figure 1: Conceptual model of the AIM architecture

Main innovation of the proposed approach in managing the energy of household appliances, constitutes the bridging of functionality of home communication and power distribution networks with the aim to control the latter by the former through communication services.

The AIM gateway is a communication component that has the ability to host user services, while serving communication with user terminals over the indoor and outdoor networks and implementing control of the power line network by employing special, power line communication interfaces. The AIM gateway has a key enabling role in coupling the two home network types.

Apart from providing bridging logic, the AIM gateway implements the basic substrate for:

- The deployment of user services,
- The implementation of interoperability between network components, such as sensors, household appliances, specialised network components, etc, and for,
- The accommodation of service creation and execution environments.

Thanks to the adoption of the AIM gateway, the AIM architecture may host service requirements coming from diversified user groups and implement flexible interconnection schemes with the components needed for appliances energy control.

Concerning the last two issues, given the current time and budget limitations, in building up its architecture the AIM project will address mainly three user groups and three appliance categories. Nevertheless, to retain applicability of the resultant technology on other household appliance types, such as water heaters, solar panels, etc, the project will deploy generic solutions, wherever selection between diverged technologies should be made.

1.2 Identification of functional components

Figure 2 shows a first instance of the AIM architecture as it has been conceived by the time of project preparation. In this initial architectural diagram there are two main components with significant role in the organisation of communication between the appliances and the services of the network. The EMD and the AIM gateway are not only key components in the implementation of interoperability between the appliances and the user services, but also offer the basic communication substrate for the realisation of higher-level logic that pertains to user operations management and the control of appliances' functionality.

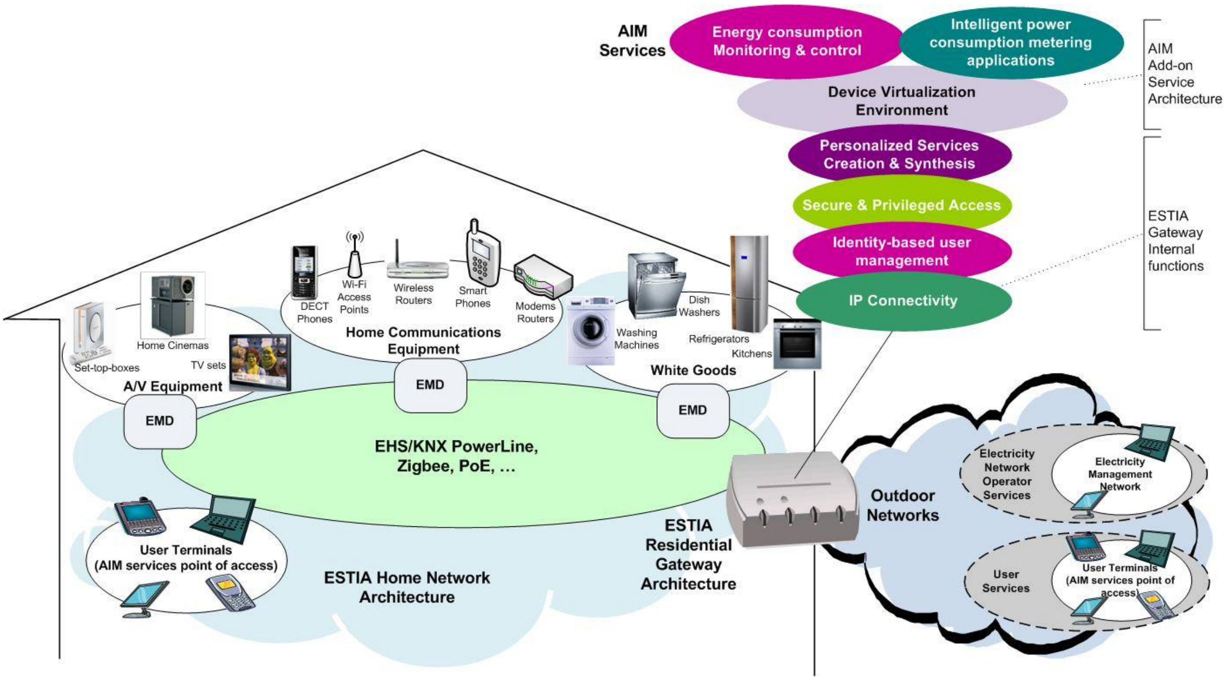

AIM Services
Energy consumption Monitoring & control
Intelligent power consumption metering applications
AIM Add-on Service Architecture
Device Virtualization Environment
Personalized Services Creation & Synthesis
Secure & Privileged Access
Identity-based user management
IP Connectivity
ESTIA Gateway Internal functions
DECT Phones
Wi-Fi Access Points
Wireless Routers
Smart Phones
Modems Routers
Home Communications Equipment
Home Cinemas
Set-top-boxes
TV sets
A/V Equipment
Washing Machines
Dish Washers
Refrigerators
Kitchens
White Goods
EMD
EMD
EMD
EHS/KNX PowerLine, Zigbee, PoE, ...
User Terminals (AIM services point of access)
ESTIA Home Network Architecture
ESTIA Residential Gateway Architecture
Outdoor Networks
Electricity Network Operator Services
Electricity Management Network
User Services
User Terminals (AIM services point of access)

Figure 2: Instance of the AIM architecture as outlined in the technical annex

To be able to identify such higher-level logic and its relations with the lower-layer network components we draw up a second instance of the AIM architecture, which is depicted in Figure 3. This instance aims at illustrating organisation of the internal architecture components according to their intra- and inter-relations within or outside the frame of the two main components.

For reasons of maintaining an overview of the system requirements, this second architecture instance has organised components in correspondence to the main requirements diagram set out in figure 1 of D2.1. This way it can be easily deduced which components are affected, when, for example, requirements for the network are in question.

The main functional entities identified in the figure above are:

- The AIM core logic, that will be hosted partially in the wide area network and partially in the AIM gateway;
- The EMD;
- The appliances and the network part that concerns communication of the appliances with the EMD;
- The user applications and the network part that concerns communication of the users with the AIM gateway.

The 'components' are the functional entities. Among these components some are totally internal to the functional entity and some appear as traversing two or more functional entities, behaving as 'links' between the functions provided by each functional entity. The AIM gateway and EMD functional entities provide the core logic of the architecture. In particular, the upper layer functions of the communication substrate are offered by the AIM gateway and the IP connectivity components, whereby it ensures communication with the users, the EMD and the appliances.

On top of the latter two components there are the identity management and secured & privileged access components. Both components belong to the same functional level because they implement essential service access functions, such as user recognition, privileges identification for service access and secured communication with the components of the outdoor network.

On top of the identity management and secured & privileged access components, there is a device virtualisation environment, whose purpose of existence is to enable residential users to define in an abstract way energy management functions, using proper semantics that will be built up in the context of the project.

The output of the device virtualisation environment is fed to the service personalisation & creation component, which undertakes ‘incarnation’ of the energy management function in the form of singular service. Finally, the services born in the latter component are exploited as individual service components in the context of energy control, monitoring or metering applications.

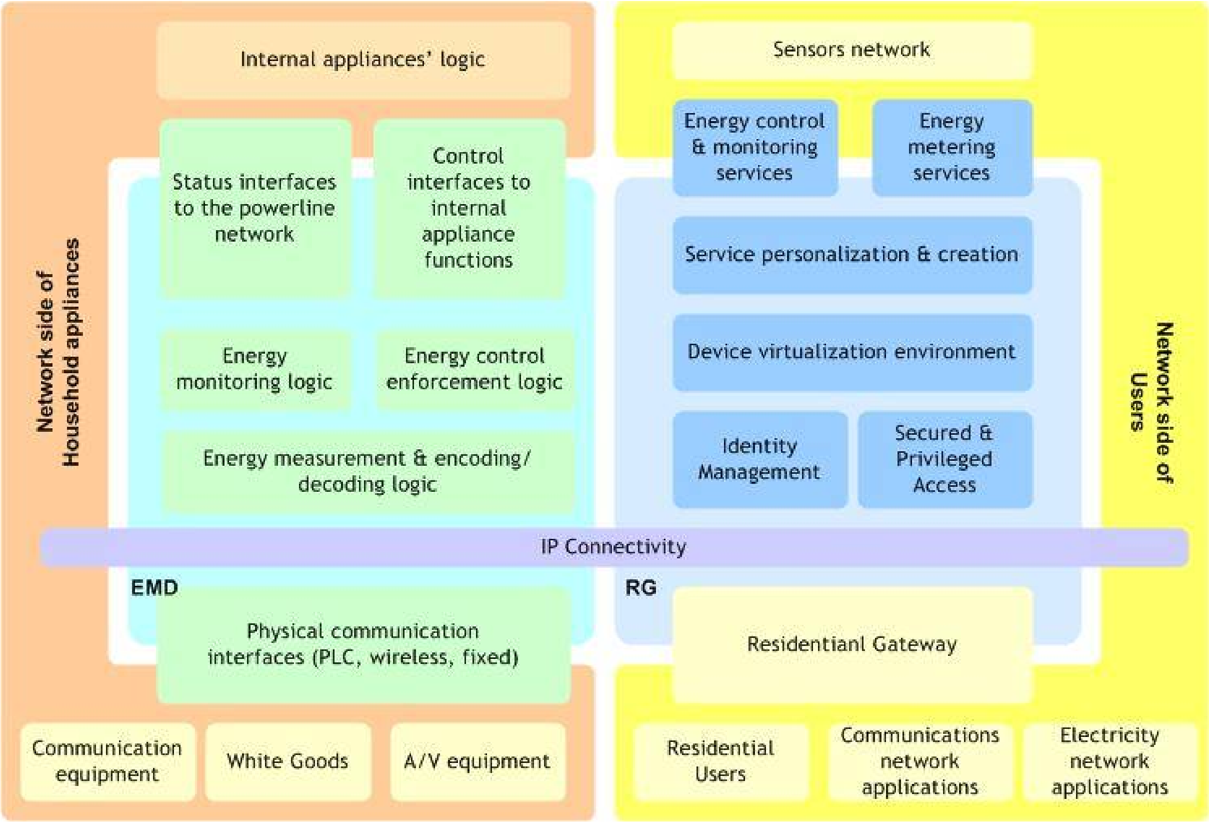

Internal appliances’ logic
Status interfaces to the powerline network
Control interfaces to internal appliance functions
Energy monitoring logic
Energy control enforcement logic
Energy measurement & encoding/ decoding logic
Network side of Household appliances
EMD
Physical communication interfaces (PLC, wireless, fixed)
Communication equipment
White Goods
A/V equipment
IP Connectivity
Sensors network
Energy control & monitoring services
Energy metering services
Service personalization & creation
Device virtualization environment
Identity Management
Secured & Privileged Access
Network side of Users
RG
Residentianl Gateway
Residential Users
Communications network applications
Electricity network applications

Figure 3: Instance of the AIM architecture

The EMD functional entity is linked with AIM gateway functional entity via the IP connectivity component, meaning that communication between the AIM gateway and the EMD is implemented over the IP protocol. The EMD is the functional entity in charge for implementing energy management functions towards the household appliances. As such, it employs two types of communication interfaces: a low-level power line interface that allows physical communication with some appliance types and also facilitates real time measurement of energy consumption for the appliances that are connected to the same power line of the mains; and a high-level type that is employed solely for exchanging control and status information with household appliances implementing custom-made communication protocols. The latter interface may not necessarily be of power line type but is subject to the choice of the appliance manufacturer.

In addition to the two core functional entities, the architecture provides a group of household appliances encompassing functions, which must be managed in terms of energy consumption, and a number of user applications grouped in three use-cases.

The two peripheral entities and the core functional entities are altogether connected via the IP protocol. Moreover, further enhancement of platform-automated operations beyond the usual user configurable scenarios is achieved through the inclusion in the home network of a sensor network that allows detection of humans' presence and movements at home. With this addition, the platform becomes capable of accommodating logic for more intelligent energy saving scenarios, such as automated switch off of the communication equipment when there is no user at home.

All four functional entities outlined in this section are specified in detail, in terms of internal logic, in chapter 4. In the following two chapters we identify the operation modes that the AIM architecture must support in order to retain compatibility with user requirements and give an account of its services and applications.

1.3 Operation modes

To enable services and applications implementation, the AIM architecture has envisaged two basic modes/profiles of operation: **monitoring** and **active control**. Formation of services will be implemented as combination or utilisation of either of these modes.

In the **monitoring mode** the home network only receives energy consumption figures of the connected appliances. These figures may be made available to users wishing to monitor in real time the energy consumption of their homes or may be aggregated by applications exploited by institutions having interest in profiling energy consumption of neighbourhoods or larger geographical areas for better energy generation planning or statistical use.

In the energy monitoring mode, power consumption values can be obtained in two ways distinguished by the ability of the appliance to communicate to the network the mode is in.

The first way relates to appliances of which power state cannot be sent to the AIM gateway by the appliance itself as either there is no possibility for external communication in form of primitives exchange or the protocols used for such purpose are confidential and therefore not beneficial for the project. In this case the EMD is used for measuring in real time the energy that these appliance types consume. As is defined in D2.3, appliances of such type are profiled experimentally, by measuring the consumed energy in each supported mode. Following this method, all experimentally measured energy consumption values are set in the database of the AIM gateway in order to be compared with the values that the EMD measures in real time.

The second way relates to appliances that "understand" the mode they are currently operating and also to the possibility of communicating it to the network in the form of known messages. Measurement of the energy consumption of these appliance types does not involve the EMD. The appliances make known their status to the AIM gateway, which retrieves the actual consumption value from the profile record of the database.

In the **active control mode**, the network has the ability to enforce changes in the status of the active or standby devices. Such a feature is useful for the implementation of energy conservation services, where a certain threshold of energy consumption is set by the user and the AIM gateway attempts to achieve it by masking particular appliance functions of which energy consumption exceeds the agreed threshold.

Switching of appliance internal modes in the active control mode, is achieved through the exchange of control primitives between the EMD and the household appliances. The notion of which appliance function must be masked or replaced by any other lower consuming one is taken by the AIM gateway after parsing the profiles of the appliances found in the home environment.

1.3.1 Services and applications

The AIM architecture is going to support a number of services and applications.

With the term **service** we identify the network logic concerted under the control of AIM gateway in order to yield particular types of network functions that can be made available to the users of the AIM system in the context of user applications. For example, the monitoring of appliances' energy consumption is a form of service that network may offer to users. Another form of service is the ability of the gateway to control internal appliance functions.

All services of the AIM system are accommodated on the AIM core logic that may be hosted by the AIM gateway or by a "cloud-based" service platform, so that the home users may manage them by removing, modifying or designating no one's using the virtualisation environment.

With the term **application** we identify the piece of software that the user exploits in order to access the services of the AIM core logic. Each application may use one or combinations of available services in order to yield desired functionality.

For better technical overview and user requirements visibility, the project has categorised user applications in three use-cases, each one addressing the requirements of particular user groups. According to those user requirements, the project will design and develop a number of applications (in the context of the WP4), at least one per each use-case, to be used for the evaluation of the overall system.

1.4 Security design of the AIM architecture

1.4.1 Design of authentication, identity and policy management

The residential gateway (RG) with the device virtualisation environment (DVE) is the main access point for the end-user of the AIM system. Therefore the realisation of authentication, identity and policy management rests on the RG.

Access to the system is available:

- Locally by accessing directly the DVE via a web based Graphical User Interface (GUI)
- Remotely by mobile phone service managed by telecommunication operator

Local access: The home access to the DVE services is possible through a Web GUI. Access to the GUI is protected by a username and password login. Since the local GUI is already located in a secure environment with limited access (only family and guests) this security mechanism is sufficient for local authentication. For access over a WiFi network, the communication channel must be protected by at least WEP or WPA security.

Remote access: The telecommunication operator provides a mobile GUI in order to let the user access some DVE services when he/she is outdoor. Outdoor user identification for the AIM system is provided by the telecommunication operator. He is able to recognize the users through their mobile SIM number and filter the request in the telecom platform before reaching the households.

The DVE - telecommunication operator communication is provided by a Web Service (WS) exposed by the DVE through the RG. The WS communication is protected by three security levels:

1. The GW that hosts the DVE software has a firewall that accept connections only from the telecommunication operator IP
2. The entire communication is based on the secure protocol HTTPS
3. The connection to the web server that hosts the DVE WS require a user and password authentication

The management of user identities in the AIM system in the household is handled on the RG by the DVE. Each user of the DVE is assigned to a role, which then determines his or her access to the system. Three roles for the local GUI are already known today:

- administrator
- advanced user access
- basic user access

Furthermore a user for external access can be seen.

For these roles a policy-based access to devices in the DVE is established. Each role is related to a different view of the local GUI. When a user accesses the GUI he is automatically directed to the GUI view associated with his role.

- A basic user, generally associated with a common user with little technological experience, has access only to the simplest functions of the DVE (i.e. program a new task on a device). Major changes requested from the basic user require an administrator intervention.
- An advanced user has more functions available than the basic user. He has full control of the devices and environmental settings related to him.

They are both not able to access and modify system settings that are managed only by administrator. Typically, users and their policy are generated during installation phase of the AIM system. Management of these policies itself has to be restricted to users with administrator role, of course.

A detailed description of the authentication, identity, security and policy management in the DVE will be provided in the Deliverable 4.3.1.

Another part of identity management is the management of the DVE identity when communicating with external networks for privacy reasons. Controlling the information accessible from outside networks is already possible through the access limitations for different roles. Privacy can also be ensured by removing the identifying information from the data. This requires an intermediary node, which shields information like IP addresses from the host in the outside network. For the telco operator's services privacy is only limited to which information can be accessed, as the telco knows the IP addresses assigned to the household and must connect the mobile GUI running on a smartphone to the matching AIM system. For the utility operator a communication scenario with pseudonymity can be constructed. The goal would be to deny the utility knowledge of specific household information when receiving the schedule of energy consumption for each household. Here the telco operator would act as a pseudonymiser, masking the DVE ID sent as identifier with a pseudonymous ID. The utility would then only know that these households with their scheduled consumption exist and could address them for load saving request by their pseudonym. The telco operator would be able to undo the pseudonymisation.

1.4.2 Communication through firewall and NAT

Communication between a home network running behind a router with dynamic IP addresses and a firewall is a standard problem for households using e.g. DSL connections. Therefore several solutions for establishing communication with a node behind a firewall and NAT exist.

The easiest possibility is to open a pre-defined port in the firewall. The opened port is then re-routed with NAT forwarding rules to the residential gateway (RG). Security in this scenario has to be provided by the RG. Since the DVE external interfaces of the RG are based on Web Services, the opened ports should be HTTP or HTTPS, which is more secure.

Alternatively, a virtual private network (VPN) can be established between the communication node on the outside and either the router itself or a VPN gateway in the network. In the latter case, VPN connections have to be re-routed to the VPN gateway. The security features of a VPN enable the external host's communication to be treated like a node on the local network.

Both scenarios are standard internet repertoire and can be employed optionally.

1.4.3 Security architecture and the H interface

Before discussing the comments regarding the H interface, it should be advised that during the implementation of the AIM architecture described in D2.2 the implementation of a physical interface H was discontinued. This decision was taken in D3.3.1, submitted in September 2009, in section 2.3.

As described in D3.3.1, section 2.3, a secure communication method to and from the operator network is possible. An EMD with security capabilities can use a ssl/ssh secure socket layer communication, which would allow direct access through an opened port of the router's firewall. This technology is a proven secure protocol with millions of applications today.

For EMDs without security capabilities, a logical communication interface H can be created by connecting to the Residential Gateway (RG) and using the RG as a proxy for the EMD communication. The security implementation for accessing the RG is then used for the access to the EMD.

Both approaches include the requirement of user empowerment. In both cases the user decides, to whom he gives the credentials (keys, certificates, passwords) necessary to access the EMD – either directly or via the RG. A detailed management of rules for access control can be implemented on each device. This allows an administrator to define access rights different users. When using the RG as single point of access, the rights management can be performed by the device virtualisation environment (DVE). A single EMD with direct external SSL access has to be either synchronised with the RG or use separate access control mechanisms.

The concept of access control is a well-known instrument in ICT. Since its bearing on energy savings is limited, it is not considered a primary concern for the AIM project. The approach of using the RG as the single point of contact between outdoor network and home network allows enhancing the AIM architecture with access control at a later point in time.

2 Analysis of state of the art and impact on AIM architecture

2.1 Introduction: Trends in the area of energy saving technologies

2.1.1 Trends in the area of low power components

For many years the situation in CMOS technology development was twofold. For all portable equipment such as mobile phone or cordless phone energy saving it was a key issue, not for CO_2 reduction, but for convenience: to extend the operating time before recharging. Significant effort was spent to that aim. Special technologies and libraries have been developed with low power consumption at the expense of performance. Circuit level means such as dynamic clock reduction and switched (gated) clock have been implemented. Design tools have been adapted to support these features (normally tools assume clock signal). Power down, sleep modes and switch-off of temporary unused blocks further improve energy saving.

For all wired equipment, however, energy saving was not an issue for decades. Performance and time-to-market were the main goals, both features having rather tendency to increase energy consumption.

Hence the potential for power saving for chips in wired applications is high. But in practice power savings will need long time and will be costly. Why?

1. Low power CMOS technologies cannot be used for wired components. They are too much optimised for power saving at the expense of performance. New processes will have to be developed with power-performance trade-off optimised for the applications.

2. Mobiles and handhelds have one single low voltage power supply. In wired applications the environment has sometimes much higher voltage values. Additional protection means are needed such as SoI (silicon on insulator) or higher breakthrough voltages.

3. Although circuit level power saving means such as gated clock are known their application to existing circuits need complete rework of existing circuits. In some cases building blocks would have to be redesigned from scratch. This includes the costly regression tests and bears the risk of introducing new errors.

4. In the past for the sake of reducing development time building blocks contained unused parts, as their removal would have consumed more time.

5. A technical fact is that future CMOS technology shrinks will have increased leakage current. CMOS technology normally has no bias current and consumes energy only at low-high/high-low transitions, hence proportional to the clock. Halting the clock or reducing it to very low values drove energy consumption to almost zero. This advantage will be lost for ultimate nano-scale CMOS technologies. Instead a trade-off between power dissipation, area (cost) and performance will have to be carefully obtained for each application.

Another aspect is that all components of IT appliances are still under high cost pressure, and time-to-market is still a major goal. Who is willing to wait one more year for a low power home gateway, while his colleague/ friend/ neighbour already benefits from the new functionality? And will he accept the higher price? Hence the advent of low energy chips will depend to a large extent on the consumer behaviour.

2.1.2 Trends in area of microelectronics

Today’s trends in consumer electronics devices are leaning towards the integration of multiple functions in a system-on-chip design. Battery-life concerns require management of active and standby power as well. The designs today address power issues from the very beginning.

Designers are now taking an architectural view of power. Instead of relying solely on physical optimization techniques, they are focusing on power closure early in the design cycle, starting with the system level, followed by RTL, gate, and layout. The basic idea is that every specific stage of the design flow can help saving energy.

Every consumer-electronics products today is designed in order to do accommodate more functions with reduced need for energy. Squeezing more and higher performance logic into smaller areas requires power management, including attention to packaging, cooling, heat absorption, and dissipation.

2.1.3 Trends in area of software

In addition to choosing low-power components and/or reducing leakage current in their designs, producer has started writing more efficient software control. Inefficient software design and implementation can void power saving gain at component and system design stage.

As the power consumption of the involved component depends also by the software that control the frequency, operation mode, and pin states. The most efficient power-management scheme controls each component's power supply in a device, through software, shutting off power to components not needed, or placing components in sleep mode.

A lot of focus appears to be on power-aware physical implementation vendors, including clock gating, voltage domains, power-aware-clock placement, gate sizing, and dual-Vth optimization.

To deal with power-management issues on power analysis and optimization at all levels in the design flow, from architecture to sign-off. New complementary tools have been developed as like as optimization platform for concurrently reducing the active and leakage power while maintaining timing and signal integrity.

2.2 Proceedings of standardisation bodies/industrial forums

This chapter summarizes information on governmental, private and industrial bodies working on energy saving applications and environmental impact mitigation strategies. Details of these bodies have been extracted from the Methodology deliverable D1 of the ITU Focus Group on climate change (http://www.itu.int/ITU-T/focusgroups/climate/).

Table 1 provides an overview of standardization work in progress. This ranges from the development of standards for the collection of data that are used in climate models through to the labelling of products sold to the general public. Further details of the work of the various bodies are given in the subsequent sections.

Area	*Organization*	
	International	**Others**
Policies	**UNEP and World Bank, International Energy Agency**	**European Commission, OECD**
Indicators and statistics	**WMO**	**OECD**
Data collection	**ISO TC 211**	**IEEE SCC 40**
Environmental managem	**ISO TC 207**	**-**
Corporate reporting	**ISO JTC1/SC7**	**Greenpeace, GHG Protocol Initiative**
Energy efficiency of equipment	**IEC, ISO, ITU-T**	**ATIS, CENELEC, Energy Star, ETSI**
Energy efficiency of networks	**ITU-T**	**Ethernet Alliance, Energy Efficiency Inter-Operator Collaboration Group, FTTH Council, IEEE P802.3az, TIA**
Energy efficiency of data centres	**-**	**Efficient Servers, Green Grid, TIA**
Electronic waste	**-**	**Basel Convention (MPPI & PACE), European Commission, TTA**
Equipment labelling	**-**	**Collaborative Labelling and Appliance Standards Programme, CEN/CENELEC, Energy Star, TCO, Electronic Product Environmental Assessment Tool (EPEAT)**

Table 1: Overview of standardization bodies work

As an extensive analysis of these standards will be made in the WP6 deliverables below we present two bodies that are mostly relevant to the work of AIM: the ITU Focus Group on climate change and the EE group of the ETSI, on the built up of environment-aware communication technologies.

2.2.1 The ITU FG on climate change

The Focus Group has the scope of identifying, from the standardization viewpoint, within the competences of ITU-T, the impact of ICT on Climate Change, in particular the reduction of ICT's own emissions over their entire lifecycle (direct impact), the mitigation that follows through the adoption of ICTs in other relevant sectors (indirect impact), and facilitating the monitoring of relevant climate parameters.

With respect to this scope, the FG analyzes and identifies gaps in the areas of definitions, general principles, methodology and appropriate tools to characterize the impact of ICTs on Climate Change and support the development of appropriate international standards.

The FG is currently working on three deliverables, D1 on terms and definitions, D2 on gap analysis of existing standards and D3 on methodologies for the calculation of the impact of ICT on energy saving and CO_2 emissions.

The AIM project has already performed a project presentation at the group's plenary meeting held on 1st September 2008 and three contributions to deliverable D2. Furthermore, the project is co-editor of deliverable D2 and plans to continue contributions to D3, after D2 is finalised at the end of the year 2008.

2.2.2 ETSI EE

The Technical Committee EE is responsible for defining the environmental and infrastructure aspects for all telecommunication equipment in different types of installations.

The Environmental activity covers:

- Environmental conditions on the telecommunication equipment (mechanical, biological and climatic conditions);
- Active substances (mechanical and chemical);
- Equipment acoustic noise emission;
- Environmental tests for all telecommunication equipment and facilities, including customer premises;
- Observation of European environmental legislation, in terms of ecological aspects, and assessing its impact on Telecommunication infrastructure and equipment.

The infrastructure activity covers:

- Definition of the power supply interfaces of all telecommunication equipment, installed in telecommunications centres, access network and in customer premises. This includes aspects of power supply system, earthing and bonding methods of telecommunication equipment and supervision and monitoring of power and cooling systems;
- Definition of equipment practice for telecommunication equipment installed in telecommunication centres and outdoor enclosures and of the thermal management standards for the co-location of equipment delivered by different suppliers in the same facility or ETSI rack.

Environmental activity in terms of ecological aspects covers the combination of climatic, physical, chemical, and biotic conditions that may affect the growth and welfare of organisms and nature conservation. In particular:

- The reduction of energy consumption in telecommunications equipment and related infrastructure;
- The alternative energy sources for powering telecom/datacom equipment.

The main standards produced and maintained by EE are:

- EN 300 019 series: Environmental conditions and Environmental tests for telecommunications equipment;
- EN 300 132 series; Power supply interface at the input to telecommunications equipment;
- EN 300 119 series: European telecommunication standard for equipment practice;
- EN 300 253: Earthing and bonding configuration inside telecommunications centres.

EE liaises with the major worldwide standard organizations (e.g. ATIS, IEC, ITU-T CENELEC) on the fields covered by EE. The EE Technical Committee comprises representatives from the Telecommunication network operators and equipment suppliers of Europe, China, Japan and the US.

Furthermore, in the frame of the EE/EE2 group (powering and control/monitoring interface), ETSI has recently publicised the new standard ES 202 336-1 on the control/monitoring interface for network technical environment in the telecom/datacom premises. This interoperable standard is open and using TCP/IP http XML and so is in line with NGN TISPAN work and the IETF specification for alarm and performance supervision of internet network.

As the project build on the latest NGN technology, in this specification and in the sections related to interfaces, the consortium is evaluating this standard with the intention to adopt it in the implementation of the service management interface.

2.3 Communication technologies

2.3.1 In-house communication technologies

There are many field bus communication technologies on the market for different uses, like car technology, industrial automation and home and building automation.

For the in-house communication in the AIM project the short distance communication based on wires or wireless technology is the most relevant. Wired networks like IEEE 802.11 and Power Lines are common. In some cases special communication networks based on proprietary lines could be found. For technical equipments of homes and buildings, like heating, climate, lighting, household appliances and alarm equipment, different companies developed their own field busses. Main standards in building automation are LON, LCN, BACnet, KNX, EIB, EHS and BatiBUS. In the following, a short abstract of these technologies is given:

- LonWorks (LON) is a field bus system owned by Echelon. It is used for industrial-, building- and home applications. LON offers features like decentralized networks including routing facilities. The used protocol is called LonTALK and is standardized in EIA 709.1 and ENV13154-2. The following transmission media are possible: Twisted Pair, Power Line, Radio, Infrared, and fibre optic.
- LCN stands for Local Control Network and is designed to fulfil all demands on modern building control and automation requirements. It represents an automation system which can be easily implemented in any kind of building, like private homes, schools, hotels, hospitals, office buildings of any size,etc...
- BACnet (Building Automation and Control Networks) was developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). BACnet is an American national standard, a European standard and an ISO global standard. BACnet defines multiple physical architectures to handle high and low speed networks, as well as point-to-point connections. This emulates the structure of most automation systems.
- The Konnex (KNX) Technology is an open standard for all applications in home and Building control. It was established by the Konnex organisation in a convergence process with the former European Installation Bus (EIB), BatiBUS and European Home Systems (EHS). KNX is mainly downward compatible with these busses. In the KNX standard for the physical layer the following transmission media are defined:
    - Twisted Pair,
    - Power Line 110 (PL110, center frequency110 kHz, 1.200 Bit/s) (EIB compatible)
    - Power Line 132 (PL132, center-frequency 132 kHz, 2.400 Bit/s) (KNX, EHS compatibility in KNX „A-mode“))
    - Radio frequency (RF), 868 MHz, 38,4 Kbit/s

  KNX brings a lot of comfort and flexibility to homes and buildings. The KNX is called to be "the world's only open STANDARD for Home & Building control". The first KNX Standard 1.0 was defined in 1999. It is specified in the European standard EN 50090 and the international standard ISO/IEC 14543-3.
- The European Installation Bus (EIB) is the successor of Installation Bus (Instabus). It is a decentralized open system to manage and control electrical devices within a facility. EIB allows all electrical components to be interconnected through a proprietary electrical bus. Every component is able to send commands to other components, no matter where they are located. All devices within the network are connected with an electrical bus made of twisted pair cable. The EIB bus topology is assimilated to home and building constructions. It is based on a peer-to-peer network in combination with couplers. The EIB is one the leading field busses in Europe for home and building applications. EIB is an open standard and was developed to increase power savings, security, comfort and flexibility.
- European Home Systems (EHS) defines architecture for device communication, discovery and control. Through the EHS network, a white goods appliance can advertise its state and

services and can receive remote commands. The European Committee of Manufacturers of Domestic Equipment (CECED) defines unified objects and actions for white goods appliances. As transmission media are defined: twisted pair, powerline, coaxial cable, radio frequency, Infrared

- BatiBUS presents one of the first field busses for home and building automation. It was developed to control sensors, actors and appliances and make communication between them possible. Applications for this bus are climate and ventilation, illumination and lighting and security and alarm technology. Twisted pair cables will be used as transmission medium. BatiBUS is standardized by CENELEC and under ISO/IEC as JTC1/SC25.

All these standards should be interoperable with the AIM EMDs and equipment. It should be able to fit and be a part of the AIM architecture.

2.4 Research projects

A number of research projects are active in the field of energy management technologies.

Project Acronym	Field of work
DINAR	Management of energy sources and supply
DEHEMS, BEAWARE, BEYWATCH, AmI-MoSES, DIADEM, INTUBE	Monitoring technologies for CO_2 mitigation, energy sparing
E4U, GENESIS	Synergy creation and policy shaping of energy aware initiatives for Labelling, CoC, etc

Table 2: Relative research projects and area of involvement

AIM is mostly related to those projects working on monitoring issues and in particular with BEYWATCH and DEHEMS. Both projects deal with technologies of household energy monitoring, as well as with methodologies for “connecting” households’ energy consumption with CO_2 emissions. With regard to these two projects, AIM offers the enabling technology that allows generic profiling and energy measurement of the appliances composing the home environment. Moreover, through its use-cases, AIM offers a generic methodology for appliances energy management and control that can be adopted by the two projects in the development of their monitoring solutions.

A brief description of these projects can be found in Annex: “Related research projects description”.

2.5 Challenges and identification of progress beyond state-of-the art

The challenges in the state-of-the-art affecting the project are summarised in chapter two of this deliverable, where the trends in the area of energy saving technologies were identified, specifically in low power components, microelectronics and software.

Concerning the trends in the low power components, they affect the design of the AIM low power home gateway. Concerning the trends in the microelectronics, the fact that every consumer-electronics products today is designed in order to do accommodate more functions with reduced need for energy affects the project work in the sense that AIM architecture will make use of these functions to manage the energy consumption reduction.

Concerning the trends in the software, the efficient power-management scheme for controlling each device components' power supply, shutting off power to components not needed, or placing components in sleep mode were considered in the AIM's Energy Management Device (EMD).

Adopting as the baseline of its work plan the state-of-the-art approach introduced by the ADSL Forum, the project will extend the concept of using discrete power mode levels for mapping the various communication modes of xDSL modems and DSLAMs, in the operation of white goods (refrigerators, ovens, washing machines, dryers), audiovisual equipment (TVs, DVDs, Set-top-Boxes) and home communication devices (wireless routers, DECT phones, residential gateways, modems), and will introduce new power levels appropriate for mapping the modes of operation of all household appliances. This way it will be made possible to associate, the power consumption of each household appliance internal function with one metric, the power mode level, and thus devise the basic technology for "green" products, featuring partial power up capabilities organised in "user logic" blocks.

Having devised a number of power modes for use by all home appliances, and a technology for the virtualisation of their power consumption, the project will work on profiling their energy consumption by associating the energy consumed by the appliance with the power mode it is in. This will be made possible by processing the real time power consumption measurement being sent by the appliance over the home network to a central processing point (i.e. a residential gateway) with its current power mode. Achieving this goal will allow the project to introduce accurate power metering services to be hosted in the home network (e.g., on residential gateways as OSGi services) or be offered on standard terminals through operator networks.

Having defined discrete modes of operation, the project will be able to draw up a new state-of-the-art activity, that of establishing mechanisms for appliances functionality virtualisation using semantics technology. With this new technology the user will be able to program alone energy resources distribution among the appliances at home by configuring energy consumption per appliance type and internal function.

Concerning the problem of stand-by devices power consumption management, the project will draw up a new state-of-the-art power management technology that will feature intelligence in tracing and switching off stand-by devices, autonomously, by invoking special, network controllable, power switching devices. This technology will be mainly based on the interception of events, being sent over the home network to a centralised control point at the moment an appliance enters the stand-by mode, and in more intuitive scenarios, on the processing of the power consumption measurement.

3 Specification of use-cases

The functionality that will be offered by the AIM system is intended to be used by four different types of users, namely utility providers, telecom operators and third party service providers, device manufacturers, and of course the local users themselves. This chapter provides representative use cases of the AIM system that were developed from these four distinct directions. Note that we do not attempt to provide an exhaustive list. The outcome of the discussion of this chapter will motivate the need for specific functional components in the AIM architecture.

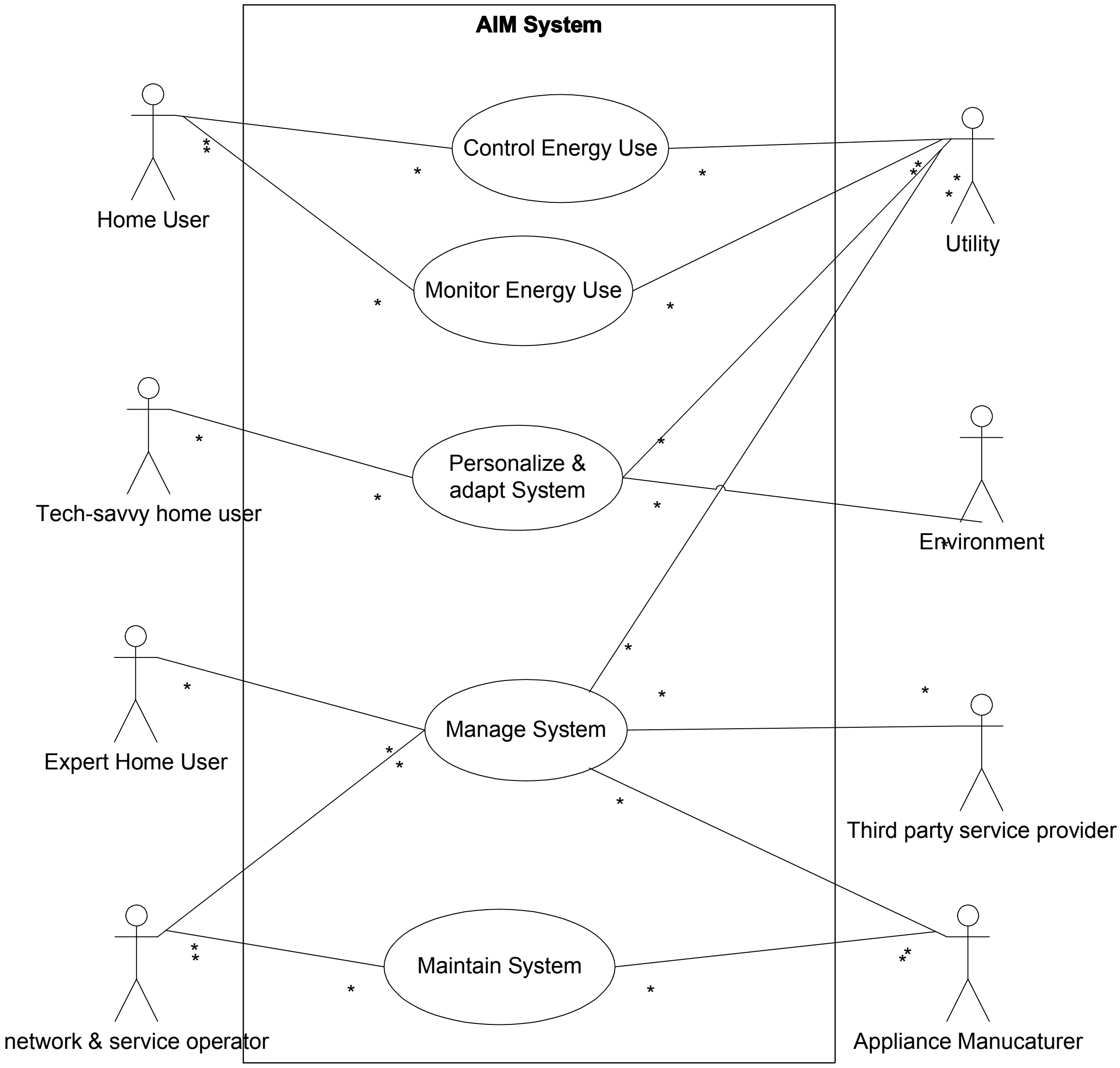


Figure 4: Example of responsibility use case

These diagrams represent as ellipses the top-level use cases main functionalities of the system, inside the boundary of the system (rectangle), with the actors (external to the system) who are involved in these functionalities.

The distinction between management, maintenance and personalization of the system is explained at the beginning of this document.

The distinction between three possible roles of the user is not set in stone and some users will obviously straddle all three roles depending on their inclination. What is important is the idea that the system can be operated in default mode (corresponding to the default "home user" role) without any tinkering or even requiring reading a user manual.

The "tech-savvy" home user does at least read the user manual and adapts the system to his/her own preferences. The expert user is able to engage in adaptations that are more technical and may update the system himself when e.g. new equipment is added.

The most difficult and/or tedious maintenance tasks (lifecycle of software, correction of bugs, etc) are supposed to be performed by service providers.

For each user type a number of services are feasible concerning energy use management and energy use monitoring.

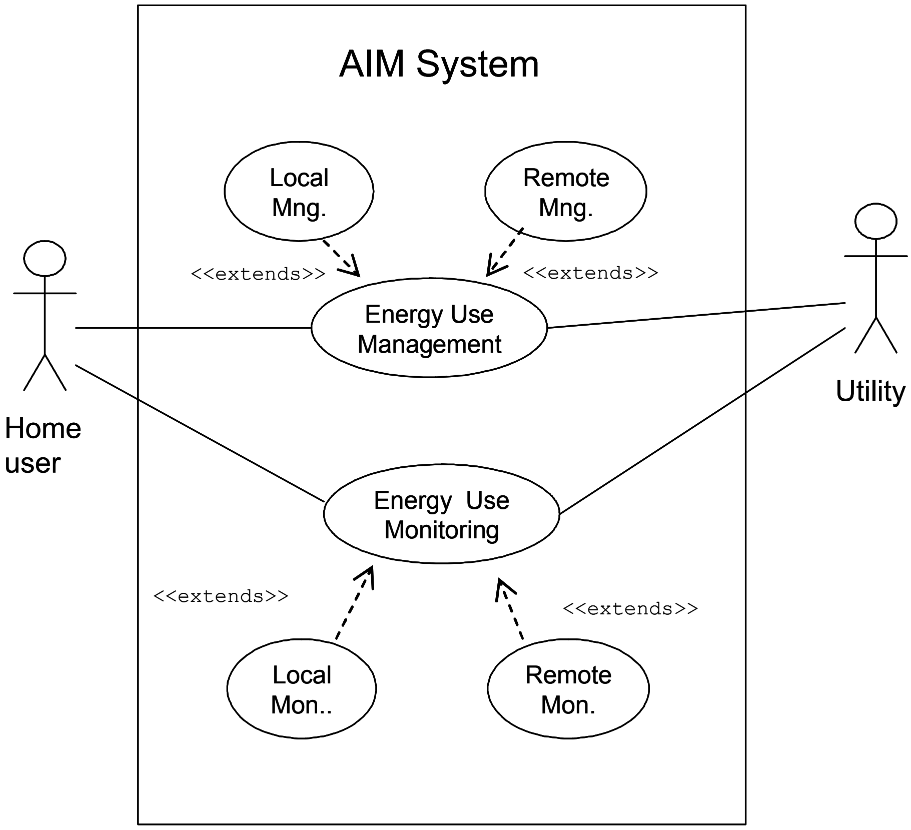


Figure 5: Feasible services for the AIM system

3.1 General sequence charts

Following the description given above, in this section we outline the sequence charts that convey the operation of the basic functions of the architecture.

In sections below the term ‘remote’ is valid for both indoor and outdoor usage of AIM services. Its adoption has been deemed necessary for the differentiation between the normal user-appliance manual interaction and the envisaged AIM-related user-appliance, through the network.

In the figures depicted below the dashed lines symbolise return/response messages and the full lines originating messages.

3.1.1 Remote monitoring

The remote monitoring is a core AIM use case that involves all AIM entities. In the monitoring use case the user submits a request for monitoring the energy consumption of the home environment, a specific appliance or a set of appliances and receives back a real time energy consumption figure.

As it is depicted in the figure below, the gateway has the role of request coordinator towards the appliances and that of the energy value aggregator and estimator, whereas the EMD undertakes routing of the requested message toward the target appliance(s) and the reception of the corresponding responds.

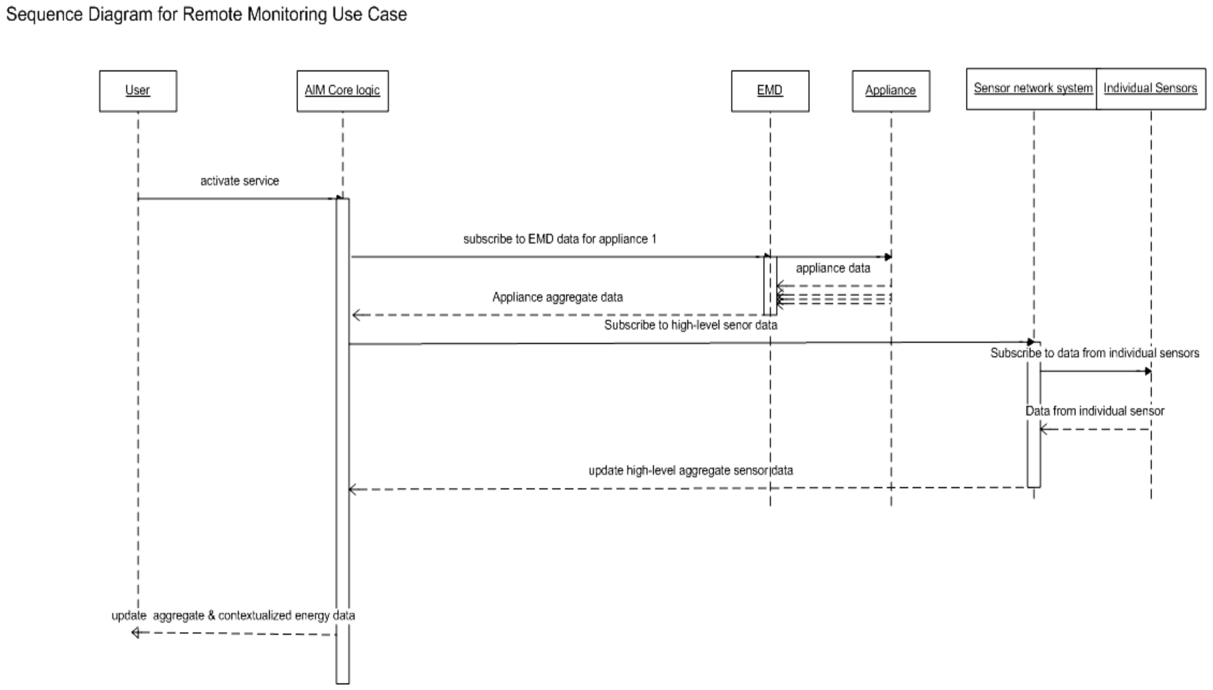

Sequence Diagram for Remote Monitoring Use Case
User
AIM Core logic
EMD
Appliance
Sensor network system
Individual Sensors
activate service
subscribe to EMD data for appliance 1
appliance data
Appliance aggregate data
Subscribe to high-level senor data
Subscribe to data from individual sensors
Data from individual sensor
update high-level aggregate sensor data
update aggregate & contextualized energy data

Figure 6: Remote monitoring[1]

3.1.2 Remote control

In the control use case the user or the AIM logic itself submits to the EMD a control request for for a specific appliance or a set of appliances and receives back an appropriate acknowledgment.

As it is depicted in the figure below, the gateway has the role of request coordinator towards the appliances and that of the energy value aggregator and estimator, whereas the EMD undertakes routing of the requested message toward the target appliance(s) and the reception of the corresponding responds.

[1] Dashed lines: return/response messages, Full lines: originating messages

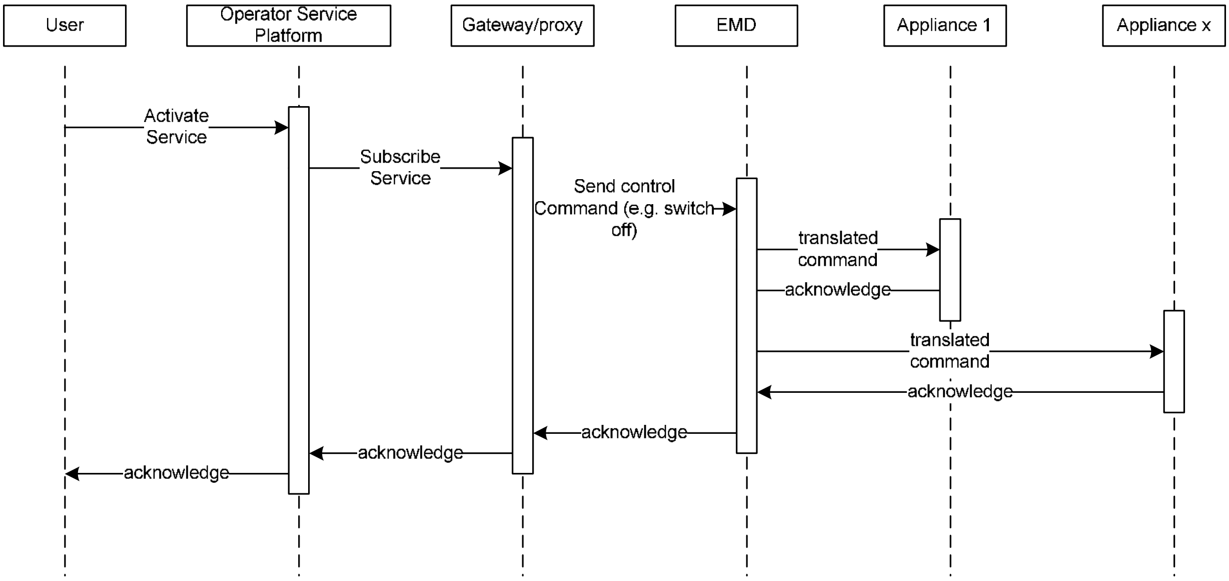


Figure 7: Remote control

3.2 Operator

The following section presents in detail several use cases that are important for the telecom operators. They are mainly focusing on the energy management related services. Detailed UML diagrams are also provided.

3.2.1 UC Operator 1: service provisioning

Description

This scenario describes the service provisioning. It involves two entities: the third party that has developed a service and the operator which checks the service bundles and can guarantee uploaded software in the AIM gateway.

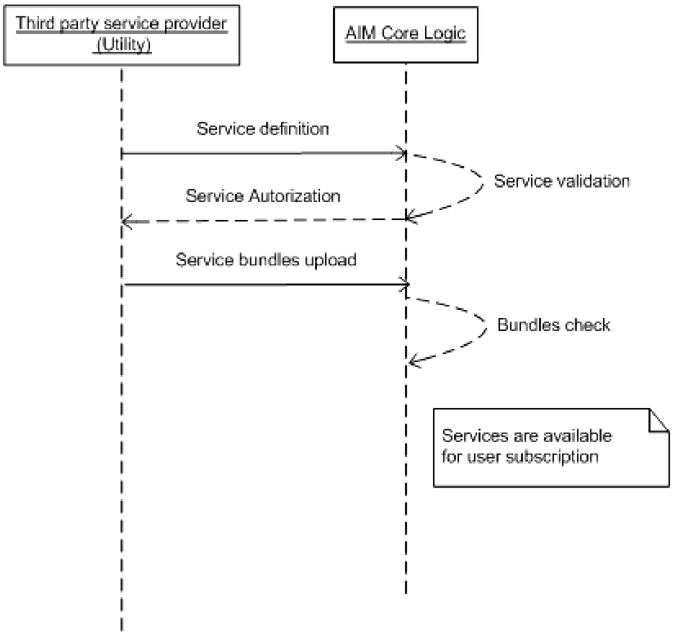


Figure 8: Service provisioning

3.2.2 UC Operator 2: service subscription

Once services are available on the operator platform, users can subscribe to a service. He selects the service on the platform, installs and activates the service.

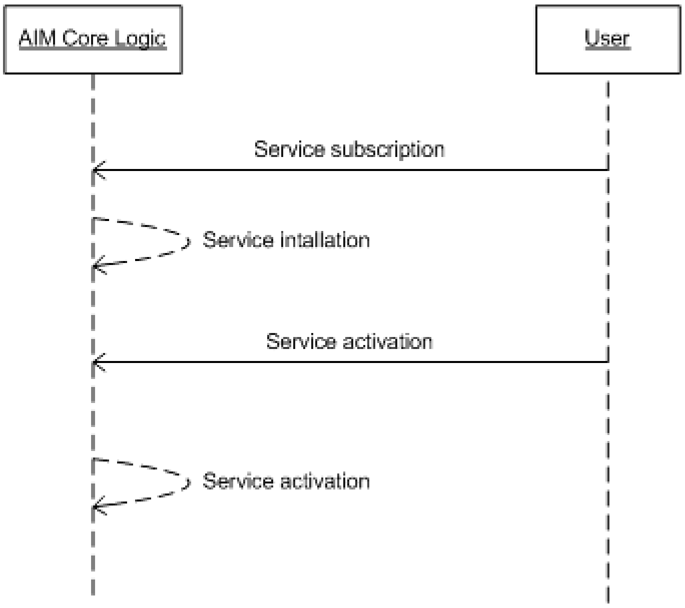


Figure 9: Service subscription

3.2.3 UC Operator 3: service configuration

The user can modify some parameters of his services. The Service platform offers a graphical interface to modify parameters. If one or more parameters are modified, the Telco bundles of the AIM gateway wake up service bundles. A telecommunication API allows service bundles to upload new values of parameters.

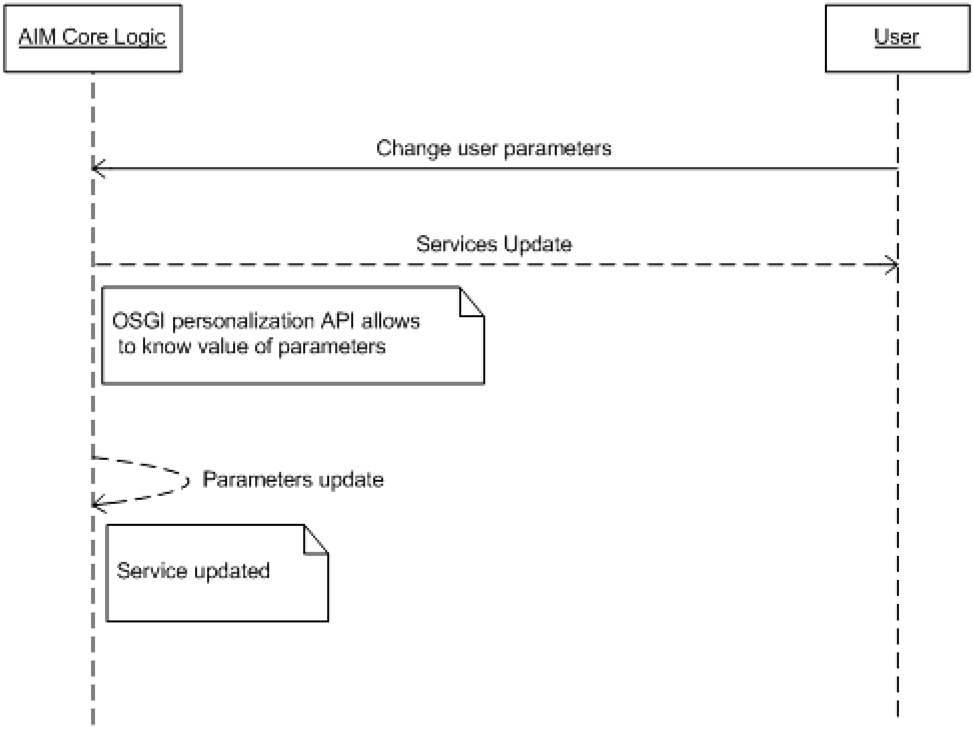


Figure 10: Service configuration

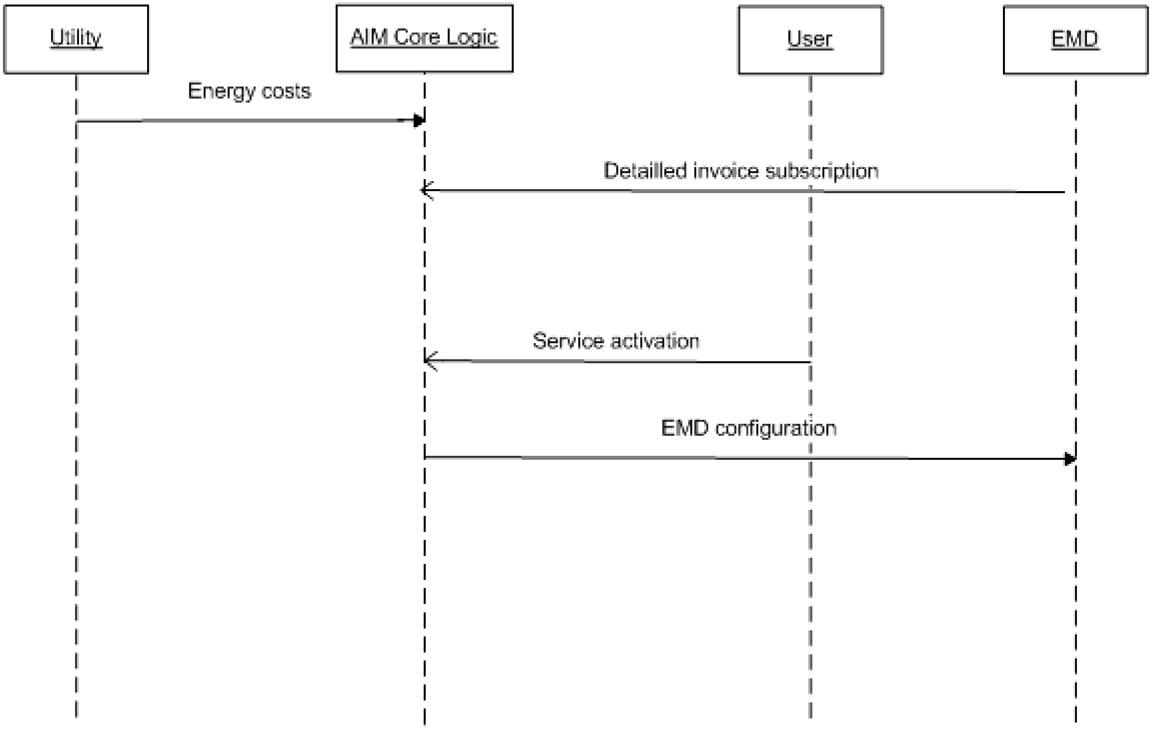
3.2.4 UC Operator 4: detailed invoice

Mister Smith considers his electricity invoice too expensive. He would like to understand why his home is so energy consuming and how he can reduce himself his invoice.

He has already subscribed to Orange services and has access to the Orange portal named "MyHouseOrange.com". The portal allows him to subscribe to an energy consumption detailed service.

After the subscription process, he receives a pack with one or more EMD. If it is his first subscription to Orange home services, he receives also an AIM gateway to connect to his broadband access. If he has already an AIM gateway he doesn't need a second one.

After self and simple installation, he can consult on the "MyHouseOrange.com" portal a detailed description of use (kW and Euro) of each electric device, or type of devices, or by usage.



3.2.5 UC Operator 5: easy configuration

Mrs Jones has already subscribed to the Energy pack service. She would like to configure her service. The service supports three modal interactions:

- She can download the Orange widget to configure the service, to send commands or receive status from devices;
- She owns an innovative physical device to configure the EMD;
- She has a dedicated application or an Instant Messaging client on her mobile;

She doesn't want to login each time she wants to consult or configure her service.

3.2.6 UC Operator 6: outdoor location

Mr and Mrs Niel have no kids and have a holiday house. At the end of the weekend, when they leave it, the Orange Mobile network detects that they left the local GSM cell and go back to their main home. Then, the service switches off the heating system and electronic devices if necessary.

When the Orange mobile network detects they are going to their holiday home, the service starts heating system in order they find a comfortable temperature.

3.2.7 UC Operator 7: abnormal situation

Mr Niel has configured his services (with UC2) interface to receive an alarm when abnormal energy situation occurs. He receives a SMS with abnormal situation description.

3.3 Utilities

3.3.1 UC 1 Utilities: flexible tariffs

The utility wants to introduce an incentive based business model which means that the customer can directly participate in savings and benefits that the utility can generate through a flexible cost model. To realize such a business model a communication path between the utility and the customers, which provides the required information (tariff/pricing information), has to be established and the customer needs to have a device which is at least capable of displaying the actual tariff-information. This functionality should be provided by the AIM-gateway.

One possible way for introducing flexible tariffs is that the utility sends a pricing profile for the next day which includes the tariffs for every hour. This would be just a finer differentiation of “time-slices”. In peak times the energy would be more expensive than in off-peak times. Now the customer knows when the more energy intensive services should be used.

Another way for flexible tariffs would be the possibility for customers to buy a certain amount of kilowatt-hours for consumption. This would require more communication between the utility and the customer, since a purchase order must be carried out and the crosscheck whether the purchased amount of energy is already consumed needs more communication between customer and utility. Nevertheless, the AIM Gateway can be used as central device to organize the communication and information exchange between utility and customer.

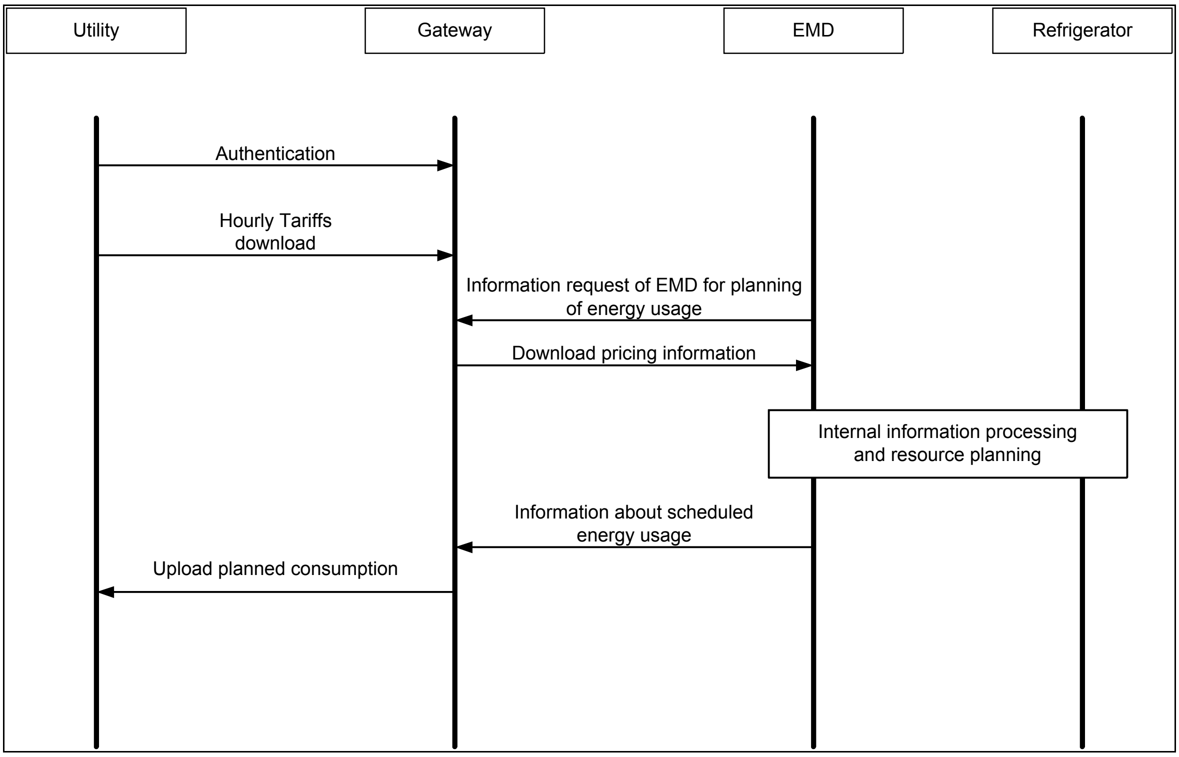

Utility
Gateway
EMD
Refrigerator
Authentication
Hourly Tariffs download
Information request of EMD for planning of energy usage
Download pricing information
Internal information processing and resource planning
Information about scheduled energy usage
Upload planned consumption

Figure 11: Sequence diagram for flexible tariffs

3.3.2 UC 2 Utilities: remote load control

In times of frequently changing prices and changing availability of additional power generation capacities the requirements for remote load control becomes a challenging aspect in power grid operation.

When a utility knows that in its network unused load which can be controlled remotely is available, it could plan with that buffer to be able to buy cheaper energy.

Mr. Schmitt owns a refrigerator which is capable of producing cold air and stores it in a separate part of the fridge to be released when required. The required amount of energy for that operation is known to the utility. In times where alternative energy generation is able to provide very much energy (e.g.

strong winds for the windmills) energy becomes much cheaper and cleaner which is an advantage for all parties.

This kind of remote control would allow the use of carbon dioxide free energy when it is available and would help to integrate this kind of energy generation better into the whole system of energy generation and usage.

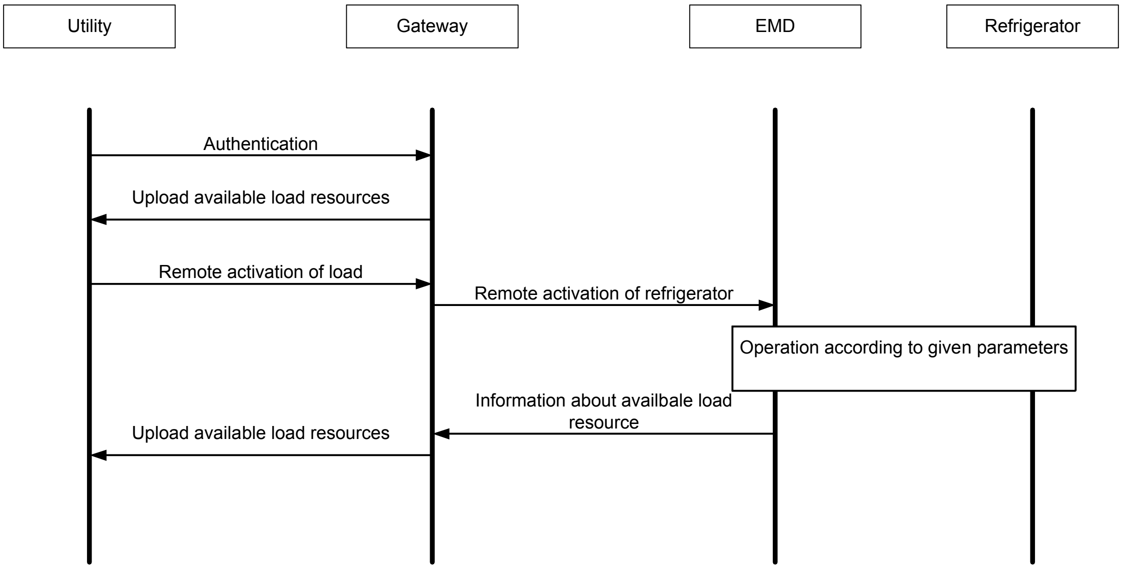

Utility
Gateway
EMD
Refrigerator
Authentication
Upload available load resources
Remote activation of load
Remote activation of refrigerator
Operation according to given parameters
Information about availbale load resource
Upload available load resources

Figure 12: Sequence diagram for remote load control

3.3.3 UC3 Utilities: remote control energy creation

A special use case for remote control is to control distributed energy generation. This would mean that the utility can "build" a virtual power plant by controlling the different available distributed energy generation sources from the customers connected to its distribution network.

3.4 Local users

According to the general use case diagrams presented above, local users can interact with the system to perform a set of basic set of operations that include the monitoring of energy use, the personalization of energy use and gateway maintenance (for expert users only).

In the following we specify in more detail these use cases for local users and include also the interaction of the sensor network with the system.

3.4.1 UC Local users 1: monitoring energy use

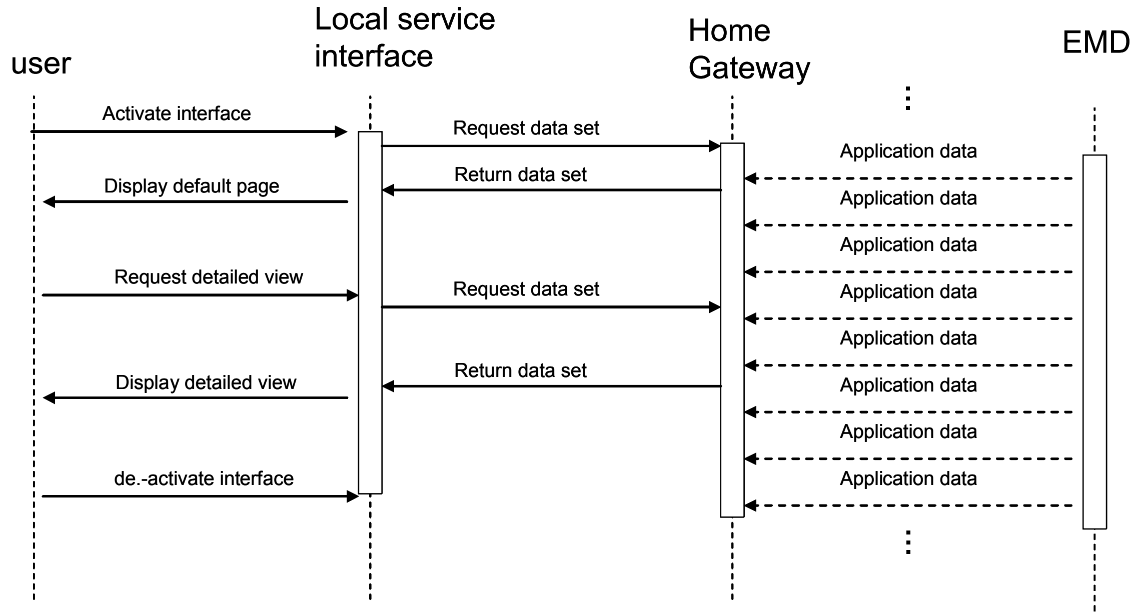


Figure 13: Local monitoring of energy use – sequence chart

Home users can access to the energy use monitoring service of the AIM system through a local interface to the service using a terminal (PC, PDA, etc.) that is connected to the home gateway via the home networks. Data provided by the service is obtained in general aggregating and elaborating raw data provided by the EMD(s). The specific data provided and the way in which it is presented to the user depends on the monitoring energy use application that is installed in the home gateway.

3.4.2 UC Local users 2: personalize energy use

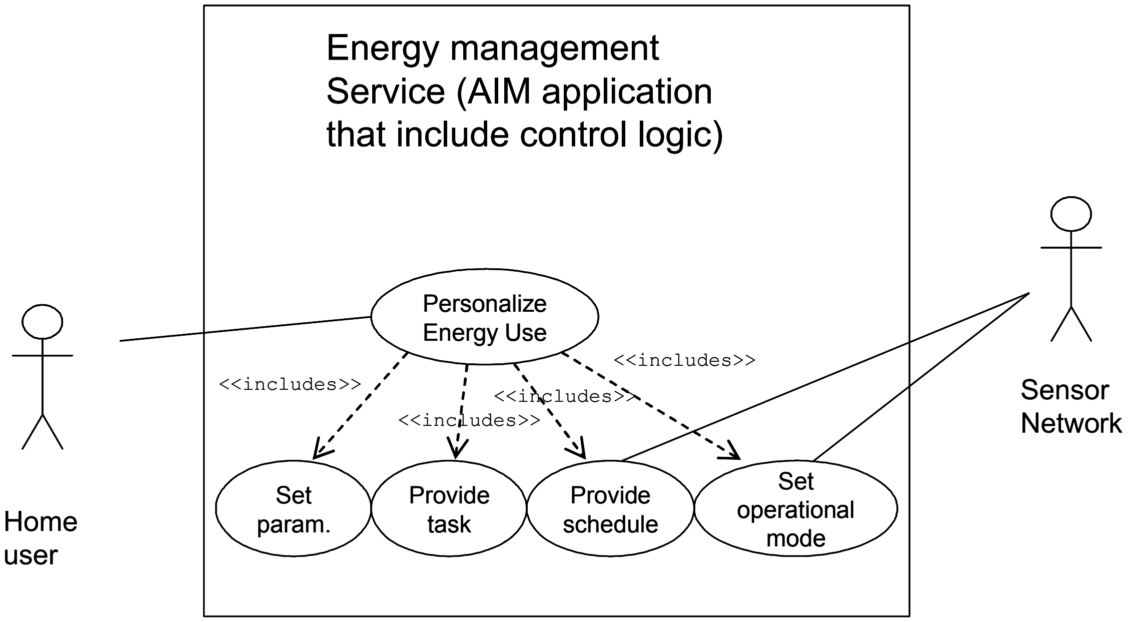


Figure 14: Diagram for personalized energy use

The personalization use case is enabled by an energy management application that is installed into the home gateway and can be accessed locally through a service interface or remotly trough the service platform provided by the network operator. This application includes the energy management logic and allows the user to define the way in which home appliances operations are orchestrated by the AIM system. The user is required to provide some inputs to the application and, depending on the level of expertise, it is also allowed to configure and personalize the control system. The sensor network can simplify the task of the home user providing automatically some inputs to the system.

Figure 14 shows a more detailed use case diagram of the energy use management that includes a set of use cases that can be available to the users and the sensor network.

The use case set parameters considers all operations that allow a user to modify the parameters that are used by the system control logic, such as for example the parameters of the utility function that define the cost/comfort trade-off, the desired temperature levels of the various operation modes, etc.

The use case provide task considers the operations for requesting the execution of a specific task to home appliances, like, for example, cook the meal by 7PM, wash clothes during night, etc.

The use case provide schedule allows to set the schedule of activities to be performed by the system and to inform the system about the presence of users at home or in some specific rooms of the home.

The use case set operational mode allows the user to set some predefined operational modes of the system, like, for example, activate the night mode of the heating systems or the vacation mode of the global system, etc.

The use cases provide schedule and set operational mode can also be accessed by the sensor network that can for example schedule some activities (like e.g. run the washing machine) or set an operation mode (like e.g. turn off a set of devices off) when it detects that the users are no longer at home and will likely come back when the scheduled activities are over. The sensor network makes use of real time data sensed by sensor devices and historical data stored into user profiles. Figure 15 shows the detailed use case diagram of the energy use management.

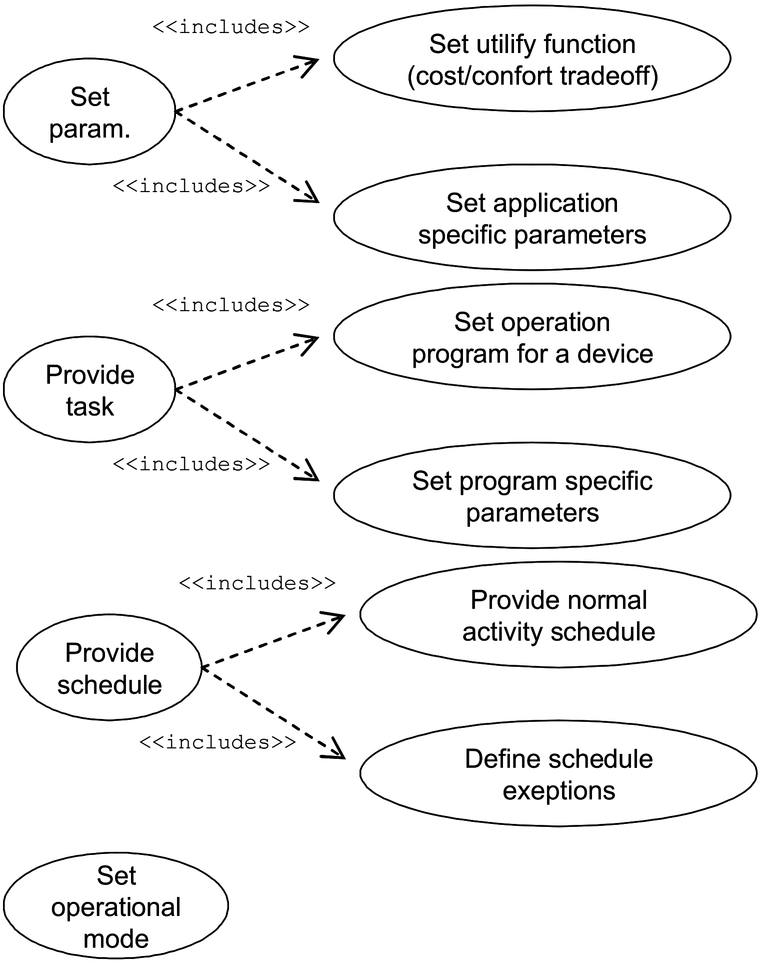

Set param.
<<includes>>
Set utilify function (cost/confort tradeoff)
<<includes>>
Set application specific parameters
Provide task
<<includes>>
Set operation program for a device
<<includes>>
Set program specific parameters
Provide schedule
<<includes>>
Provide normal activity schedule
<<includes>>
Define schedule exeptions
Set operational mode

Figure 15: Detailed use case diagram of the energy use management

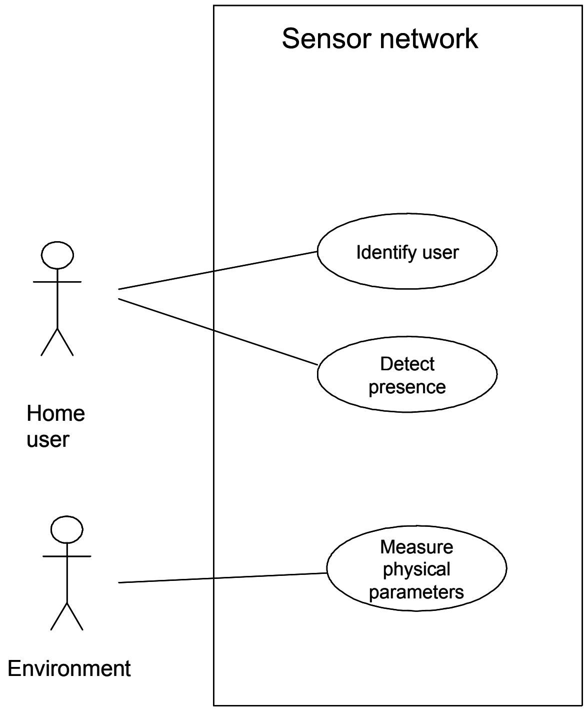


Figure 16: Use case diagram of the sensor network

Figure 16 shows the use case diagram of the sensor network that interact with home users to identify them and detecting their presence and with the environment to measure some physical parameters, like e.g. the temperature, the light level, etc.

A sequence chart of the energy use personalization accessed locally by the home user is presented in Figure 17.

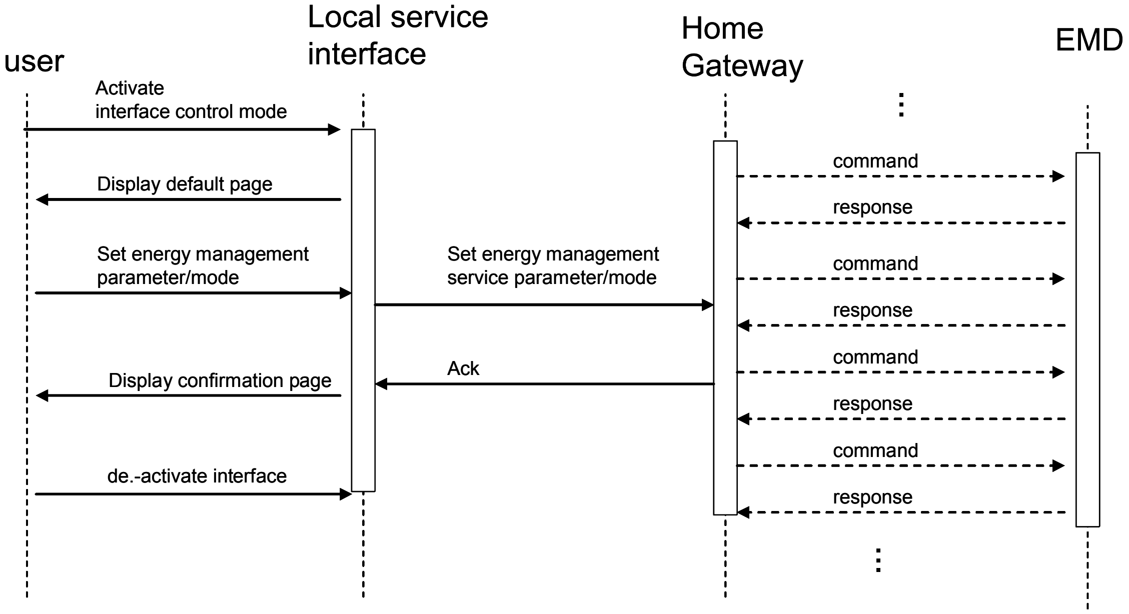


Figure 17: Local management of energy use personalization - sequence chart

3.4.3 Example usage scenarios

Example N°1 – Usage scenario during the workweek

The user is a typical worker that lives in household only in the early hours of the day and come back in the house in late evening for dinner and the night.

The general objective of the user is to minimize incurred costs and to this purpose he sets the system with the following general system function: Minimize energy consumption during a period of time (i.e. 6 hours, 24 hours, week, month)

Objective: minimization of energy consumption during the specified interval of time.

We are in winter, the day of the user start at 7:00AM when he wakes up.

He desires a pleasant temperature in the rooms that he visits in the morning for preparing breakfast and dressing himself before going out for the work. He sets a temperature of 22 °C in the bedroom, bathroom and in the kitchen. He doesn't want to warm up the living room because he doesn't use this room in the morning.

While the user is not in the house, it is not necessary warming up any room over a specified threshold of temperature so, at 8:00AM when the user goes out, the system is free to manage temperature just considering the cost minimization objective and minimum temperature constraints. Obviously, user desires that at 7:00PM, when he is back home, the temperature in the house is again around 22 ° C like in the morning but this time in all the rooms.

The schedule of user's typical day can be provided to the system through a local interface or it can be estimated by the sensor network based on the analysis of the time series of user presence at home and in the rooms of the house.

The user also desires that when he is back at home in the evening the clothes that he putted in the washing machine in the morning are washed and dried. Accordingly to the general settings of the system, the goal is to reduce energy cost for washing the clothes. The system can select an available program to reduce energy consumption considering the type of clothes to be washed. The system is also capable of managing the schedule of the washing program considering its duration, the constraints set by the users and the information of energy cost during the day.

Example N°2 – During the workweek with discrete power levels in devices.

Like in previous example, the user is a typical worker that lives in household only in the early hours of the day and come back in the house in late evening for dinner and the night.

The general objective of the user is to minimize incurred costs and avoiding exceeding a defined threshold of 2kW/h. The selected general function for the system is: Allocate energy consumption in a period of time (i.e. 24 h) avoiding exceeding a defined threshold (i.e. 2kW/h).

Objective: energy consumptions are allocated in 24h/day to avoid peaks of energy requests to the provider.

The energy provider informs that energy is cheaper than usual if the user doesn't exceed a threshold of 2kW/h when the maximum power allowed is 3,3 kW/h.

The system operates to have an instantaneous total consumption of energy always below 2kW/h.

The system has also the ability to operate at single connected devices levels and to manage for each one various power levels diversified for every function that the devices accomplish in every single moment of time. With this kind of logic the system can power-off single components of the device or power-on the devices for a longer period of time but with smaller costs.

The user wants to cook a meal in the microwave oven and doesn't want to exceed a defined threshold of 2kW/h. The system knows the energy being used by the other appliances and threshold of 2kW/h and it calculates the residual energy to reach the threshold. Based on the available programs for cooking the meal and the residual energy, the system chooses the best one.

The user also asks the system to manage displays of all the devices based on the presence of the user detected by the sensor network. Each device is described in the ontology by its components and the system knows if a display is available on them or not. The system can simply power-on the display when the user is in the room and power it off when the user leaves the room, or it can perform more complex control functions considering for its decisions also the time of the day and the estimated probability that the user will use a specific device. Similarly, the system can manage available discrete energy consumption levels associated to appliances internal functions or components based on the needs of the user, his presence in the room and the probability of using a specific device based on user profile.

The user sets the system to manage automatically the lights in the rooms. He decides to activate the functions that manage the light bulbs so that to compensate smoothly the growing darkness of natural light. The light level in the room is detected by the sensor network.

Example N°3 – On vacation

The user leaves the house to go on vacation and his objective is the minimization of incurred costs to manage the house when he is away.

The objective function that is selected by the user is: Minimize energy cost during a period of time (i.e. 6 hours, 24 hours, week, month)

Objective: minimization of total energy consumption in a period of time without considering incurred costs. It is necessary to define if the minimization is operated for a day, week, month or year.

The user can turn off some kind of services available in the house while they’re not going to be used without him but he needs that some other services are also guaranteed during his holiday.

The system knows the devices that are available to be turned off completely or not.

The user doesn’t need to manage temperature so its control system is turned off.

Devices that usually are in stand-by mode like modem, TV, microwave oven and washing machine are also turned off.

Refrigerator and freezer stay in power-on state in order to maintain food in good conditions.

A date/time for the return of the user has been provided to the system by the user so it can restore the normal functioning of the devices before the user is in the house.

4 Architecture specification

Figure 18, gives an overview of the AIM reference architecture. The architecture is decomposed into a number of core functionalities. These components are described in more detail in this section. Several of these components need to be implemented in devices while others not. Furthermore, we also distinguish different components based on their importance for realizing AIM services. For example, the advertisement of EM service by a device is crucial for notifying the home network regarding its EM capabilities. A relation between the requirements set in D21 and the components of the architecture depicted in Figure 18 can be found in Annex B.1

4.1 Overall architecture and building blocks description

AIM bridges the outdoor and indoor networks with the view to provide the means for controlling the functions of the household appliances through a number of different applications addressing three user categories, the residential users, the network operators and the energy generation utilities.

To realise this concept the AIM project adopts the architecture depicted in Figure 18. In this, the indoor (home) network is bridged with the outdoor networks through the “AIM system logic”, whereby users are enabled to manage the functions of household appliances, thus being able of controlling the energy consumed in their households.

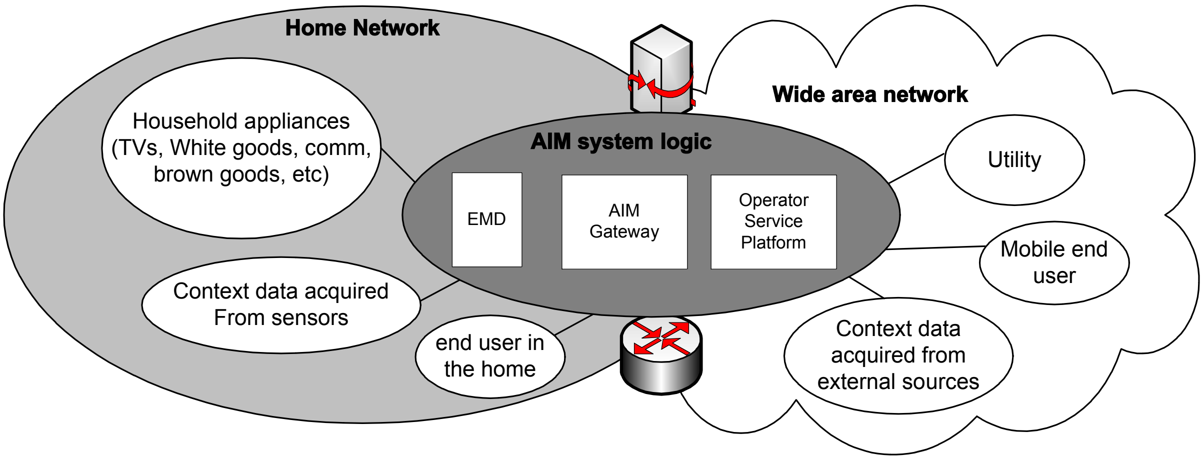

Home Network
Household appliances (TVs, White goods, comm, brown goods, etc)
Context data acquired From sensors
end user in the home
AIM system logic
EMD
AIM Gateway
Operator Service Platform
Wide area network
Utility
Mobile end user
Context data acquired from external sources

Figure 18: Generic system architecture

In the figure above, the AIM gateway, appearing as a building block of the AIM system logic, may optionally host part or the whole of the AIM system logic. In the case, where the AIM gateway is used as a passive component, service logic is hosted on the operator service platform.

The consortium has decided to adopt this flexible service realisation concept for purposes of preserving scalability and flexibility of the overall architecture. Thus, interested actors (operators, third parties and home users) have more freedom in the implementation of energy saving applications.

4.1.1 The AIM core logic

The AIM system logic is the main building block of the architecture, providing the interconnectivity means between the home network and the outdoor networks and the software substrate for the implementation of energy saving applications.

The building block is comprised of two functional entities, the AIM gateway, providing communication coupling between internal and external networks and the Energy Management Device (EMD), providing specialized logic for the implementation of energy management functions.

4.1.1.1 The AIM gateway

The AIM gateway has the roles of bridging the functionality of the home network with the user applications residing in the wide area network (outdoor networks) and providing harmonisation of communications between the users and the involved network components over the IP protocol.

Concerning realisation of energy saving applications, in cases where the gateway is used as an active component, it serves as the focal point of services exchanging information with the household appliances through exposure of an abstract, high-level application programming interface.

For scalability, upgradeability and openness reasons, the gateway should be implemented as an open, standardised architecture. To fulfil this requirement and to optimise system development the consortium has selected to adopt the ESTIA gateway which is based on the open services execution framework of OSGi. Details on the internal architecture of the ESTIA gateway are provided in later sections.

The ESTIA gateway will host most of the energy management functionality, including:

- Appliance capabilities discovery: Appliances shall be traceable concerning the operation modes they support, e.g. washing programs, cooking programs;
- Appliances and user profiling: Appliance profiles as defined in D2.3 shall be stored in a database within the AIM gateway to be exploited by energy management applications in the process of deciding which appliances shall be controlled and how. In the same manner users will be also profiled so that to system is able to administer the energy management strategies set by each user, judging from their privileges;
- Virtualisation environment: This environment will enable the home user to access household's energy resources and exploit them in defining energy management processes, such as maximum energy consumption levels, priorities between appliances, etc.;
- Management of the user interface: The gateway shall provide APIs towards the three user type services, through which user terminals may access the functionality of architecture;
- Anonymization of energy consumption statistical data towards the outdoor networks: The gateway provides a communication substrate that hides the identity of the household and the user. This substrate is used for anonymizing energy consumption statistical data when it is processed by external actors, such as utilities involved in energy generation;
- Energy monitoring and management: The gateway provides user services with APIs for communicating with the EMD, the device that mainly performs energy monitoring and management;
- Harmonisation of communication between indoor and outdoor components: The low level communication substrates of the gateway are designed so that to integrate any IP communication interface seamlessly to the user services and applications, hence enabling harmonisation of communication between indoor and outdoor networks.

4.1.1.2 The Energy Management Device (EMD)

The EMD realise an interface role to the energy control logic of the AIM architecture, consisting of energy monitoring and management.

Energy monitoring consists of monitoring the energy consumed by the each appliance and reporting the value to the system logic via the AIM gateway.

Energy management consists of maintaining specific energy consumption thresholds set by home users by applying on household appliances various control models such as state alteration, switching off and standby management.

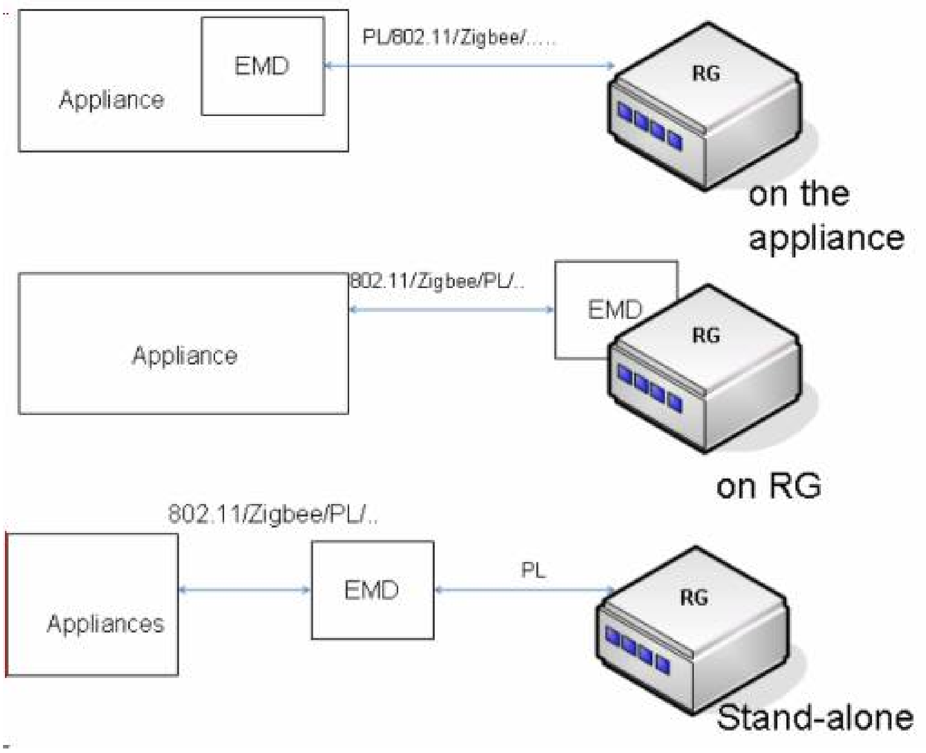


Figure 19: EMD hardware configurations

The EMD can either be hosted inside the controlled appliance, be integrated inside the residential gateway, or be an independent device, mediating the communication between RG and controlled appliance. More details regarding each scenario are provided in section 5 of this document.

4.1.2 The appliances

Appliances are defined as the devices to be controlled by the architecture for energy saving purposes, through their function modes.

Although only three appliance categories are about to be examined in the context of the project in terms of energy management, the proposed architecture shall be useful for potentially any household appliance gathering the following characteristics:

- Expose a physical communication interface;
- Have discrete operation modes;
- Allow operation modes to be controlled through network commands.

4.1.3 User interfaces

Users shall have access to AIM services through applications compatible with any user terminal type. In particular, home users shall be able to access the services of the AIM gateway through wireless/wired home terminals, such as PDA and PC based consoles, while outdoor users and third parties shall be able of accessing home environment through operator services, making use of mobile phones and PC based consoles.

In some cases, where security and service integrity is guaranteed by third parties operator networks, outdoor users will be able of accessing their home environment without the need of using an operator network.

In all cases, the user interface coincides with the user application hosted on the user terminal and allowing users to access the services of the home network. To preserve solution generality and viability, AIM leaves the matter of building user applications up to the potential users of the architecture. Therefore, any application implementation technology and message communication method may be exploited as long as it has no impact on the protocols of the AIM gateway, but structured access on the services of the platform is only possible through the APIs deployed on the AIM gateway.

4.2 System functionalities

The architecture is decomposed into a number of core functionalities. These components are described in more detail in this section. Several of these components need to be implemented in devices while others don't. Furthermore, we also distinguish different components, based on their importance for realizing AIM services. For example, the advertisement of energy management service by a device is crucial for notifying the home network regarding its energy management capabilities.

4.2.1 Energy management

4.2.1.1 Energy monitoring

Monitoring is an essential feature of the AIM architecture. For users without knowledge of their power consumption it is hard to save energy and energy costs without losing some living comfort. Therefore it is important to have some monitoring feature for the AIM devices.

For low level monitoring each household appliance should have an indication for the current state and power consumption, so that the user can easily recognise its state. This can be provided by the household appliance or the EMD.

More detailed information could be shown on local communication devices like PCs or mobile phones as well as web applications. Depending of the functionality of the handhold device, ASCII or HTML data will be transmitted, either from the AIM gateway or for special functions from the EMD to the user communication unit. It is important to show to the user the current and history of the power consumption of the AIM devices and if possible of the whole household. For the user it is not comfortable to look all the time on his power consumption chart. It will be more convenient to view the power consumption and the costs of the last day/week/month/year on demand. In parallel a profile of planed power consumption and offered user adjusted power tariffs from the utility or service provider should be shown. After comparing the consumption with a former period new decision in behaviour, controlling and tariff selection can be made.

4.2.1.2 Energy control

The pivot of energy control in AIM is the EMD unit. Apart from its physical interfaces, the AIM EMD employs a slim version of the IP protocol, which allows it to communicate with high level user applications, compatible with home protocol technologies, like OSGi, UPnP and HTTP. Particularly, the use of the HTTP protocol will allow implementation of a Web Server functionality, which will run locally on the EMDs and will allow an easy EMD configuration.

Realisation of power management applications shall be made possible, through the involvement of the "device virtualisation environment". With this environment, a user will be able to access and orchestrate the power management capabilities of his environment by using **semantic** representations, having on one hand the possible administration functions (e.g. monitor, control, etc) and on the other the addressed household appliances types.

This "device virtualisation environment" will be accessible on the AIM gateway and its functions will be linked to properties such as service personalisation, user identification and privileged access, all offered by the ESTIA AIM gateway architecture discussed later-on.

4.2.1.3 The AIM device virtualisation logic

The main building block of the AIM Device Virtualisation logic will be its "**Management procedures configuration environment**". Users will be able to create power management procedures, such as power consumption thresholds, metering functions, etc, through the use of appropriate administration and appliance function semantic representations. Virtualisation logic is used because it enables us to buffer-out and mask hardware and software implementation specific attributes from the rest of the AIM architecture.

Virtualisation is defined as a generalised way of managing the energy consumed by the appliances of the home environment in the context of the Device Virtualisation Environment (DVE). Appliance types and operation modes corresponding to certain energy consumption levels are "semantics" that can be utilised by home users through the GUI of DVE to define their own energy management strategies. The process by which these semantics are composed with each other so as to build up a certain energy management strategy is called devices, semantics or even resources virtualisation. In this context, proper semantics functions are the operation modes that appliances support and which are associated with specific energy consumption levels.

To implement the management procedure requested by the user, the environment will output its content to a “**knowledge interpreter**”, tasked to turn the incoming abstract descriptions into compatible OMA Device management (DM) logic.

In this process, the Device Virtualisation logic will utilise two databases, an **Attribute database** encompassing descriptions of the various semantics used by the “Management procedure configuration environment” and a **Context database** encompassing descriptions of the EMD supported functions.

Having turned the abstract procedure notations into OMA DM compatible commands, the Device Virtualisation logic will forward the outcome of this process to the enhanced OMA DM logic block, which distributes of the appropriate commands to the appropriate EMDs and implements their requested configuration.

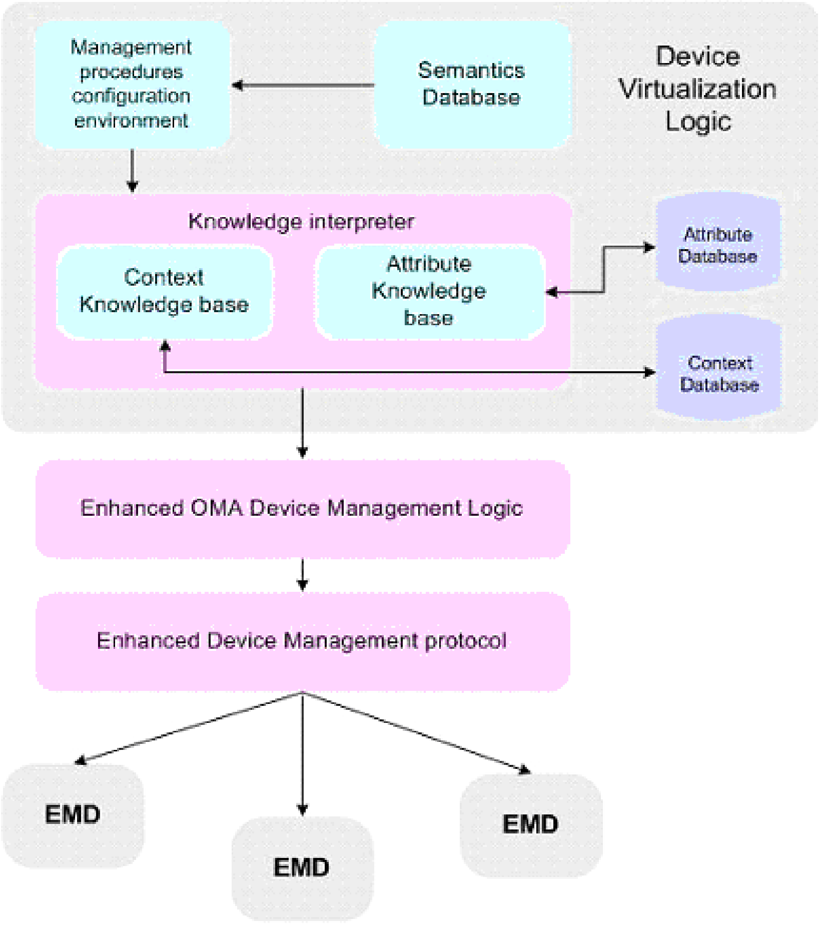

Management procedures configuration environment
Semantics Database
Device Virtualization Logic
Knowledge interpreter
Context Knowledge base
Attribute Knowledge base
Attribute Database
Context Database
Enhanced OMA Device Management Logic
Enhanced Device Management protocol
EMD
EMD
EMD

Figure 20: Device virtualisation logic architecture.

Below, two simple examples for the virtualisation logic applications are given:

- Example 1: The home user selectes the washing machine, the refrigerator and the oven and sets for them a cummulative upper energy consumption level, beyond which the AIM logic should control them by means of switching them off or swithing to a less energy consumption program.
- Example 2: The home user selects the audiovisual equipment (TV, HiFi, DVD players) and sets them in a mode where the AIM logic checks whether they are not used throughout day time and switches them off. The AIM logic may do the same in user programmable night hours, e.g. after midnight until 12:00 pm.

4.2.1.4 Design of external interfaces

Physical integration within the AIM communication network dictates the adoption of a generic interface that will grant connectivity of an EMD to any physical medium, no matter if it is wireless (Zigbee, Bluetooth, WiFi, GPRS, etc), fixed (802.11, PoE, etc) or Power Line (KNX, LonWorks, etc). Concerning the physical integration with household appliances, the project will use information from appliance manufacturers in order to build a generic bus through which the various commands will be enforced. The interworking of the AIM power management architecture with communication networks shall be made on the basis of exploiting the capabilities of the IP protocol of the EMD.

4.2.1.5 EMD usage scenarios

The EMD is used as primary means to interact with AIM appliances. Below we present two cases that demonstrate how the EMD can serve this role. More specifically we discuss the implementation of the standby and active modes through the EMD.

4.2.1.5.1 Stand-by mode implementation using an EMD

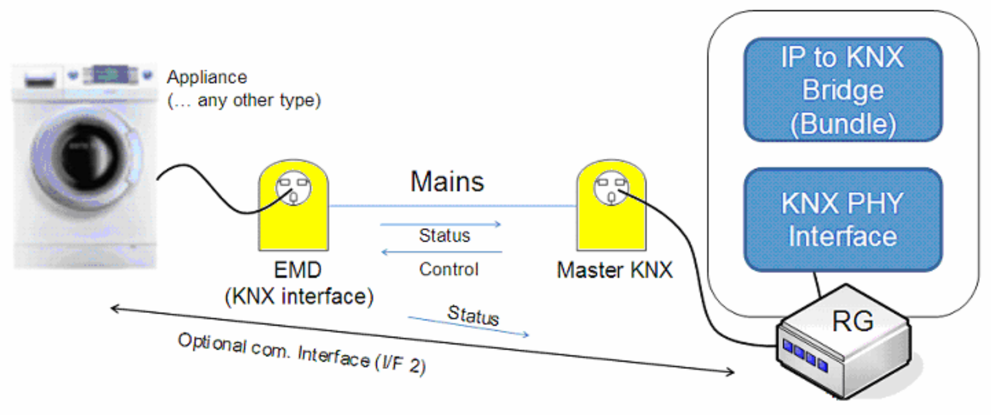


Figure 21:Implementation of an EMD with a KNX interface

In AIM, stand-by is performed by switching off the power outlet to which an appliance is connected. The EMD should be pre-programmed so that it ‘knows’ to which appliance it is connected. At any given time, the AIM gateway may choose to switch off the appliance by sending an execution command to the EMD.

The AIM gateway would only be allowed to execute this task for specific sets of appliances (e.g. not for refrigerators) and under specific events; e.g. following a user command or time schedule (e.g. past midnight) or even automatically, by utilising the AIM sensor network.

To implement an energy standby mode, an EMD should be aware whether the connected appliance is about to enter a standby mode. This information can be provided by the appliance itself (by sending a command to the Gateway via the Power-line network or I/F2, eg. WiFi, ZigBee, IEEE 801.11, etc) - or by an EMD implementation of real time energy consumption monitoring. It is worth noting that the energy consumption of a KNX control box is very low in sleep mode (~100 mWatts).

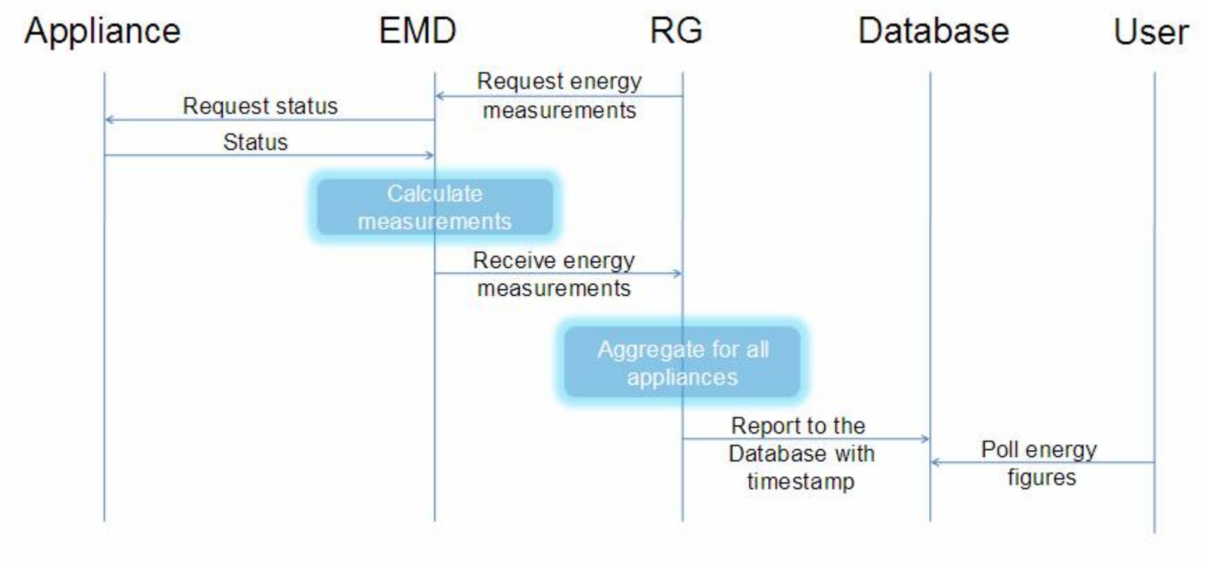

Appliance
EMD
RG
Database
User
Request energy measurements
Request status
Status
Calculate measurements
Receive energy measurements
Aggregate for all appliances
Report to the Database with timestamp
Poll energy figures

Figure 22: Energy status polling

To support this cause, as can be seen in Figure 22, AIM provides a series of energy polling functions, which are controlled by the AIM gateway, reaching the controlled appliance. An embedded database is used to log the responses and provide value threshold checks.

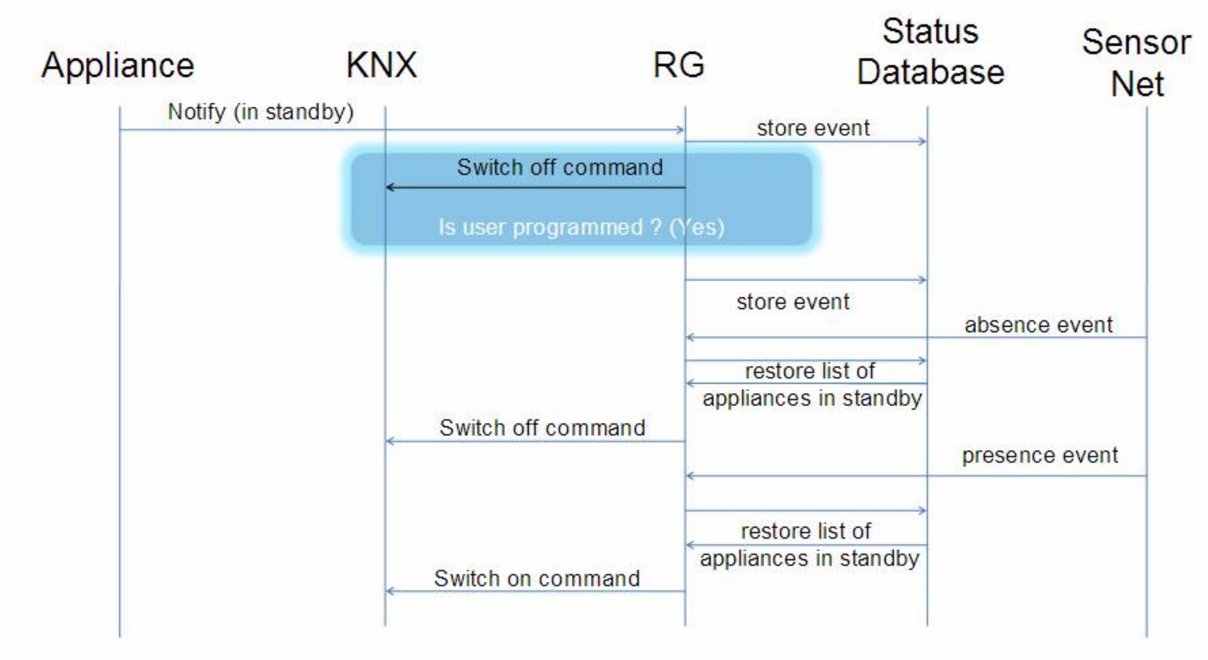


Figure 23: Standby implementation message flows

A similar case is evident in AIM Switch-off commanding, which involves the AIM actors and the AIM database. An AIM appliance notifies the AIM gateway on its standby state. The AIM gateway registers this event in the database and finally sends a switch off command to the appliance. A similar procedure switches on the appliance and registers the event in the database.

4.2.1.5.2 Energy management in active mode using an AIM EMD

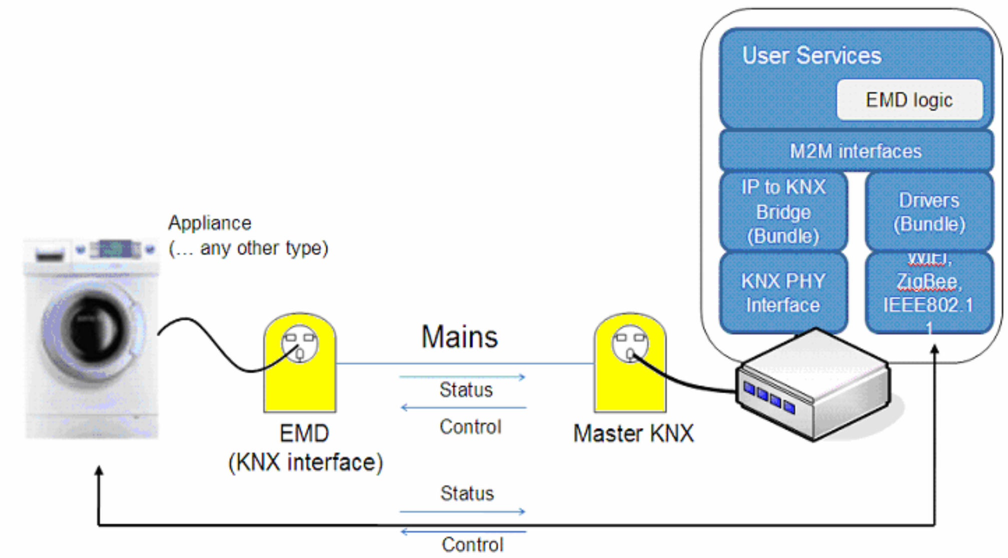


Figure 24:Showcasing the use of KNX for communication between the EMD and the AIM gateway.

Active mode energy management constitutes the core of the AIM architecture. We should note that either Power-line or pure COM interfaces may be used in this case.

The **EMD logic** consists of: **a)** energy monitoring, **b)** energy management, **c)** standby management.

All other necessary EMD functions can be implemented either inside the AIM gateway, in the controlled appliance or as an individual external electronic box component.

In energy management (example case): The user sets a maximum energy consumption limit for the AIM topology, and the AIM network restricts the appliance operational mode to that limit.

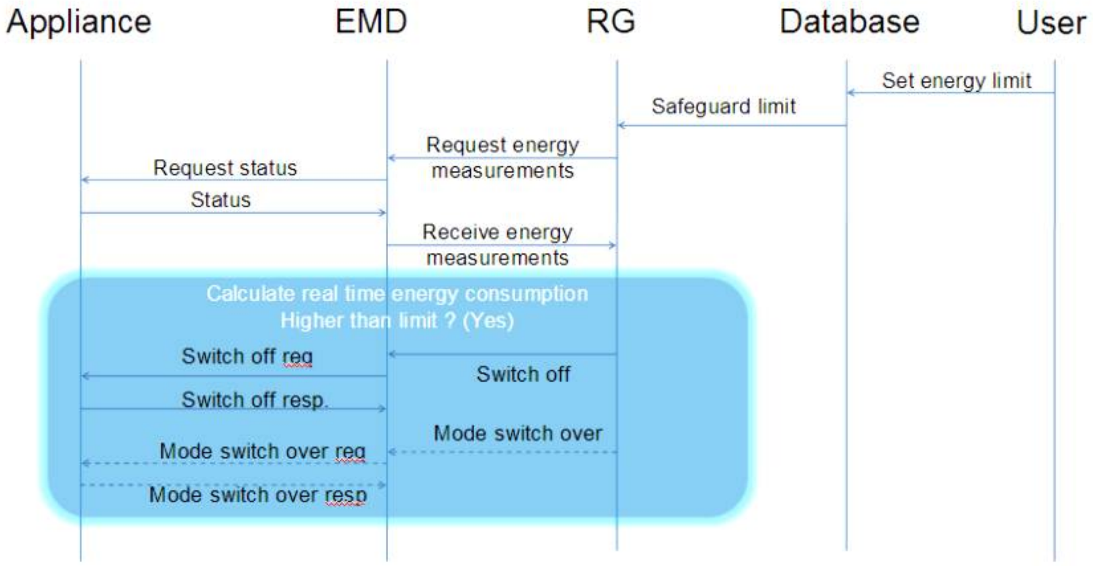


Figure 25: Exchange of commands in the AIM architecture for limiting the energy consumption according to user requirements

4.2.2 Management of appliance functions

Devices are managing their internal functions without explicit control from the network. On the other hand, they can export to the network higher level power consumption/functionality modes that are allowed to be managed. It is up to the device manufacturer and the devices themselves to decide on this.

The digital control system of each white good is able to manage its internal functions according to the value of external data acquired from the network and supplied by the gateway.

4.2.2.1 External data used for appliance functions management

The main "external data" used by the appliance control systems for managing internal functions are:

a. Power threshold selected by the home user for avoiding to overcome low tariff limits;
b. Power threshold proposed by the utility during critical supplying conditions;
c. Maximum admissible power peak (according to the energy contract);
d. Current total power consumption in home environment;
e. Real-time clock for managing load shifting function and, also, for giving to the home user an always updated information on day time;
f. Ambient temperature and humidity;
g. Current energy cost;
h. Daily energy cost profile.

4.2.2.2 Appliance functions types

The main functions managed by the appliance digital control systems, according to external data coming from the network, are the following five:

1. **Power levelling**

   The control system of each connected appliance continuously compares the value of the current total power consumption "d" with the current power threshold value (it is the minimum value among "a", "b" and "c") and activates the "power levelling function" when it overcomes such threshold. When "a" and "b" values have not been set, "c" value is assumed as default threshold. During the execution of power levelling function, each appliance reduces its power consumption according to its priority level, being such priority level dependent on appliance type and working status (or program phase). For instance, the oven's priority is higher than the washing machine's one because eating is more important than washing; similarly, washing machine's priority during the heating phase is higher when the water temperature is cold and decreases when such temperature increases. Each appliance manages its power levelling function using two delay timers: the first timer controls the delayed start of power reduction activity (power decreasing delay: PDD) after a power levelling condition taking place; the second one controls the delayed start of power recovering (power increasing delay: PID) when power levelling condition is expired. High priority appliance (oven) has a high PDD and a low PID; low priority appliance (washing machine) has a low PDD and a high PID. It means: when a power levelling condition occurs, the washing machine starts deceasing its power consumption quicker than the oven, and the latter decreases power only if the power reduction done by the washing machine isn't enough for eliminating the power levelling condition. The effectiveness of power levelling algorithm has been already checked. Considering AIM white goods, power levelling function is applicable only to washing machine and oven.

2. **Load shifting**

   Load shifting function is driven by daily energy cost profile ("h") and based on real time clock ("e"). If the user enables the load shifting function on the washing machine, it starts working when the lower energy tariff takes place. In other words, the appliance activates automatically a delay timer for reaching the first low energy rate period. Load shifting function is applicable only to washing machine.

3. **Energy monitoring**

   The appliance control system allows the execution of this function by continuously sending its working status to the gateway. The gateway executes energy monitoring function by using the appliance energy profiles stored in its database.

   When a proprietary Power Metering Adapter is connected on the power line plug of the appliance, energy monitoring function can be directly based on the measured values of the energy actually consumed by the appliance.

4. **Efficiency estimation**

   This function takes place when a proprietary Power Metering Adapter is connected on the power line plug of the appliance. Efficiency estimation is performed by comparing the measured energy consumption of the appliance with the expected one according to specific working phases.

5. **Performance monitoring & alarm**

   This function takes place when the appliance control system detects a low efficiency working condition: for instance, when an open door condition lasts for too much time, depending on the appliance type. In such a case, the appliance control system sends an alarm message to the gateway in order to properly inform the user.

4.2.3 Device virtualisation environment and semantics

The Device Virtualization Environment (DVE) is a rule engine application that allows the residential user to interact in a smart way with the AIM system. The process of domestic environment abstraction and description is called “domestic environment virtualization”.

The DVE, which is the AIM system energy saving services provider, needs all the information available about the domestic environment, such as: the description of the house in terms of rooms and theirs environmental parameters, the description of managed devices, the best management rules for each device and the user preferences about the device management.

In order to describe and manage such information, the DVE is internally based upon an ontology[2] that formally defines a homogeneous and flexible schema for the data to be managed. Such ontology is implemented over Semantic Web technologies: the logical language is OWL-DL (Web Ontology Language – Description Logic) based upon the RDF/XML (Resource Description Framework / eXtensible Markup Language) syntactic representation.

Thanks to this ontology, we can also use logic expression to enable reasoning and logic rules. The rule engine has the role to verify the correctness of the provided information and to infer missing information from the available knowledge. A detailed description of the rule engine and the ontology will be provided in the Deliverable 4.3.1.

Users interact with DVE using a Graphics User Interface (GUI), the user can select all the desired functions, enforce actions on devices, monitor status or simply ask for energy saving functions.

The GUI is a Web-Based interface compatible with different HTTP browsers so the user can access the DVE from his/her Personal Computer, mobile PDA, Smartphone, etc.. This kind of technology will allow further development for accessing DVE from other devices as TV or HiFi set or even any device with a display and that supports browsing.

[2] An ontology is a formal representation of a set of concepts within a domain and the relationships between those concepts. An ontology is a "formal, explicit specification of a shared conceptualization". It provides a shared vocabulary, which can be used to model a domain — that is, the type of objects and/or concepts that exist, and their properties and relations.

As shown in Figure 28, the DVE communicates with the AIM gateway and it can operate the changes to the devices connected to the AIM system.

The DVE is an application that includes different subjects. Apart from the GUI, there are three knowledge containers:

- An ontology that describes the home environment, the devices connected and their relative functionalities;
- A MySql Database that stores users accounts and relative data about their preferences (user profiles);
- A MySql Database that stores the sensor network data about the environment and the presence of the users.

The three containers interact with a Rules Engine through an application programming interface (API) for the databases and ontology.

The actions inferred from the Rules Engine are translated into actions for the RG by mean of Machine-To-Machine (M2M) API.

In the M2M API a set of functions is available for managing every kind of device (i.e. Turn On, Turn Off, Stand-By, Read State, Read Energy consumption).

These sets of functions (monitoring and control), that are specific (proprietary) for every device, are matched and translated with the functions stored in the knowledge base.

The DVE can manage all the devices according with the user profile and the generic operational mode of AIM system decided by the user.

The user operates on a defined set of functions available through the GUI. The application, after analysing the knowledge base, returns a result action that is forwarded to the RG and the result is confirmed to the user by the GUI.

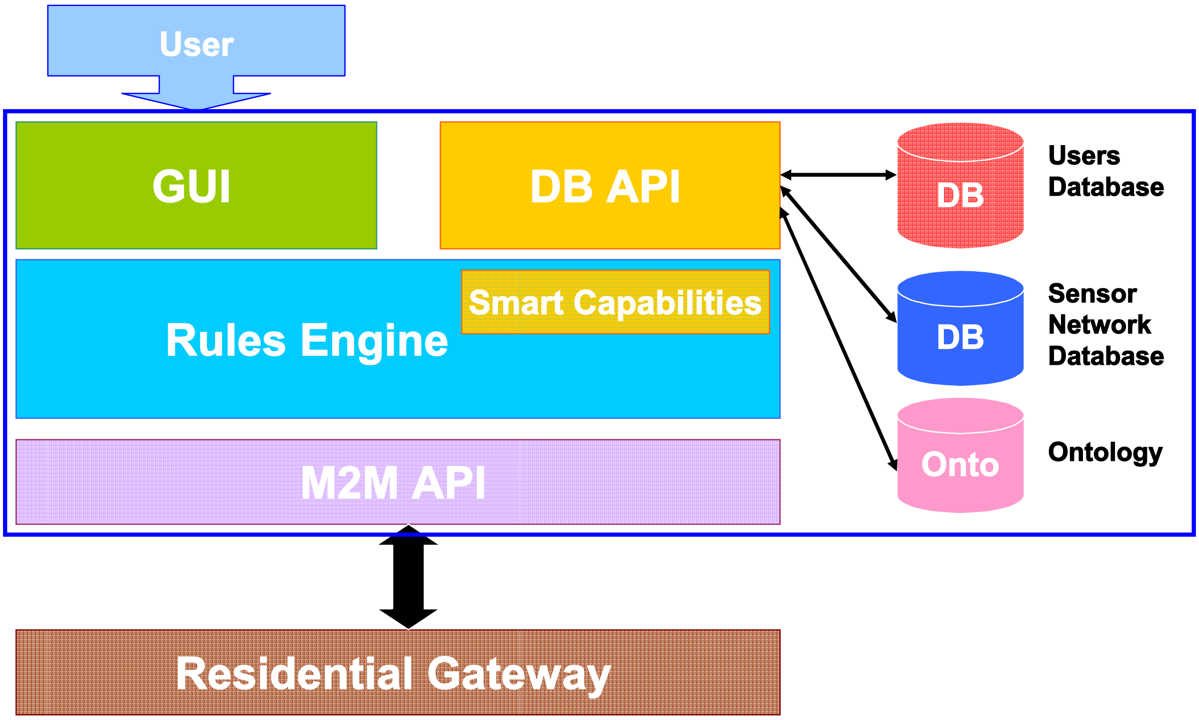


Figure 26: Device virtualisation environment

The actions available to the user on the GUI could be:

- User Login;

- Set a mode for managing the entire system without more action by the user (energy saving mode, limit consumptions threshold mode, vacation mode);
- Program a specific device to operate:
    - Set a cooking program;
    - Set a washing program;
    - Set a desired temperature;
- Schedule an action for the system;
- Read Measure Total/Device specific (Energy Consumption, Costs);
- Read the list of all devices connected to the system;
- Monitor the state of a device.

4.2.4 Services accommodation

4.2.4.1 Energy management service discovery

An AIM service directory is necessary for ‘discovering’ or publishing the power management profiles and functionality of the various AIM controllable devices in the residential network. When a device obtains an IP address, the subsequent step is its discovery by other AIM entities. When a new device is added to the network, the AIM protocol allows the device to advertise its power management services to control points on the network.

Similarly, when an EMD is added to the network, the AIM discovery protocol allows the EMD to search for AIM devices, for which their power attributes can be managed over the network. The fundamental exchange in both cases is a discovery message containing a few essential specifics about the device or one of its associated services, for example, its type, identifier, and a pointer to a more detailed information dataware. The AIM discovery protocol could be based on the Simple Service Discovery Protocol (SSDP) similar to UPnP.

4.2.4.2 Energy management service advertisement

An AIM device will advertise its power management profiles, e.g. the energy consumed per function. Devices should not only advertise these profiles, but should also advertise their energy management capabilities / services. Moreover, a device manufacturer should have the flexibility to implement in a standard way a subset of the AIM functionality. In terms of the related design work and due to several device specifications involved in the AIM architecture, three different EMD configurations have been proposed.

The first one dictates integration of the AIM EMD within the controlled appliance. This is applicable in cases where there is design access to the appliance prior to its manufacturing stage.

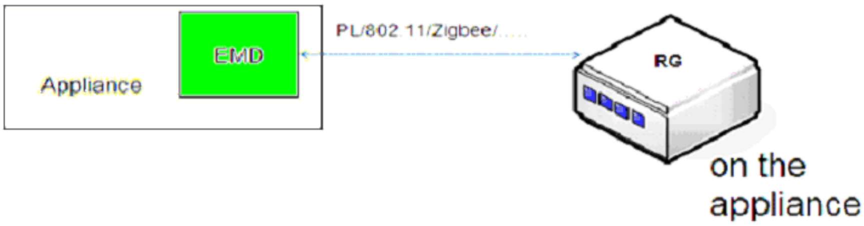


Figure 27:Communication between an EMD embedded in the appliance and the AIM gateway

In this case, the EMD is nothing more than a PCB board or even specific firmware modules that can be integrated into a controlled device during manufacturing.

The second design option specifies a stand-alone EMD, which communicates with the AIM gateway over the Power Lines, or uses some other kind of standardised wired, wireless, or serial communication protocol, to connect to the AIM controlled device. This is the typical design option in add-on scenarios, where we must adapt the AIM system to co-operate with existing household devices, utilizing potential communications and control links to the latter.

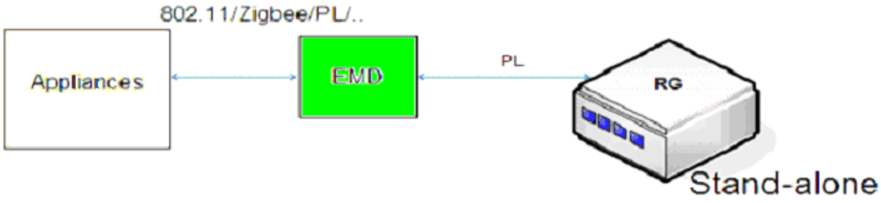


Figure 28: Communication between an external EMD and the AIM gateway

The final design specification is applicable in low end control applications, where the EMD hardware is integrated inside the AIM gateway, using standard communication protocols to existing household appliances.

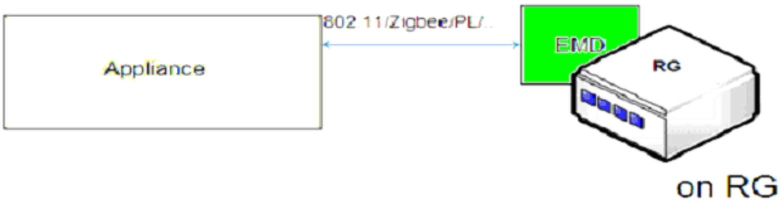


Figure 29: Communication between an EMD co-located with the AIM gateway

4.2.5 Components offered by the ESTIA project

The ESTIA project contributes to the AIM project with the OSGi AIM gateway concept. OSGi (www.osgi.org) represents a standardized java framework for software components. These interworking components, called bundles, reside inside a micro-computer architecture. The OSGi framework contains all the necessary components to install new bundles (actually java .jar files), activate or deactivate them, remove them, and, most importantly, use the functions of bundles installed on a platform by other bundles.

The AIM gateway (Residental Gateway) is the centre of the home network. The Gateway provides the physical medium and the corresponding networking technologies for interconnection with the ESTIA home networking devices including PDAs, WiFi phones, DECT phones, Fridges, Ovens, Washing Machines, TVs & Set-top-boxes, Electrical installation devices, etc. The following graphic shows the Gateway as the centre connection point for several device classes.

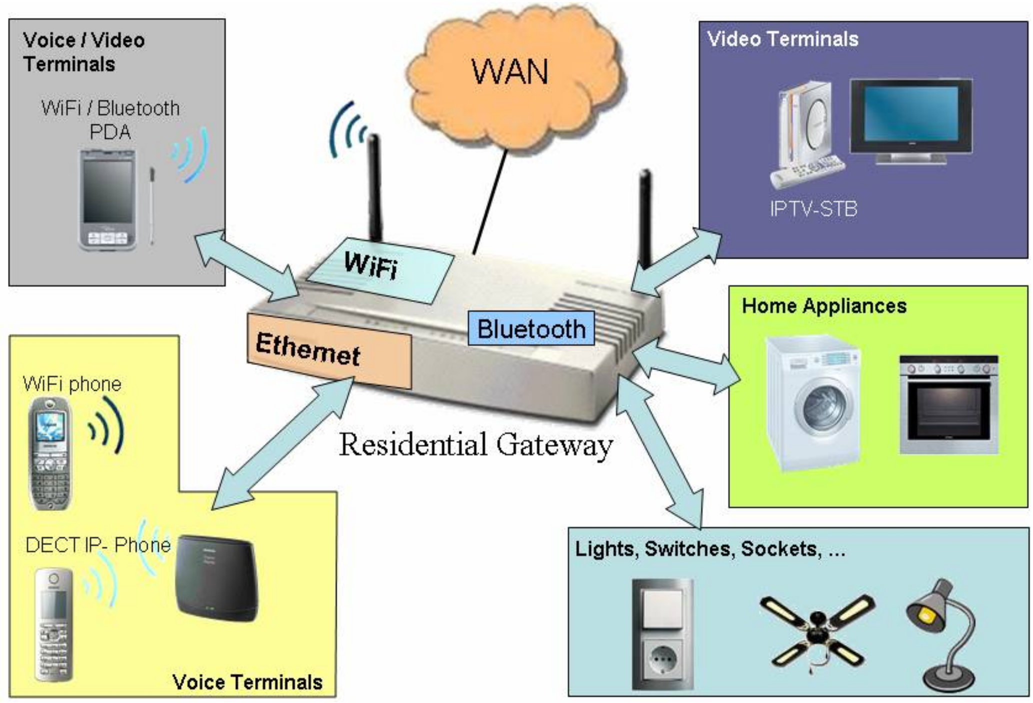


Figure 30:The residential gateway my host other functionalities besides the AIM core logic

Bundles may be updated dynamically without the need to shut down the framework, which is probably the most essential feature of OSGi. Such updates may be done by remote access to the framework. This allows the provision of **dynamic APIs**, i.e. a new bundle provides new functions, which may be discovered and accessed by other modules without prior definition of a higher layer API. This makes OSGi particularly suitable as a platform for AIM gateways.

Another key concept for home networks represents the usage of OSGi bundles as proxies for services, which are not contained on the OSGi platform itself, but hosted on other devices in the household. Such applications may be used by OSGi bundles in the very same way as bundles which are installed locally. Therefore, the use of OSGI bundles which are native to other technologies (such as Universal Plug and play, Bluetooth etc) may be used to offer functions contained in the existing OSGi platform - and may be offered (or published) to other devices as native functions, although they are not actually native. This allows OSGi to support **import and export services**.

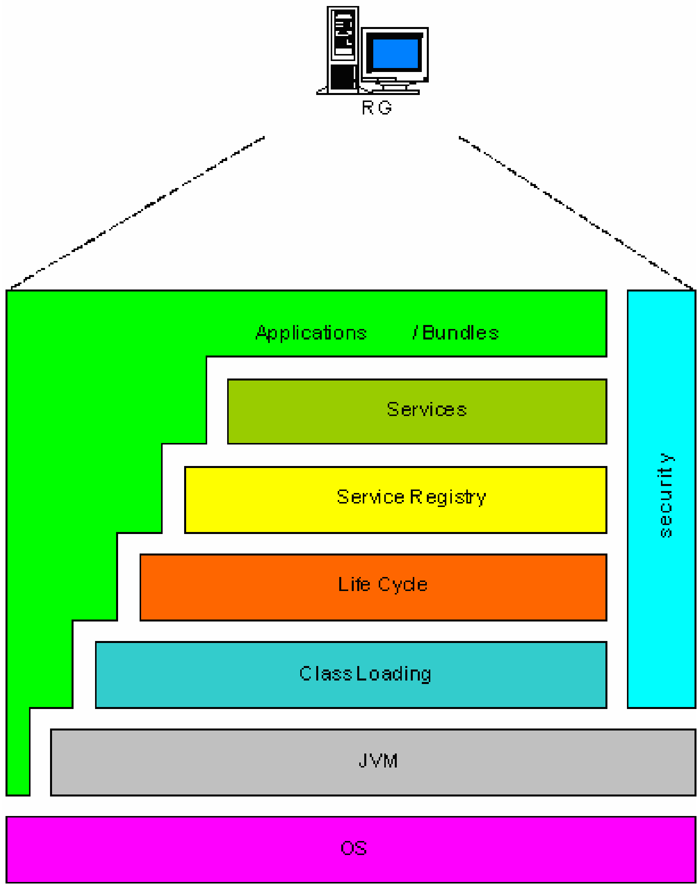


Figure 31:The concept of bundles and OSGi services

4.2.5.1 The concept of bundles and OSGi services

A service is specified as a Java interface implemented by some bundles, lookups can be used to track services from other bundles using a query language. A bundle is the deliverable application: It registers the services. When a bundle is stopped, it is cleaned up, registered services are removed and references to other services are removed. Bundles can be notified when a service they depend on is unregistered and class path dependencies are managed.

This model allows long running applications with dynamic software updates.

A bundle is packaged as a JAR (zip) file containing:

- Java classes;
- Manifest with information about the bundle;
- Resources (i.e., images, libraries, etc.).

A bundle can also act like a DLL (shared library). The OSGi framework provides mechanisms to support continuous deployment activities (for example a local console or an administration web page). A bundle can go through various stages while the Framework is hosting it:

- Installation;
- Activation;
- Deactivation;
- Un-installation.

This sequence is called the Bundle lifecycle and it is depicted in the following figure.

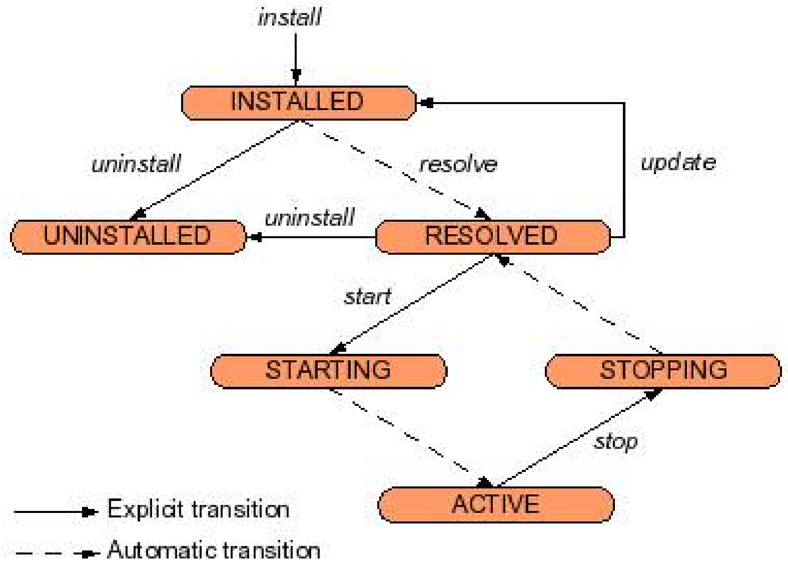


Figure 32: Bundle lifecycle

Once the bundle is activated, the offered services can perform their intended functionalities. When the service is no longer needed, the bundle is deactivated and uninstalled. One of the main advantages of the OSGi framework is that a bundle can be updated with a new version on the fly after its activation.

4.2.5.2 OSGi in the AIM gateway

The OSGi framework is the spirit of the OSGi service platform, which addresses issues caused by running multiple applications in a single JVM. Its responsibilities include: class loading, life cycle management, service registration, and security issue.

- *Class loading*. OSGi allows the solution to share classes among bundles instead of making them private. This attribute lessens the bundle size and memory footprint.
- *Life cycle management*. This component ensures that bundles are dynamically installed, started, stopped, updated and uninstalled.
- *Service registry*. A service registry is the object container for OSGi services. Services are just Java objects published by one bundle so that other bundles can use them. Associated Java objects could be anything, even a HTTP server engine, for instance, is a Java object. A Java object is registered with an interface name and a set of properties. For example, the OSGi HTTP Service would be registered with the *org.osgi.service.http.HttpService* interface name and properties such as *vendor=Oscar*. Service registry enables bundles to register their objects, looking for matching services and being notified when services are coming-in or going-out. Service registry therefore links bundles together and turns the OSGi service platform into a component framework.
- *Security*. OSGi security is based on the Java 2 security model. The access modifier in Java 2 security model makes classes, methods, and fields private (accessible only by classes in the same package), protected (accessible by sub-classes) or public. OSGi extends this model by adding an extra level package private to the bundle which indicates these packages are only accessible by code inside the package but restricted by other bundles.

Bundles, which are installed on an OSGi, register their APIs in a registry server. Other bundles may access this registry to look up functions offered by all the executing bundles in the platform. By using **Proxy Bundles**, this concept may be extended to services offered by other remote devices in the home network.

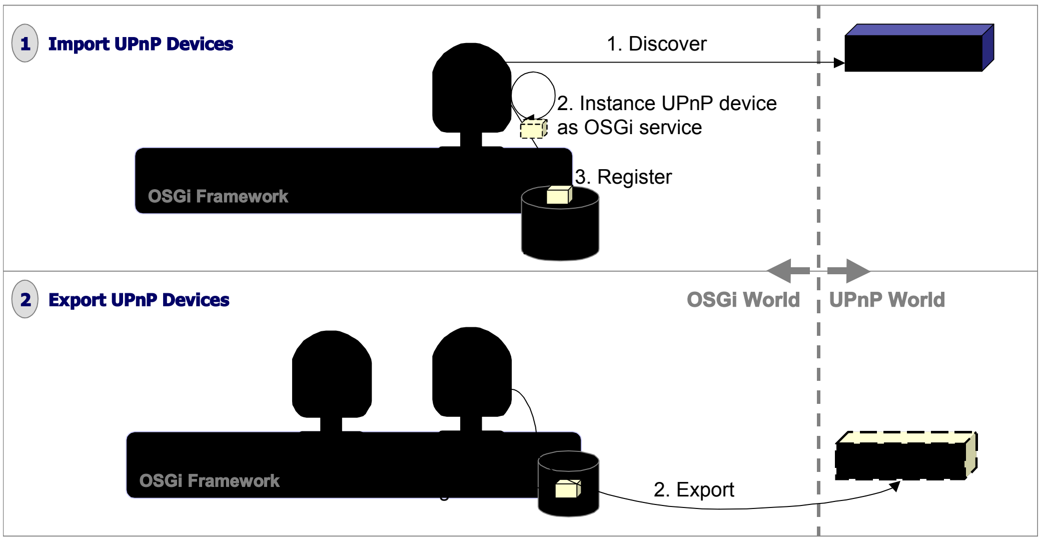


Figure 33: Using an OSGi base driver as service proxy

For example, the home network contains a Universal Plug and Play (UPnP) device (such as a UPnP enabled Television Set of a Set-Top-Box). In order to communicate with such devices, a UPnP bundle is required to exist on the OSGi platform, the so called **UPnP base driver**. The UPnP base driver handles the communication over UPnP enabled protocols. Following discovery, the Universal Plug and Play (UPnP) base driver instantiates a corresponding OSGi device and registers this device in the OSGi registry. The external UPnP device may now be discovered and used by all other OSGi bundles on the platform. This way, the functions available outside OSGi through UPnP have been imported onto the remote OSGi platform using a Proxy bundle (OSGi base driver).

In the opposite direction, services contained on the OSGi platform could be exported or exposed to other devices. In this case, the Proxy bundle (UPnP base driver) looks up the functions in the service registry and advertises its related functions.

Import and export of services is not limited to local networks or home networks. In the very same way, the OSGi platform may connect services offered in the Wide Area Network (WAN). For the chosen WAN technology (such as peer-to-peer technologies for services discovery, respectively web-services), corresponding base driver bundles need to be installed. This way, services contained within the home network may be accessible from the WAN, for remote operation or for remote configuration management.

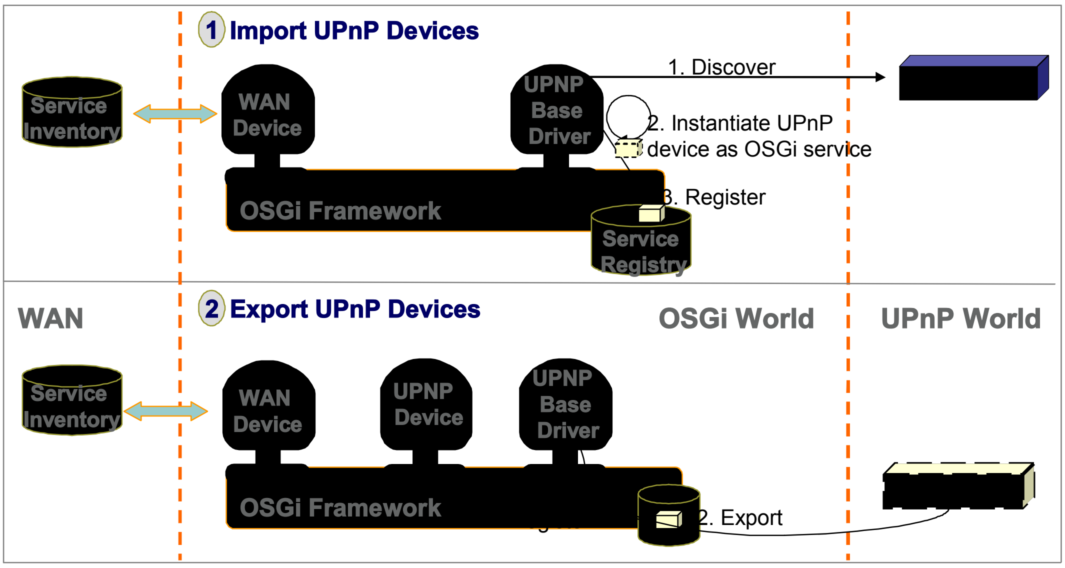


Figure 34: Dynamic import and export of services - using OSGi in combination with other technologies which support service discovery

4.2.5.3 General concepts in service discovery

Discovery of bundles within the OSGi platform depends on the following conventions: **(1)** on the registration of services in a registry; **(2)** on the formal description of interfaces for functions; and **(3)** on the communication of newly available functions (or functions no longer available). The same concepts apply to service discovery in local networks and wide area networks. There are available components of technologies for zero-configuration-management in local networks such as UPnP, Bluetooth, SLT etc. The same concepts apply to service discovery of wide area networks such as Web-Services, CORBA or peer-to-peer based discovery mechanisms such as JXTA.

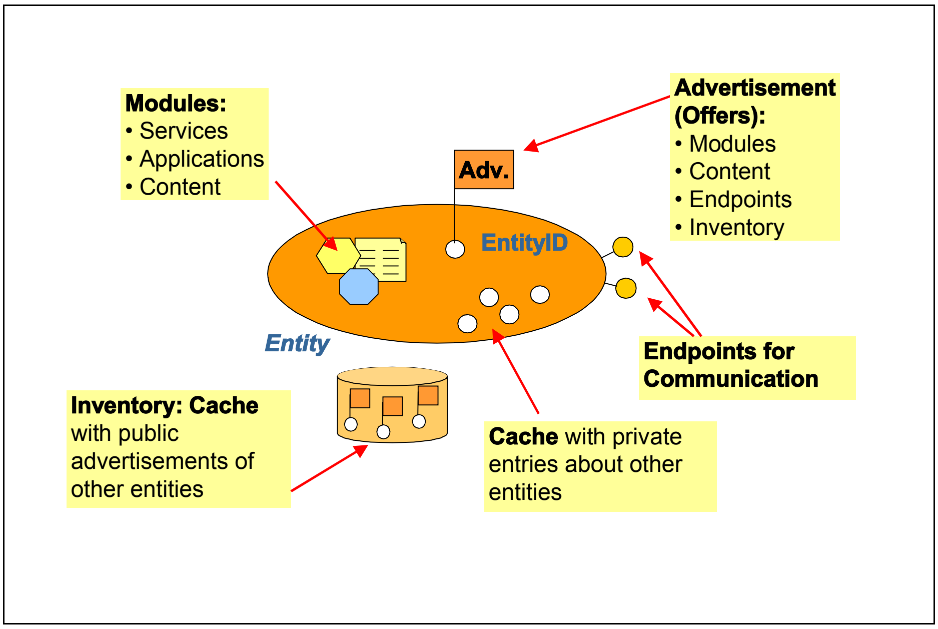

Modules:
• Services
• Applications
• Content
Advertisement (Offers):
• Modules
• Content
• Endpoints
• Inventory
Adv.
EntityID
Entity
Endpoints for Communication
Inventory: Cache with public advertisements of other entities
Cache with private entries about other entities

Figure 35: Dynamic handling of supply and demand

The bundle, server or functional entity, which offers services or wishes to consume services, is called an OSGi **Entity**. An Entity may contain several modules, i.e. services to offer (such as routing capabilities, or look-up capabilities), applications, or just content. An entity may contain knowledge about other entities in its cache, but, as such, it is not verifiable to its exterior environment.

The only visible part of an Entity is its '**advertisements**'. Advertisements contain the modules or functions offered to other entities, including the communication capabilities of the entity (protocol, port and object reference it is using). Advertisements may be locally hosted (such as in Bluetooth devices), or using entities, which are specialised to handle other 'advertisements', i.e. inventories of registries.

This generalised concept is far too abstract for any practical use in any implementation. However, it may help to portray the basic concepts behind dynamic service discovery and the mechanisms required to handle zero-configuration networks across a multitude of existing technologies. In this abstracted level, OSGi is close to UPnP and wide area network concepts such as Web-Services.

4.2.5.4 Positioning within a broader scope

The functional group handling User and Devices profiles within ESTIA's AIM gateway (Residental Gateway) was responsible for storing information related to the users of the ESTIA home network, as well as the devices attached to the network. Due to work decomposition and distribution at the early stages of the project, it was decided to dissociate this information from that affecting the policies definition, creation and management.

Nevertheless, and in order to allow these operations, the User and Device profiles would maintain per subscriber and per device a set of specific parameters, allowing categorization and differentiation of users and profiles, in order to apply corresponding policy operations in a consistent way - and with a certain degree of granularity (e.g. access rights to specific Gateway services).

An internal API was provided towards these functional elements, so that they could access and modify, if necessary, the information contained within the profiles. At the same time, the profile functionality group provided a graphical user interface, allowing profile management for the administrator of the AIM gateway or its users.

4.2.5.5 Standards/other specifications documents used

The design of the profile functional group was based on an embedded SQL Server database management system (DBMS), such as the open source McKoi embedded Java SQL Server. This SQL server was packed inside its own OSGi database bundle. The SQL service constitutes an augmentation to the OSGi's registry service. It is able to track a connected device's attributes and XML setup data from a unified and centralized repository. This repository can be updated remotely using a web interface service.

When the actual profile to a device is sought, an access to the SQL service yields XML templates, which can be submitted to the OSGi registry service. Minimal data on the device needed to be communicated (e.g. device manufacturer and id); the specific functional attributes are stored transparently and uniformly inside a database structure, inclusive of XML scripts, associated bundle information , actual file locations etc. Basing the storage of the different profiles as XML files inside a database is advantageous. The structure of these registry files, or profiles, is dictated by a User profile "template" and a Device profile "template", both defined as XML scripts. These two templates are conveniently interconnected by the SQL service for each associated AIM device.

The software architecture for the AIM gateway, based on the OSGi architecture, facilitated the design of special APIs provided by the profile functional group. Therefore, an OSGi bundle, behaving as an OSGi service-provider to other bundles, published the requested profile API functionality while other bundles used the service provided by the previous one. Two different APIs, in the form of two different OSGi service bundles, one for **User profile** operations and the other for **Device profiles**, are executing.

In order to integrate the XML handling operations within the RW OSGi bundles, the JAVA API for XML Binding (JAXB) was used. This API allowed the mapping of the structure defined by an XML Scheme into a tree of classes, generated by the JAXB binding functionality. Further operations allowed the mapping of XML documents, compliant to the reference XML Scheme, with runtime data structures compatible to the reference tree of classes obtained in the original binding.

4.2.5.6 Technical approach

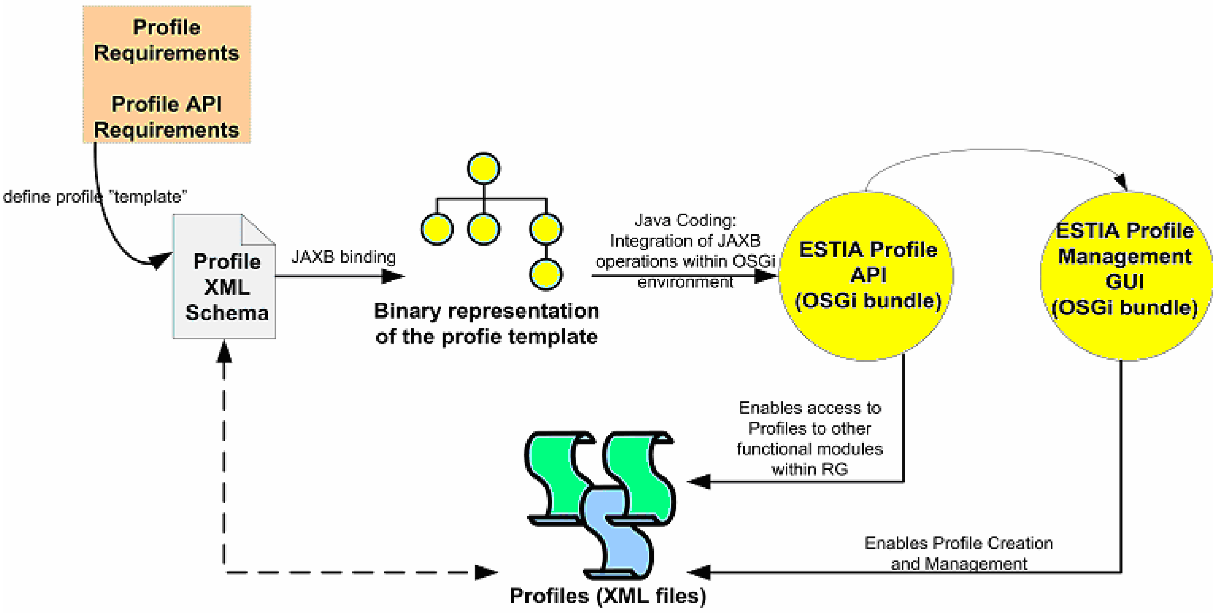

Profile Requirements
Profile API Requirements
define profile "template"
Profile XML Schema
JAXB binding
Binary representation of the profie template
Java Coding: Integration of JAXB operations within OSGi environment
ESTIA Profile API (OSGi bundle)
ESTIA Profile Management GUI (OSGi bundle)
Enables access to Profiles to other functional modules within RG
Enables Profile Creation and Management
Profiles (XML files)

Figure 36 : Profile technical approach and implementation processes

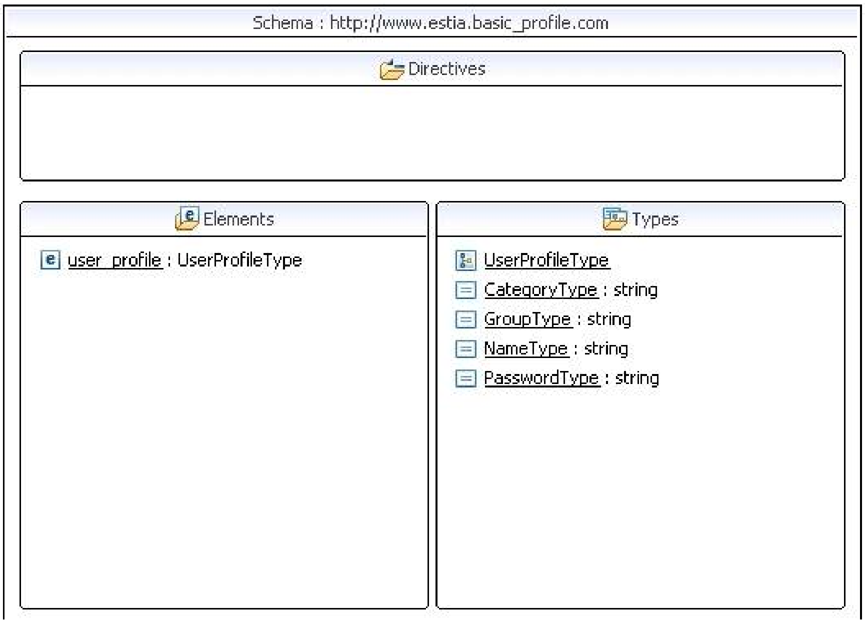
The technical approach of the basic profile APIs utilized the JAXB standard to manage XML based profiles via Java objects. The User/Device Profile API can be seen as two independent OSGi bundles that enabled profile management (in basic functionality). Other OSGi bundles take advantage of the basic profile management and/or provided value-added services.

4.2.5.7 Basic bundles for profile management

The User/Device Profile API consists of two interfaces, the API itself (basic OSGi bundle) and the JAXB-enabled binding, providing a representation of the Profile template. In the following segment the XML schema definition of the User and Device profile is introduced. The XML schema was used by the JAXB process to generate the dedicated class structure that was imported by the API.

4.2.5.8 User profile schema

A representation of the initial user profile is presented bellow as an example (based on Eclipse's Web Tools project Editor).



Schema : http://www.estia.basic_profile.com

Directives

Elements

user_profile : UserProfileType

Types

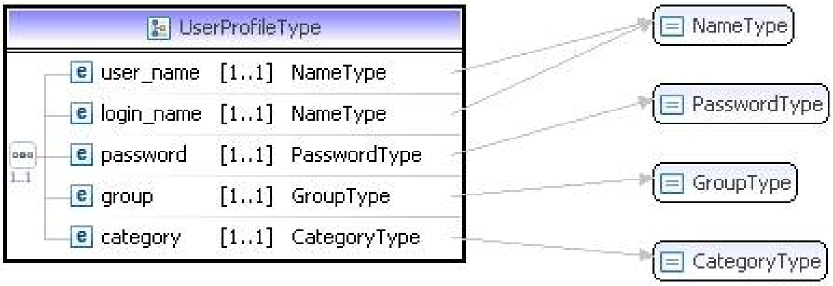
UserProfileType
CategoryType : string
GroupType : string
NameType : string
PasswordType : string

Figure 37: User profile elements and types

A single root element "user_profile" of complex type *UserProfileType* has been defined in the profile. Other types have been also defined as they appear in the figure, mainly *NameType*, *PaswordType*, *GroupType* and *CategoryType*.

These definitions responded to the differentiation of the different elements defined for the main type UserProfileType. As shown, the elements defined for this basic profile were the following:

- User_name: the complete id of the user;
- Login_name: the chosen name within ESTIA for that user;
- Password: the password associated to the user within ESTIA;
- Group: an identification of the group-membership of the user that allows to relate each user to different policies established in the ESTIA network;
- Category: an identification of the category assigned to the user that allows relating each user to the different policies established in the ESTIA network.



UserProfileType

user_name	[1..1]	NameType
login_name	[1..1]	NameType
password	[1..1]	PasswordType
group	[1..1]	GroupType
category	[1..1]	CategoryType

Figure 38: User profile elements and types

Many other parameters could be also part of the user profile and will be added when required, according to the respective scenarios. Other parameters could be associated or even had varying multiplicity. For example different *AuthenticationTypes* could be defined containing each a login_name and password, and allowing a user to have multiple elements of this type.

The reason to define these different types was to allow modifications of the schema in a modular way.

```
<simpleType name="NameType">
<restriction base="string">
           <minLength value="3"></minLength>
           <maxLength value="30"></maxLength>
      </restriction>
```

NameType definition

In the same way the *PasswordType* has been defined as an 8 characters string element as shown below. This is only a demonstrative example, since the final requirements could be different.

```
<simpleType name="PasswordType">
<restriction base="string">
           <length value="8"></length>
     </restriction>
```

Password Type definition

The *GroupType* and *CategoryType* had been defined as enumerations of string elements with a set of predefined values as shown below. Therefore three different groups of users were initially defined in ESTIA: users that belonged to the ESTIA network (with no administrator rights); those that belonged and had administrator rights; and those that did not belong to the ESTIA network but might use it as “guest users”, visiting an ESTIA controlled home at a certain point in time.

```
<simpleType name="GroupType">
 <restriction base="string">
           <enumeration value="inhabitantUser"></enumeration>
           <enumeration value="guestUser"></enumeration>
           <enumeration value="administrator"></enumeration>
      </restriction>
```

GroupType definition

The value *inhabitantUser* was kept in the profile but the final API used a value *residentUser* instead of the original one, due to a modification of nomenclature during the API specification with the rest of partners. In the same way, the *CategoryType* was defined as an enumeration of predefined values, child or adult, which represent the two initial sets of user categories that would be used in the Policy Management Module in combination with the *GroupType* defined previously.

```
<simpleType name="CategoryType">
      <restriction base="string">
            <enumeration value="kid"></enumeration>
            <enumeration value="adult"></enumeration>
      </restriction>
```

CategoryType definition

In this case the API provided a different value (*child*) corresponding to the *kid* value within the profile. Once the different types had been defined, it was possible to complete the definition provided on the UserProfileType element .

```
<complexType name="UserProfileType">
 <sequence minOccurs="1" maxOccurs="1">
   <element name="user_name" minOccurs="1" maxOccurs="1"
                  type="AIM_basic:NameType" default="NEW_USER"/>
   <element name="login_name" type="AIM_basic:NameType"
            default="ali_baba" minOccurs="1" maxOccurs="1"></element>
   <element name="password" type="AIM_basic:PasswordType"
            default="12345678" minOccurs="1" maxOccurs="1"></element>
   <element name="group" type="AIM_basic:GroupType" default="homeUser"
            minOccurs="1" maxOccurs="1"></element>
   <element name="category" type="AIM_basic:CategoryType"
            default="child" minOccurs="1" maxOccurs="1"></element>
```

UserProfileType complete definition

Once the different types were completely defined, this profile was defined just as a single element of type UserProfileType as appears below:

```
<element                                                   name="user_profile"
type="AIM_basic:UserProfileType"></element>
```

User_profile element definition

As it can be seen, all the previous components appeared integrated in a single XML document conformant to the XML Schema (XSD) specification from W3C. A namespace, *estia_basic* has been defined to identify the elements conformant to this schema among different XML documents, as it will be described later on.

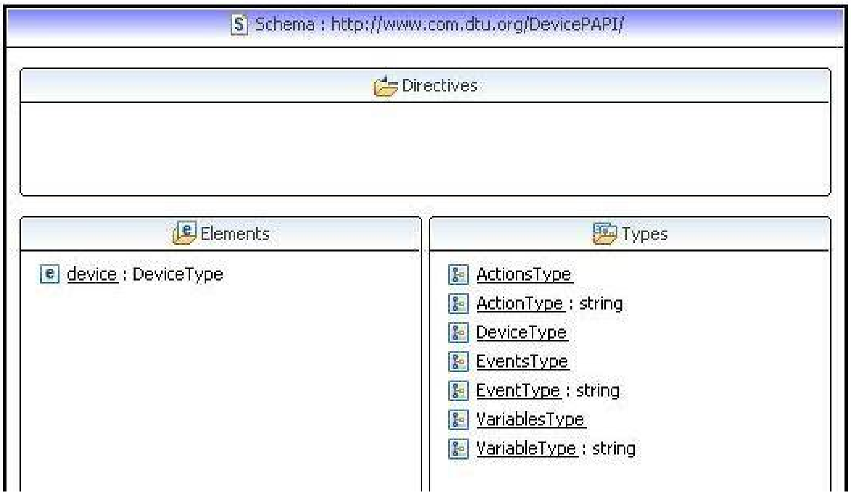
```
<?xml version="1.0" encoding="UTF-8"?>
<AIM_basic:user_profile
xmlns:AIM_basic="http://www.AIM.basic_profile.com"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.AIM.basic_profile.com
Basic_User_Profile.xsd ">

 <user_name>Jose Soler</user_name>
 <login_name>jose</login_name>
 <password>AIMini</password>
 <group>administrator</group>
 <category>adult</category>
```

User profile lements and types

The result of the JAXB binding operation of this schema resulted into a series of java classes. These classes were incorporated into the final API bundle as estia.jar file within the bundle, which allowed the different operations over the profile components.

4.2.5.9 Device profile schema

The main requirement for a device profile represented the development of a generic frame for many different kinds of devices. Therefore, the XML structure did not depend on element names specific to a single device (document-orientation). Moreover, simple data types of the device profile schema referred mainly to the type "String" (or restricted String) in order to guarantee compatibility with several vendors and description formats.



Schema : http://www.com.dtu.org/DevicePAPI/

Directives

Elements

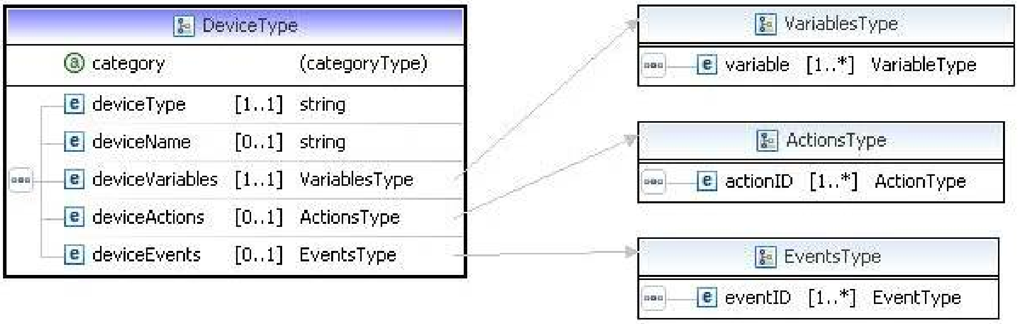
device : DeviceType

Types

ActionsType
ActionType : string
DeviceType
EventsType
EventType : string
VariablesType
VariableType : string

Figure 39: Schema types within the device profile

The type *DeviceType* represented the root for a single device whereas other types defined the inner structure of the device.



DeviceType

category		(categoryType)
deviceType	[1..1]	string
deviceName	[0..1]	string
deviceVariables	[1..1]	VariablesType
deviceActions	[0..1]	ActionsType
deviceEvents	[0..1]	EventsType

VariablesType

variable [1..*] VariableType

ActionsType

actionID [1..*] ActionType

EventsType

eventID [1..*] EventType

Figure 40: DeviceType definition and references

The *DeviceType* definition included several simple and complex XSD types:

- An identifier that classified the device into a category (value of the attribute "category", e.g. electrical device/white goods);
- An unique identifier for each device (element *deviceType*);
- An optional vendor specific device name or number (element *deviceName*);
- List of device variables that can be manipulated by events;
- List of device actions consisting of an action identifier and a reference to the device variable;

- List of device events consisting of a event identifier and a dedicated event description.

The list of device variables, device actions and device events were designed in the same way and consisted each of a compound element that was specified as a complex type (see *VariablesType*, *ActionsType* and *EventsType*). Variables in general usually referred to current settings on the device, whereas actions were used to influence these current settings. The list of events might be used to classify or retrieve the allowed settings of the device variables (e.g. a list of allowed settings for the current state).

```
<?xml version="1.0" encoding="UTF-8"?>
<AIM:device category="Electrical_Device"
      xmlns:AIM=http://www.com.dtu.org/DevicePAPI/
      xmlns:xsi=http://www.w3.org/2001/XMLSchema-instance
      xsi:schemaLocation="http://www.com.dtu.org/DevicePAPI/DeviceProfile
      .xsd ">
 <deviceType>SiemensOven</deviceType>
 <deviceName>myOven 1.5.02</deviceName>
 <deviceVariables>
 <variable id="CurrentState" eventNumber="2148" >600</variable>
 </deviceVariables>
 <deviceActions>
 <actionID>Start</actionID>
 <actionID>Stop</actionID>
 <actionID>Pause</actionID>
 </deviceActions>
 <deviceEvents>
 <eventID desc="Stand by">600</eventID>
 <eventID desc="Programmed">601</eventID>
 <eventID desc="Running">602</eventID>
```

Figure 41: Device example

This excerpt depicts an example of the EPM2-Oven, which included a single device variable and dedicated actions and events. The figure shows that the device specific parameters were always designed as element/attribute values in order to even parse a device that was not known yet. Due to this generic structure, device validation had to be clearly done at the client side of the **Device Profile** API since the device profile schema would accept all devices that followed the element structure and required parameters. Required parameters were the device type, the category and at least one device variable. Events and actions were optional.

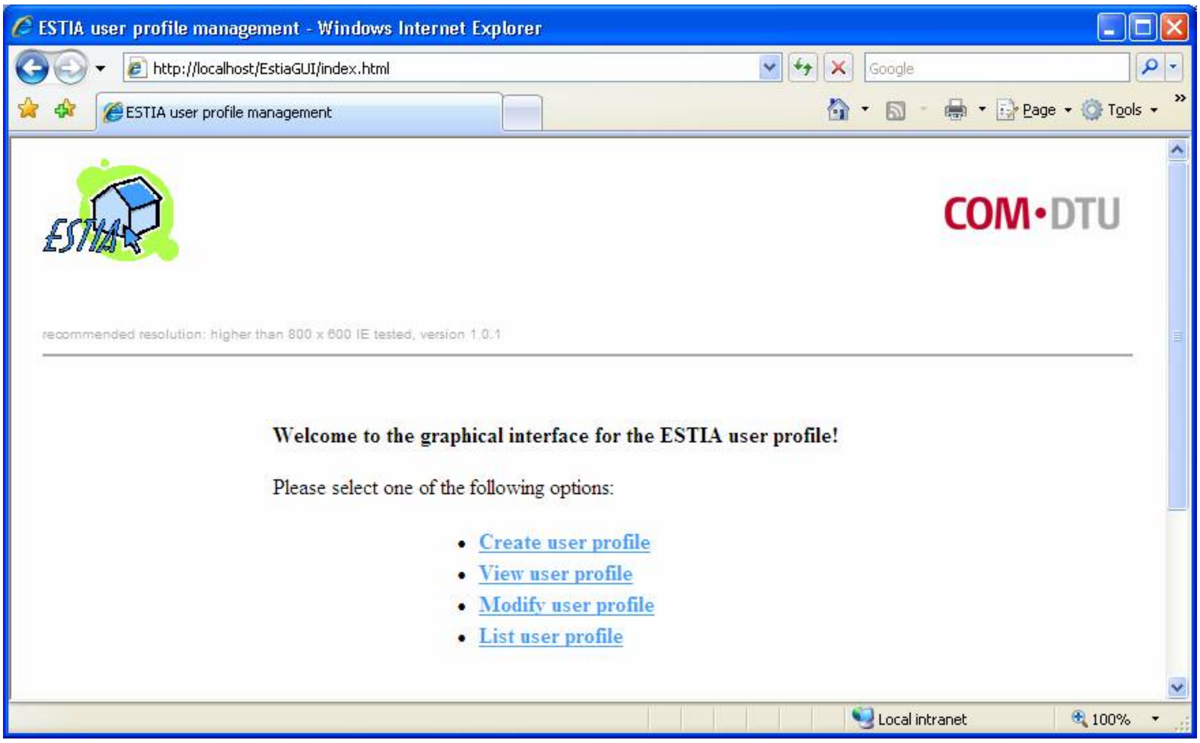
4.2.5.10 User/Device profile API and JAXB binding

The User/Device Profile API (UPAPI/DPAPI) offered an OSGi interface to other subsystems in the AIM gateway. It provided its functionality to other bundles within the OSGi architecture of the Residental Gateway. Both API´s used the JAXB binding and the generated JAXB java classes to interface with the file based XML storage.

4.2.5.11 User profile management GUI

The interface of the profile functionality module to users of the AIM gateway was based on a web-graphical interface. This interface was implemented as another OSGi bundle within the AIM gateway, using the services provided by the previous User Profile API.

The interface exposed the API functionality and made it available to an administrator or user to access, create or modify profiles. The GUI was built on top of a Java Servlet container and required the HTTP OSGi bundle that was included in the Servlet container 'Jetty'. No security access verification had been included, since it was outside of the scope of the project and the module's functionality. The following image presents a screenshot of the mentioned interface.


ESTIA user profile management - Windows Internet Explorer
http://localhost/EstiaGUI/index.html
Google
ESTIA user profile management
Page
Tools
ESTIA
COM•DTU
Local intranet
100%

recommended resolution: higher than 800 x 600 IE tested, version 1.0.1

Welcome to the graphical interface for the ESTIA user profile!

Please select one of the following options:

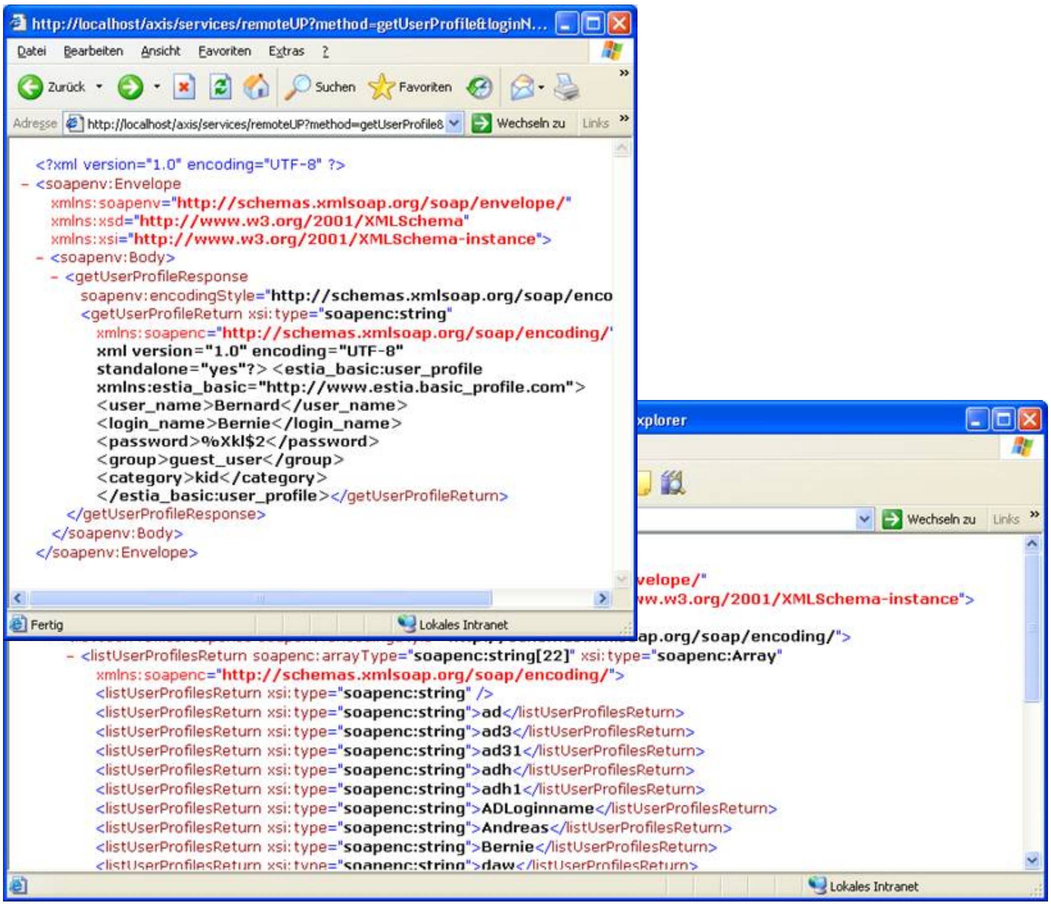
- Create user profile
- View user profile
- Modify user profile
- List user profile

Figure 42 : ESTIA's user profile management interface

4.2.5.12 Web service interface of the User/Device profile

The Web Services bundle of the User/Device Profile provided access to the overall profile information via the main identifier:

- Login name for the User Profile;
- Device type for the Device Profile.



```
  <?xml version="1.0" encoding="UTF-8" ?>
- <soapenv:Envelope
    xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  - <soapenv:Body>
    - <getUserProfileResponse
        soapenv:encodingStyle="http://schemas.xmlsoap.org/soap/enco
        <getUserProfileReturn xsi:type="soapenc:string"
          xmlns:soapenc="http://schemas.xmlsoap.org/soap/encoding/"
          xml version="1.0" encoding="UTF-8"
          standalone="yes"?> <estia_basic:user_profile
          xmlns:estia_basic="http://www.estia.basic_profile.com">
          <user_name>Bernard</user_name>
          <login_name>Bernie</login_name>
          <password>%Xkl$2</password>
          <group>guest_user</group>
          <category>kid</category>
          </estia_basic:user_profile></getUserProfileReturn>
      </getUserProfileResponse>
    </soapenv:Body>
  </soapenv:Envelope>
```

```
velope/"
ww.w3.org/2001/XMLSchema-instance">
ap.org/soap/encoding/">
    - <listUserProfilesReturn soapenc:arrayType="soapenc:string[22]" xsi:type="soapenc:Array"
        xmlns:soapenc="http://schemas.xmlsoap.org/soap/encoding/">
        <listUserProfilesReturn xsi:type="soapenc:string" />
        <listUserProfilesReturn xsi:type="soapenc:string">ad</listUserProfilesReturn>
        <listUserProfilesReturn xsi:type="soapenc:string">ad3</listUserProfilesReturn>
        <listUserProfilesReturn xsi:type="soapenc:string">ad31</listUserProfilesReturn>
        <listUserProfilesReturn xsi:type="soapenc:string">adh</listUserProfilesReturn>
        <listUserProfilesReturn xsi:type="soapenc:string">adh1</listUserProfilesReturn>
        <listUserProfilesReturn xsi:type="soapenc:string">ADLoginname</listUserProfilesReturn>
        <listUserProfilesReturn xsi:type="soapenc:string">Andreas</listUserProfilesReturn>
        <listUserProfilesReturn xsi:type="soapenc:string">Bernie</listUserProfilesReturn>
        <listUserProfilesReturn xsi:type="soapenc:string">daw</listUserProfilesReturn>
```

Figure 43: User profile and listing functionality provided over the Web services bundle

4.2.6 Appliance power modes

This section contains information compiled from D2.3. More specifically, we define here the required appliance power consumption modes that were identified as the most crucial in D2.3. One of the results was there is no need to hard-code the power consumption of specific appliance operating modes since it is impossible to do so given the plurality of devices that exist. Therefore, devices advertise their power profile modes to other devices and the EMD that are located in the home network.

Furthermore, another level of categorization of the different power profile modes was adopted. The following types of power management profiles were briefly discussed and proposed in D2.3:

1. The instant of the power consumption is manageable/flexible;
2. The amount of power is manageable;
3. It is hard to manage the time instant and the amount of power consumed.

These power modes should be advertised by each device so that the AIM system can correctly interact with the device.

4.2.7 Adapting to users

The ability of the AIM system to adapt to user specific requirements and preferences is a fundamental feature that may determine the level of satisfaction of users and the overall success of this kind of energy management systems.

It is commonly recognized that there are basically two issues that are important for user acceptance, namely the perception that the system is under direct control all the time and that it is easy to use and able to adapt automatically to needs without complex configuration processes. In the AIM system the user direct control of the system is guaranteed on one side by the possibility to interact manually with all appliances and devices at any moment, and on the other side by the definition of a set of user preferences that allow enforcing some specific behaviour. This is obviously not enough for providing an easy to use system and for this reason the AIM system includes also user profiling in order to self-adapt to user habits and to the normal way it uses home appliances. User profiling can take advantage of the supplementary functions provided by a sensor network which can provide some inputs to the system on user identification, user presence at home (and in a specific room), and the level of some physical parameters like the temperature and the light.

4.2.7.1 User profiling

The user profiling process includes basically two functionalities: a mechanism for recording some events that can characterize the way in which users interact with the home environment and the available appliances; and a simple learning algorithm that allows extracting from all these data some reasonable settings of the energy management system that is expected to be the most appropriate meet user requirements. Note that the reasoning and learning algorithms are topics orthogonal to the AIM project. Nevertheless, we expect that advances in these areas can enhance the potential energy reduction for the AIM system. The final goal of the user profiling function is that of replacing some of the required system settings based on a manual interaction with a user interface with an automatic configuration procedure that can be performed on request. To this extent, this function must be able to provide inputs to the energy management system exactly in the same way a user could do through the user interface and it can be considered a plug-in of the system that can be enabled of disabled by the user.

We point out that the user profiling function that is described here is different from the basic user profiling mechanisms described earlier, that refer only on general information regarding the user.

The event recording system allows storing the presence of users at home and in specific rooms and the period of times in which it used specific devices according to:

- The day of the week (typically week-days, week-ends, holydays);
- The time of the day (the granularity may be quite coarse like e.g. half-hour or hour).

From these data the learning system can extract some characteristics of the user habits in the form of probability distributions. For example it can derive the probability distribution of the user presence at home during week-days and week-ends (see Figure 44), the probability distribution of the presence in the living room, the probability distribution of using the HiFi audio system, etc. If relevant the learning system can also extract joint probability distributions like for example the probability of using two devices at the same time.

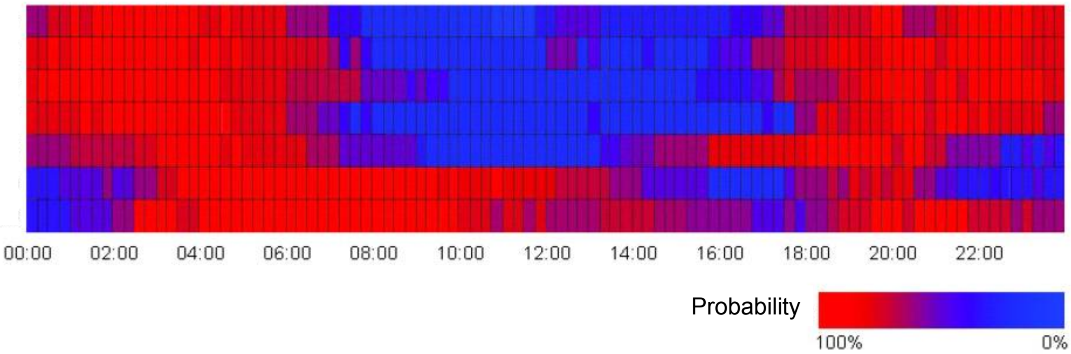


Figure 44: Example probability distribution of user at home during the week

Based on this user profile characterization, the system can take same decisions on the energy management settings for basically two main purposes:

- Set the devices in a low power mode when the probability of being used is very low and set them in some active mode when the user will likely use them (like e.g. activate screen, remote control, etc.);
- Schedule activities requested by the user in periods of times that fits requirements (like e.g. run the washing machine program before the user is back home, heat the milk 5 minutes before the user comes in the kitchen, etc.).

In some scenarios, the user profiling function can take advantage of some feedbacks provided by the user on some undesirable settings performed by the system automatically. For example, if the user is forced to activate manually a device that was set in power save by the system, this can generate a penalty to the learning algorithm that can be translated into a modification of the parameters that determine algorithm decisions.

4.2.7.2 User preferences

The functions described below are the objective functions to achieve for the energy management in the house. These functions need to coexist with specific functions requested by the users. They are not intended to change the result wanted by the user, but they manage energy allowing the user to have his/her result at the time he/she desires it and at the same time they have to pursue the objective of the settled function.

We assume the home environment populated by a user that has a defined set of devices connected to the system and also a defined set of actions available for each device.

The actions available in the home environment are:

- Manage temperature;
- Cook by microwave oven;
- Wash clothes by washing machine;
- Light up a room by multiple light bulbs.

Below there is a description of a set of discrete options available to the user for each generic action. This options impact on the AIM system giving to the system different degrees of freedom in which it can move its choices in order to achieve the goal selected by the user.

Selecting options number 1, AIM has more degrees of freedom to manage the system. In case that the user selects also the options number 2, AIM is constrained to operate with a smaller number of degrees of freedom.

Manage temperature

Air-conditioning (warm-up/cool) to a specified temperature

Air-conditioning (warm-up/cool) to a specified temperature in multiple period of time

Cook by microwave oven

Set cooking program

Execute the program selected for a specified time

Wash clothes by washing machine

Set washing program

Execute the program selected for a specified time

Lightin up a room by multiple light bulbs (3):

Select light's positions (A,B,C) to be lighted up*

Select power consumptions to be used for specified light's positions (A,B,C)*

Auto compensate room natural light to a certain threshold**

* = Options 1 and 2 offers the same numbers of degrees of freedom.

* = Options 1/2 and 3 cannot be activated at the same time

4.2.8 Anonymity and security issues

Anonymity and security is a major requirement for a system which is so closely related to personal data and privacy issues. Critics of systems like AIM always imply that the information which is required to offer services and the profiles used to simplify and/or automate the private environment can also be used to compile personal behaviour profiles and patterns of movement. Therefore, the AIM system needs to implement a standard way of handling privacy and security policy.

The requirements towards this concept are the following:

- Internal data such as personal settings, definition of profiles and other personal information have to be kept in a secure environment. The data should be encrypted before it is saved and only the user should have the possibility to access his private data;
- Internal communication between AIM Service Logic and EMD must be encrypted as well, especially when the communication technology can easily be physically "observed" (as e.g. wireless transmissions);
- External communication between AIM Service Logic and service providers must be encrypted.

4.2.9 User applications

The notion of a user in this section refers exactly to the entity that makes use of the basic AIM system that is in place. In this project, three types of users are considered, namely the outdoor users (operators), the indoor users (appliances) and possible mobile users.

4.2.9.1 Outdoor users (fixed-mobile)

These users will access the service by way of a mobile handset (typically a Smartphone) that will connect to the service platform.

The corresponding interface will be classical and adapted to the constraints of both the device itself and the portability across devices. Access via a web browser with content adapted to small screens seems the best option in this case.

4.2.9.2 Indoor users (fixed-mobile)

In the indoor communication scenario, the AIM EMD will offer power management services to applications hosted on the AIM gateway, or on other user IP terminals. In all cases, the EMD services will be accessible to users via web service interfaces as shown in the figure below.

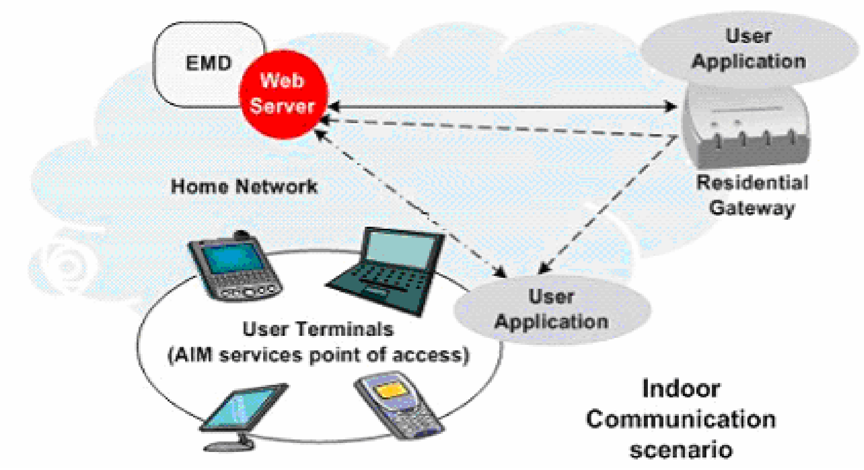


Figure 45: Indoor Communication Scenario

The user application is hosted inside the AIM gateway and communicates through a web service to any of its connected EMDs, or several in-door control terminals, like PDAs, Laptops, PCs, mobile phones or autonomous touch screens.

4.2.10 Supplementary functions (e.g. sensor network)

4.2.10.1 Sensor network

The sensor network is a component that can be used for user profiling (see Section 4.2.7). The basic function of the user profile is characterising the behaviour of users so that some settings of the energy management system can be made automatically. The sensor network provides the basic tools for gathering the information on user behaviour and its interaction with appliances from the home environment. Moreover, the sensor network provides measurements of some physical parameters like temperature and light that can be used by the system to perform some automatic adjustment of the energy management system (like e.g. regulating lighting system according to the level of natural light from windows, control the heating/conditioning system to set temperature in the rooms according to the user profile, etc.). The sensor network can also provide a mechanism for user identification (so that different profiles can be created for the different users living in the same apartment/house).

The sensor network can be implemented using several available technologies. However, wireless sensor networks are today considered the most promising and flexible technologies for creating low cost and easy to deploy sensor networks in scenarios like that considered in the AIM project. For this reason, in this project we will focus on this type of technology only.

The network considered is based on a multi-hop wireless topology which can be a simple tree topology or a mesh topology depending on the scenario and the area to be covered (see Figure 46).

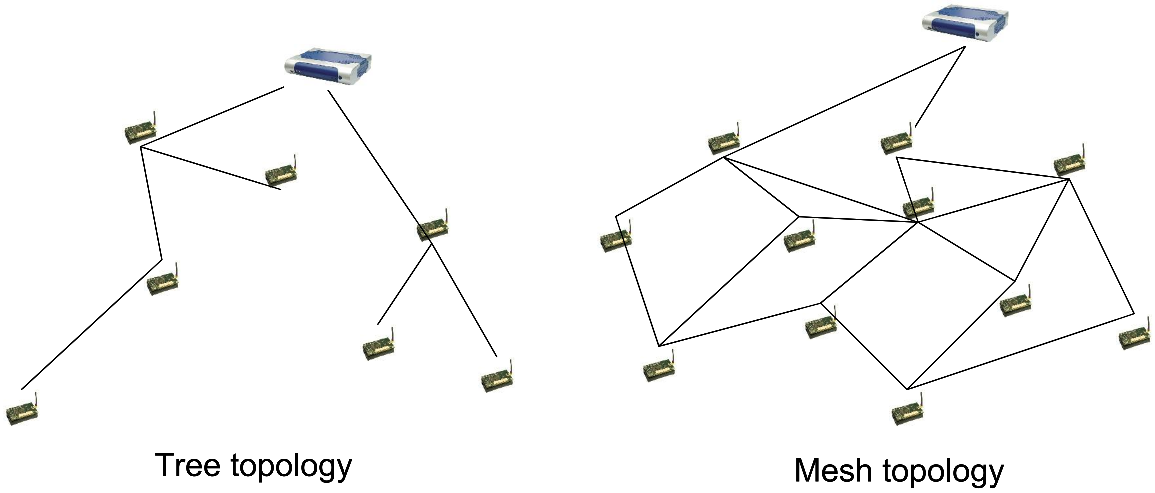


Figure 46: sensor network architecture

The network has three main protocol layers: physical layer, medium access control and routing. Different protocol suites can be adopted, including standard ones like ZigBee or Zwave.

The sensor nodes can be equipped with several sensing devices. For the AIM scenario the most relevant sensing devices include presence detection (that can be simple radar based devices or sophisticated localization systems), user identification (like e.g. RFID readers), temperature and light sensing.

Data collected by the sensor network are delivered to a sink node that is in charge of aggregating it and providing inputs to the user profiling module of the AIM logic.

5 Projection of functionalities on architecture components

In this section we provide a representative mapping of the AIM functionalities in actual hardware components. First we focus on the mapping of functionalities to the various appliances and subsequently the mapping of functionalities to additional components. In particular each appliance manufacturer has a slightly different allocation of functionalities to hardware depending on the capabilities of existing hardware.

5.1 Appliances

5.1.1 A/V

A Philips flat screen TV set which is equipped with a RJ45 TCP/IP connector is selected as the A/V equipment. The proposed mapping to hardware components is depicted in the Sketch of Figure 47. No effort is needed to adapt the software or hardware of the TV set since it will only support the operational modes that we analysed before. A standard Philips TFT will be used. The intelligence and required effort is centralised in the EMD.

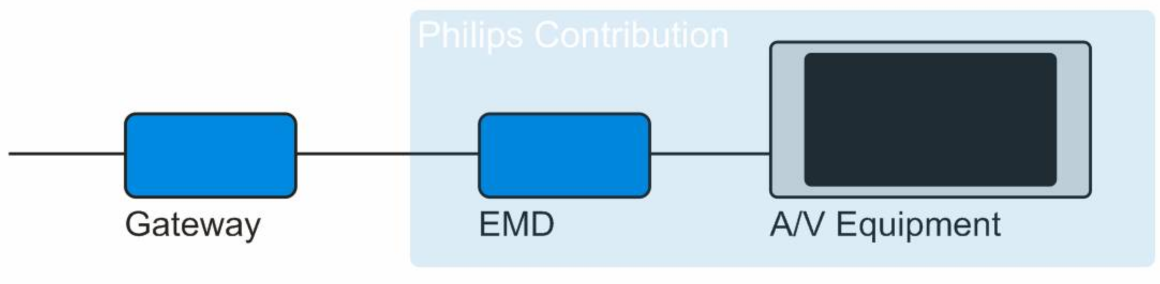


Figure 47: Sketch of the system configuration with an A/V device

An EMD will host all the functionality while the TV will not be modified. The EMD will connect to a Zigbee mesh of wireless plugs and an infrared transceiver. These plugs and equipped to switch the mains power to the A/V equipment and readout the consumed electrical energy on-the-fly. One energy management plug will be used because we only have on A/V device. The Infrared transceiver is capable of receiving and transmitting infrared signals like the Philips RC5 and RC6 standard.

In Figure 48 a schematic overview is depicted in order to show how the actual set up will look like. Via Ethernet we have access to the EMD. The interaction between the EMD and TV set will take place via Infrared (RC5 and RC6) and electromagnetic fields (Zigbee Mesh).

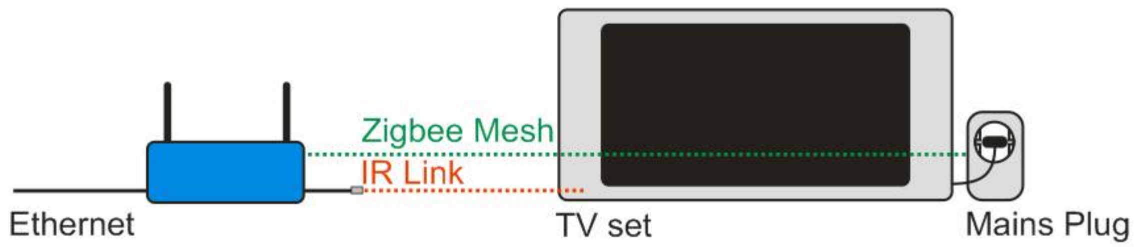


Figure 48: Schematic overview of the Philips EMD connected with a TV

Our approach is flexible. This means that other A/V equipment like a radio or other devices which are controlled via an Infrared link can be added to the system easily. The number of plugs, controlled and managed by our constructed EMD, can be increased to 60. Another reason of using the remote control gives us the freedom to putting the device in almost any state possible.

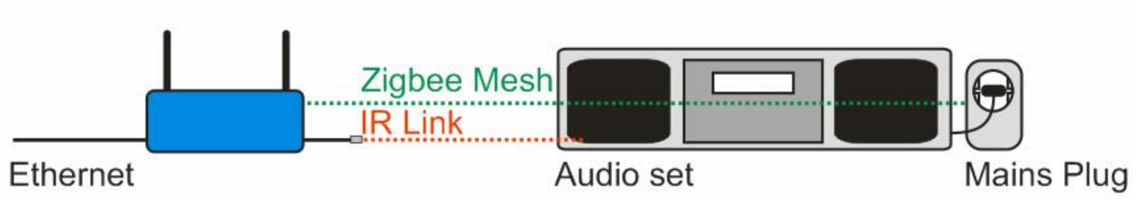


Figure 49: Audio equipment or other IR controllable equipment can also be used

5.1.2 White goods

The three white goods involved in the project are able to communicate through their I^2C port, accessible on the back of the products. A suitable adapter is used for connecting each appliance to the EMD device using a wireless link (ZigBee should be preferable), being the communication between such adapter and the appliance itself based on a proprietary protocol.

Through this communication channel, each appliance receives from the network the external data sent by the gateway (see § 5.2.1) - necessary for managing internal activities related to energy functions like “power levelling” and “load shifting”-, and sends to the gateway information about its working phase – used for energy monitoring purposes - and notifications related to possible low efficiency conditions of the appliance.

The adapter used to create a link between each appliance and EMD device is shown in the simple Figure below:

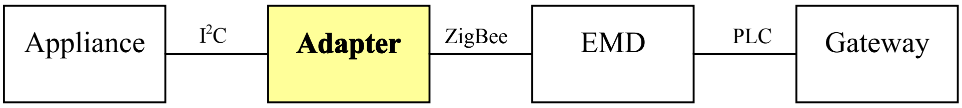


Figure 60: Sketch of the system configuration regarding white good equipments

Even if the official communication link of each appliance is based on its I^2C port, a cheaper communication technology should be convenient to explore in addition, in order to increase the commercial potentialities of “AIM Ready” white goods.

To this purpose, the applicability of a very low cost communication technology, developed and patented by INDESIT, will be tested during the project.

Such technology is able to add connectivity to an electrical household appliance without increasing its industrial cost, because it uses the same appliance’s control system for sending coded data through its power cable by mean of a proper modulation of its power consumption.

For receiving and decoding such data, a suitable plug with power metering feature is used, being such plug installed between the appliance’s power cable and a standard socket. This plug - called “smart adapter” - is also able to communicate with a local network.

INDESIT is collaborating with an important Japanese manufacturer of microcontrollers for implementing in silicon (as a microcontroller peripheral) such inexpensive communication technology in order to liberalise it (free use of the technology at appliance level).

The basic concepts of this very cheap communication technology are discussed in an article published by International Appliances Manufacturing in 2004. Such article is freely downloadable at the following link: http://www.domoticainfo.it/atti_convegni/FP_spazi_tecnologici_17_5_04/Merloni/Wrap_IAM_2004.pdf.

5.1.3 Communication equipment

Two types of communication equipment will be used, a wired WLAN hot spot and the DECT controlled power plug.

The WLAN hot spot has a wired 100Mb/s Ethernet connection to the Home Gateway. This connection will carry data and the D Interface protocol (see section 7.4). Via this protocol commands to switch WLAN on, standby and off will be transported. In standby mode the WLAN hotspot can sense WLAN clients and can send spontaneous EVENT messages to the home gateway which might then decide to command WLAN to switch on via the D Interface. Other message types such as power level, Request statistics counters, etc, are possible.

The DECT controlled power outlet will support in the first step the G protocol. The basic message power on or off will be sent as special bits within a DECT frame. In a second step the EMD will migrate into the DECT power outlet. This needs the IP transport capability of then enhanced DECT standard called CAT-iq. Also the interpreter of the D messages will have to be ported to the power outlet, which needs more processing power. Another basic message pair will be implemented then, the REQUEST <current power supplied> and the response REPLY <current is x.y Amps>. Other messages are possible.

5.2 The AIM gateway

The AIM gateway architecture, consists of the following modules:

- The Machine-to-Machine interfaces module;
- The Identity Management module;
- The Services Synthesis module.

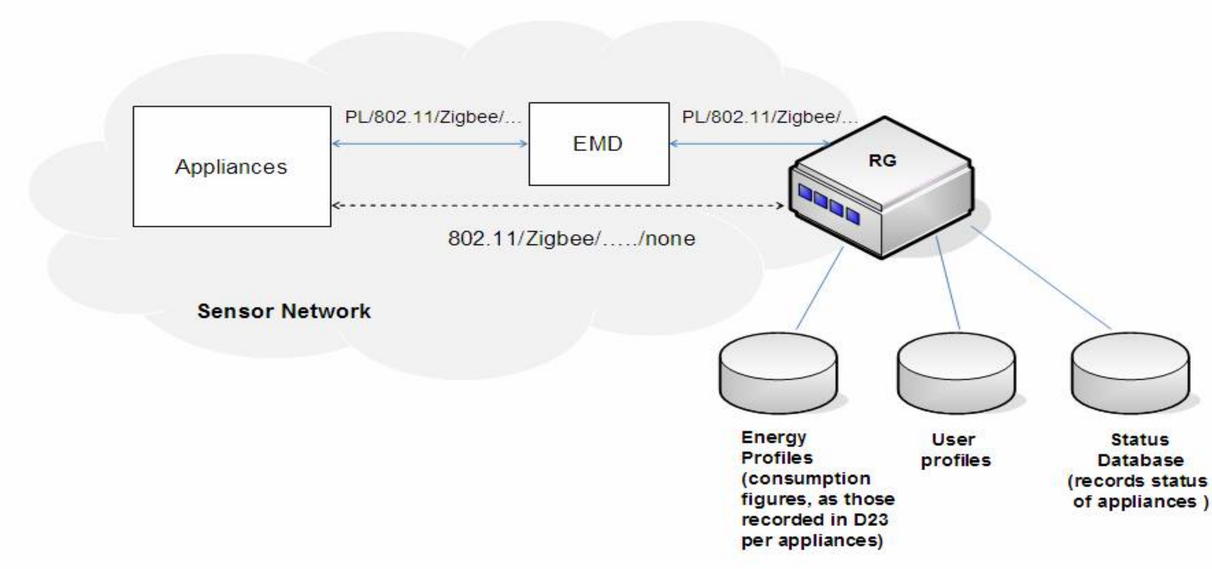

Appliances
PL/802.11/Zigbee/...
EMD
PL/802.11/Zigbee/...
RG
802.11/Zigbee/...../none
Sensor Network
Energy Profiles (consumption figures, as those recorded in D23 per appliances)
User profiles
Status Database (records status of appliances)

Figure 50: Reference model of integrating EMD in the home network

5.2.1 Internal architecture

The **Machine-to-Machine interfaces module** delivers a unified methodology and a common API for the implementation of Gateway-based services, incorporating the connected appliances. It defines a novel mechanism that consolidates the different access and communication technologies under a single umbrella, termed machine-to-machine interfaces, or M2M in short.

The **Identity Management module** is responsible for providing personalised applications to the AIM user**.** According to the Device Profile with which the User Policies are associated, the devices and the controls, which the user is allowed to access, are provided to the applications logic. This way the applications are fully personalised, based on user profiles, device profiles and associated policies. The identity management module is also responsible for user authentication / identification.

The **Services Synthesis module** allows the creation of new composite services based on existing service primitives, which are provided according to the user profiles, device profiles and the associated policies. The new composite services can be stored for future access and execution.

5.2.2 Service execution - machine-to-machine interfaces module

Inside AIM, energy controlled devices provide one or more machine accessible interfaces. Utilising these interfaces a machine partner can access and control the operation of a device. Moreover, different vendors provide their own products addressing the need for a specific functionality. For example, there is a multitude of vendors that produce washing machines. What makes these products belong in the same category is the existence of a common set of functions or operations that each and every one performs. For instance, all washing machines need to be "programmed", started and monitored for current status/ wash phase. Thus, it seems natural, from a (human or machine) user's point of view, that these devices be controllable without distinguishing whether the device belongs to one vendor or another. The exact specification and standardisation of a coherent set of functions for a certain device class is not the focus of AIM.

The project makes use of existing standards, where these are available and the functionally is comprehensive enough. AIM, however, provides an abstraction layer (the M2M) interface which can readily use and be adapted to standardized sets of functions for the supported device types. So, the AIM M2M interface allows parameterisation of the M2M interface according to a set of common operations given by some standard. This parameterisation may be of programmatic nature, i.e. needs some programming. In the long run one can envisage data-driven mapping formalisms in such a M2M interface. So from the semantic-conceptual side AIM's M2M interface essentially constitutes a Meta-Interface.

More specifically, what AIM provides is an interface technology and not a de-facto standardized, semantically coherent set of device class specific interfaces. Most of the times, and for various reasons, vendors do not expose the same machine interface format and technology, even though the functionality it corresponds to is almost the same. So, an intermediate layer is needed between the "user" and the device, which will implement a more abstract interface, focusing on the functionality, rather than the device specifics.

This is the exact role of the M2M interface; to provide a unified interface from where devices can be controlled, regardless of the brand or the "protocol" they use. M2M can also be viewed as the glue layer between the real-world physical devices' exposed interfaces and the software world that integrates and enhances the device functionality based on those interfaces.

There are four groups of devices that are engulfed in the M2M interfaces: Home Appliances, KNX devices, Set-top-boxes and User Terminals. For each of these groups, a dedicated interface is put in place. The following paragraphs describe in more detail the specifics concerning these device groups.

5.2.3 Service execution on household appliances

A freestanding freezer provides a comprehensive number of features, all related to energy management, like setting set-point temperatures for refrigerator and freezing, ambient temperature monitoring, possible use of special running modes and time setting. Special running modes are vacation (holiday) program, economy program, fast cooling and fast freezing. Fast cooling mode is designed to cool down bottles of drinks as fast as possible and notify the user by generating a specific message on a variety of available terminals.

For a washing machine, we can choose among several different washing programs, which dramatically affect the machine's energy consumption. A desired washing program can be programmed remotely, much in the same way as on the appliance itself. A set of commands, such as start, pause and stop is available, depending on the current status. All the significant events are time-logged on the Gateway.

General features of an oven could constitute the setting of cooking parameters; a user might also start baking with delay and set the duration of baking.

5.2.4 Physical interfaces and protocols used

In the AIM project, most of the communication between household appliances and the Gateway is handled by an EHS or KNX communication protocol, using the Power Line as communication media. The messages are exchanged between home appliances and the AIM gateway according to CECED/CHAIN. A Network Adapter (NA) functions as the interface to the Power Line network and transforms CECED/KNX messages received from the appliance into EHS/KNX packages, sending them back to the Power Line.

The Gateway with its built-in Power Line network adapter receives this information package and performs the reversed procedure, handing the CECED message over to the OSGi bundle, which processes the received information and takes further action according to the implemented usage scenario.

Messages are delivered via HTTP protocol, thus an OSGi framework must include a bundle, responsible for delivering and receiving messages to/from the client side. A complete list of messages with mandatory, optional and proprietary values is available at CECED/CHAIN AIS and KNX specifications.

In the initial phase of connected household appliances development, we should provide a functional profile for each individual group of appliances .The prime methods of energy management are on/off switching and dimming. Depending on its device class, each device supports specific actions and status variables.

5.2.5 Physical interfaces and protocols used

Originally, the KNX protocol was developed as an interaction tool between electrical installation devices only. No communication with IP based networks was planned. To connect KNX devices to an IP based home network several protocols and intermediate network entities are needed. The following picture gives a corresponding overview.

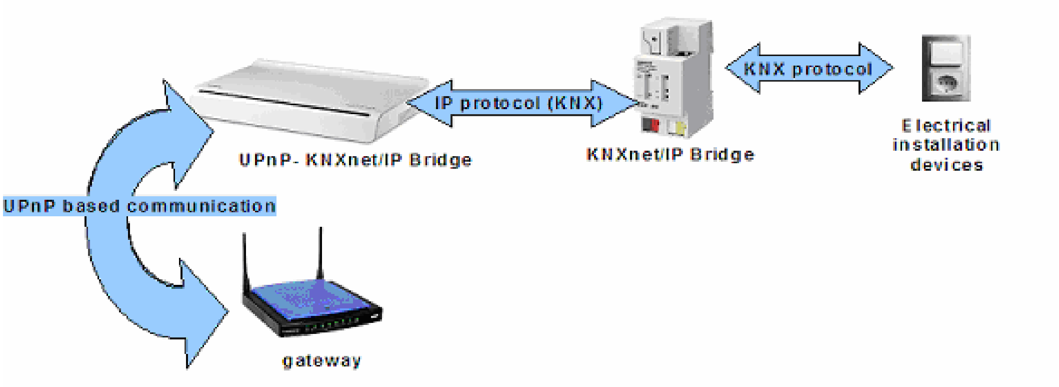


Figure 51: Protocols and entities used for addressing KNX devices

The physical interface between KNX world and the IP world is represented by a bridge (KNXnet/IP Bridge). This bridge translates mainly on the physical layer between KNX and IP. To enable communication between the AIM Gateway and the electrical installation devices via standardized protocols, a second bridge was developed. The "UPnP- KNXnet/IP Bridge" translates on application level KNX messages encapsulated in UDP/IP telegrams into standardised UPnP messages and vice versa. An Ethernet cable connects the bridge to the AIM Gateway and a standard IP is used for transmitting the UPnP messages.

The Gateway and the M2M interface are using standard UPnP mechanisms for communication with KNX devices in the AIM topology. UPnP is an application layer protocol that requires all the underlying layers of TCP/UDP on the transportation and IP network layer. All UPnP methods are well standardized.

5.2.6 Device discovery

UPnP defines several methods to obtain knowledge of connected devices. These methods are not limited to the simple discovery of a device and in addition specific methods are available to discover the different capabilities of a certain device. For this device "Discovery" mode, two methods are supported:

Discovery:Advertisement

Discovery:Advertisement is used by a device when it is connected to the network. In this case, the device sends out a multicast message to a standard IP address. Control Points receiving this message can detect the device and its capabilities.

Discovery:Search

KNX-devices will be connected via the UPnP-KNXnet/IP-Bridge to the AIM Gateway. The bridge is pre-configured with assignments of all KNX devices to appropriate UPnP devices, including user names and unique IDs. Upon boot up of the AIM Gateway and/or after a certain time period, the Gateway must send an UPnP *Discover:Search* message as UDP multicast.

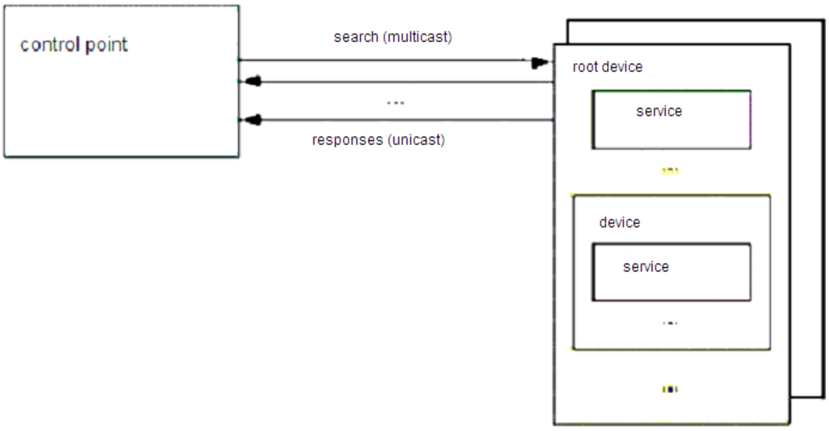


Figure 52: UPnP search procedure

This message will be answered by the UPnP-KNXnet/IP-Bridge with a response message. Following this first message exchange a couple of further messages will be exchanged describing the different available device types and services available by the bridge. The AIM Gateway must process the service descriptions in an appropriate way e.g. transfer them to the AIM personalised service database.

```
M-SEARCH * HTTP/1.1
HOST: 239.255.255.250:1900
MAN: "ssdp:discover"
MX: seconds to delay response
ST: search target
```

UPnP Discovery:Search message

Discovery:Search:Response

Following the *Discovery:Search* message, the UPnP-KNXnet/IP-Bridge returns UDP response messages to the source IP address and port that sent the multicast message. A UDP response is sent for each connected KNX device and contains information about the device - not about its available services.

```
HTTP/1.1 200 OK
CACHE-CONTROL: max-age = seconds until advertisement expires
DATE: when response was generated
EXT:
LOCATION: URL for UPnP description for root device
SERVER: OS/version UPnP/1.0 product/version
ST: search target
USN: advertisement UUID
```

UPnP Discovery:Search:Response message

5.2.7 Device description

Following the discovery process, the Gateway still knows little about its connected KNX devices. Only the information that was included in the discovery message is known (i.e. URL, UPnP type, unique identifier, etc.). To learn more about the device and its services, the Gateway can connect to the known URL. Under this URL, each device provides a detailed description of the device itself and its capabilities.

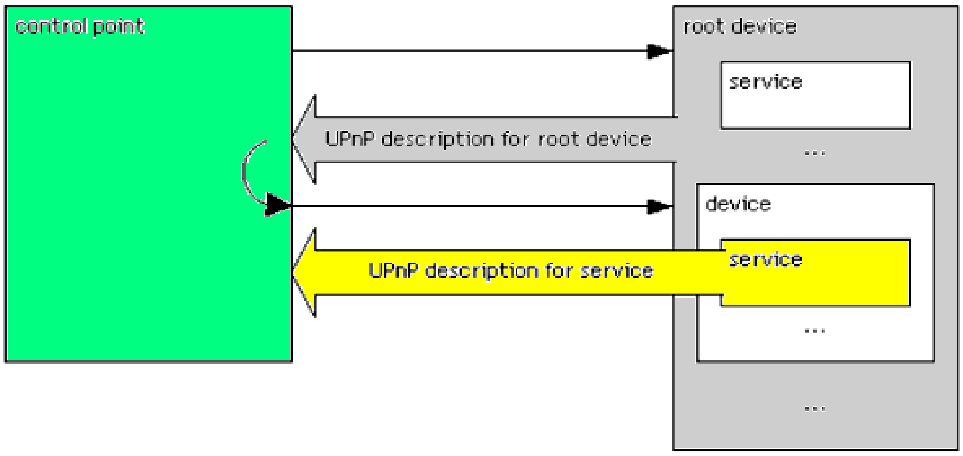

control point
root device
service
UPnP description for root device
...
device
service
UPnP description for service
...
...

Figure 53: UPnP description procedure (Source: www.upnp.org)

In general, an UPnP device description is split into two parts. The first part contains the physical and logical containers of the device description, while the second part describes the services and capabilities exposed by the device.

- **Device description**

The UPnP device description contains several parts of vendor-specific information. Since a physical device can embed several logical devices, definitions on all the embedded devices can be included in a single description. Within the AIM project, the UPnP-KNXnet/IP-Bridge as a single device, represents all the KNX devices as logical devices entities. Each device description contains among other things a user friendly name, the device type, a unique ID and in addition a list of the device's services. A URL is assigned to each service.

Using this URL, the Control Point can acquire detailed information on each service. The following table shows an excerpt of the UPnP-KNXnet/IP-Bridge device description. In this case the description is related to a single logical device – "BinaryLight:1".

```
<?xml version="1.0" ?>
<root xmlns="urn:schemas-upnp-org:device-1-0">
<specVersion>
<major>1</major>
<minor>0</minor>
</specVersion>
<device>
<deviceType>urn:schemas-upnp-org:device:BinaryLight:1</deviceType>
<friendlyName>Raum1 / Raumlicht</friendlyName>
<manufacturer />
<manufacturerURL />
<modelDescription />
<modelName />
<modelNumber />
<modelURL />
<serialNumber />
<UDN>uuid:7f26cfb9-baec-4f6c-afc2-056cad2bc06a</UDN>
<UPC />
<serviceList>
<service>
<serviceType>urn:schemas-upnp-org:service:SwitchPower:1</serviceType>
<serviceId>urn:upnp-org:serviceId:SwitchPower:1</serviceId>
<SCPDURL>/Switch.xml</SCPDURL>
<controlURL>/UD/?6</controlURL>
<eventSubURL>/sub?6</eventSubURL>
</service>
</serviceList>
</device>
/root>
```

Excerpt of a UPnP device description

- **Service description**

The UPnP service description is related to the UPnP services provided by a device. Each device can provide multiple services. By accessing the Service-URL embedded in the device description, an AIM Control Point can obtain the service description. This kind of description defines all the actions and their arguments, state variables and their data types, range, and event characteristics for each provided service. It is possible that a service may have zero or more actions. Also, an action may have zero or more arguments. These arguments may be input or output parameters. The following example shows the detailed service description of the service "SwitchPower:1":

```xml
<?xml version="1.0" ?>
<scpd xmlns="urn:schemas-upnp-org:service-1-0">
 <specVersion>
 <major>1</major>
 <minor>0</minor>
 </specVersion>
 <actionList>
 <action>
 <name>SetTarget</name>
 <argumentList>
 <argument>
 <name>newTargetValue</name>
 <direction>in</direction>
 <relatedStateVariable>Target</relatedStateVariable>
 </argument>
 </argumentList>
 </action>
 <action>
 <name>GetTarget</name>
 <argumentList>
 <argument>
 <name>RetTargetValue</name>
 <direction>out</direction>
 <relatedStateVariable>Target</relatedStateVariable>
 </argument>
 </argumentList>
 </action>
 <action>
 <name>GetStatus</name>
 <argumentList>
 <argument>
 <name>ResultStatus</name>
 <direction>out</direction>
 <relatedStateVariable>Status</relatedStateVariable>
 </argument>
 </argumentList>
 </action>
 </actionList>
 <serviceStateTable>
 <stateVariable sendEvents="no">
 <name>Target</name>
 <dataType>boolean</dataType>
 </stateVariable>
 <stateVariable sendEvents="yes">
 <name>Status</name>
 <dataType>boolean</dataType>
 </stateVariable>
 </serviceStateTable>
</scpd>
```

Example of a UPnP service description

- **Service activation**

To use a specific service of a device, the Control Point has to access the Control-URL defined in the device description of that device. Therefore the body of a HTTP POST request must specify the action and the variable that should be changed or retrieved. The following example shows a request to change the status of a power switch:

```
POST /UD/?6 HTTP/1.1
HOST: 192.168.2.1:80
CONTENT-LENGTH: 268
CONTENT-TYPE: text/xml; charset="utf-8"
USER-AGENT: JavaVM, UPnP/1.0, Siemens UPnP-Stack, v1.1 beta
SOAPACTION: "urn:schemas-upnp-org:service:SwitchPower:1#SetTarget"
```

```
<s :Envelope xmlns:s="http://schemas.xmlsoap.org/soap/envelope/"
s :encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
 <s:body>
 <u:SetTarget xmlns:u="urn:schemas-upnp-org:service:SwitchPower:1">
 <newTargetValue>1</newTargetValue>
 </u:SetTarget>
 </s:body>
</s:Envelope>
```

UPnP example for service activation request

In the example above, the Control Point accesses the logical device, which is assigned to the Control-URL "/UD/?6". In this case, an UPnP BinarySwitch is assigned to the Control-URL. The POST parameter included in the HTML header specifies that the value to be changed is listed in the body of the request. Inside the HTTP message body, a SOAP envelope includes the UPnP action "SetTarget" and the argument "newTargetValue", that should be performed. Also the value to which the related State Variable should be changed to is included. In this example the StateVariable "Target" should be changed to 1.

In the case that the action could be performed without any failure, the UPnP device responses with a HTTP OK message by repeating the executed action in the message body.

```
HTTP/1.1 200 OK
Content-Type: text/xml; charset="utf-8"
Date: Sat, 01 Jan 2000 01:15:49 GMT
Content-Length: 263
Server: Allegro-Software-RomPager/4.34
```

```
<s :Envelope xmlns:s="http://schemas.xmlsoap.org/soap/envelope/" s :encodingStyle="http://schemas.xmlsoap.org/soap/encoding/">
 <s:Body>
 <u:SetTargetResponse xmlns:u="urn:schemas-upnp-org:service:SwitchPower:1">
 </u:SetTargetResponse>
 </s:Body>
</s:Envelope>
```

UPnP example for service activation response

5.2.8 Physical interfaces and protocols used

The physical interfaces provided are Ethernet or WLAN. In order for the actions, which are part of the Web based GUI, to be transferred to the application server, Hypertext Transfer Protocol (HTTP) is utilised. The GUI is based on a Web based application that is residing in a Web Server and communicates with the OSGi bundles. The Residential Gateway contains an Application Server, which is based on dynamic Web pages. The Web pages are stateless and executed whenever the user browses the AIM web based GUI. The web pages contain Client Side components (in DHTML Javascript) which are executed at the client browser, and Server Side components (Server Pages), which are dynamic controls executed at the web server.

In the context of the AIM project physical the interfaces might need enrichment with new ones to allow support of the new appliance types. Due to the modular architecture of the gateway this activity will not affect its internal components.

5.2.9 Interfaces to other gateway subsystems

The information contained in the different profiles must be accessible within the AIM gateway software architecture from other functional modules, i.e. policy, identity management or machine to machine interface. Therefore, an internal API is provided towards these other functional elements, so that they can access and modify if necessary the information contained within the profiles.

All bundles in the Residental Gateway's OSGi architecture should be able to:

- Retrieve information from a User/Device profile:
  - As a Java object or parameter;
  - As a XML formatted string;
- Modify information in a profile;
- List existing profiles.

5.2.9.1 Interfaces to other gateway subsystems

As explained above, the PDP UI Consumer provides a simple interface that other modules may use for querying the PDP service. PDP UI Consumer offers two methods for sending / receiving XACML messages to / from the PDP services:

- sendRequest() method has been customized to generate and send valid XACML request suited for AIM purpose;
- getResponse() method allows getting the XACML response back and to process it to only get the information that is relevant in AIM context.

Complementary methods are provided to get the status information of sent requests.

5.2.9.2 Identity management subsystem

The role of the identity management subsystem is to provide personalisation to the AIM applications. This is achieved by authenticating / identifying the AIM user first, then, based on the user profile and the available devices, getting the device profiles attributes and finally, based on the policies associated to the user, providing the information required to the application level for personalised service execution. The following figure depicts the concept.

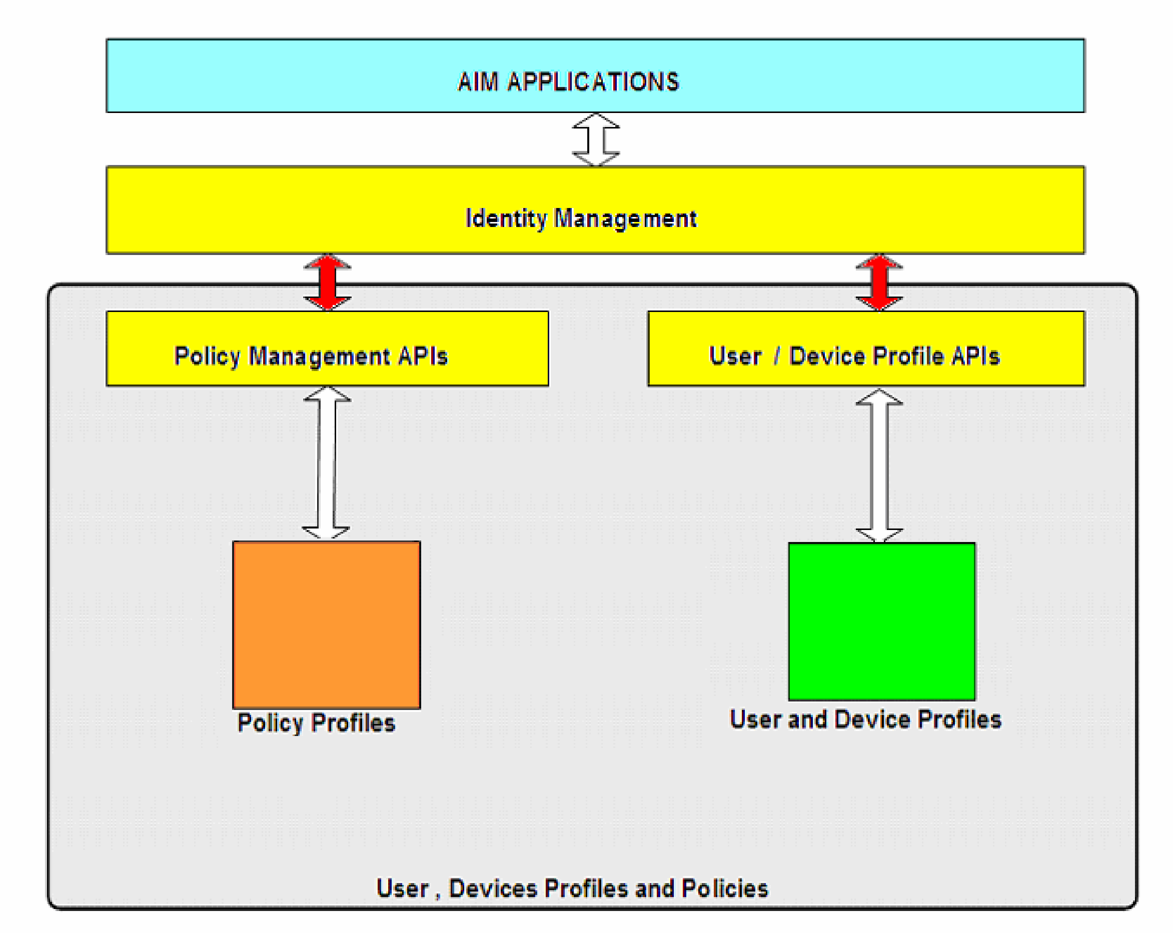


Figure 54: AIM applications and identity management

5.2.10 Supplementary servers

This service synthesis is included in the component collection of the AIM gateway service platform, which allows it to create a service, or use an existing composite service. The service management component is constituted by the following subcomponents:

- The **StorageManager**, is a server component which provides functionality to store Session and Application data from the different users that access the AIM Web application. All the other components are using the StorageManager to store component specific data. The StorageManager implements also caching mechanisms for frequently used data to improve application execution;
- The **ServiceManager**, is the server component which handles the creation, modification and execution of all other services. Each service is implemented using the CompositeService class, which has a collection (Sorted List) of execution primitives, implemented using the PrimitiveService class;
- The **DeviceManager** handles a list of available energy controlled home devices;
- The **IdentityManager**, is being used as an interaction tool with AIM users, devices and service profiles or policies, to provide personalised service components;
- The **WebServices**. This is the interface to the user, device, service profiles and policies as well as to the M2M interface module;
- The **Web Pages**. These pages are personalised and constitute the user interface;
- The **STB Addin**. This server component is used for realising the superimposing text capability on the AIM Media Center.

5.2.10.1 Service level external interfaces to other gateway subsystems

The DeviceManager uses web services to access the M2M interface API. The following figure depicts the Interfaces to other Gateway subsystems.

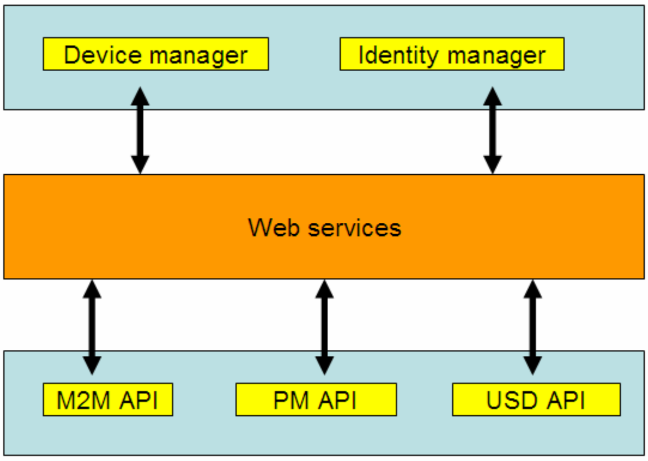


Figure 55: Interfaces to other gateway subsystems block diagram

There is a uniform pathway between the AIM DeviceManager, IdentityManaget and the AIM APIs. All these services are exposed over a uniform web interface.

On the figure bellow we can elaborate on the AIM gateway architectural components. All the functionality is enveloped in a series of OSGi bundles, which expose a set of APIs, allowing the access of sensor information in AIM, energy control of White Goods, A/V and COMs. Profiles of user and device attributes are virtualised in XML semantics. There is a Database bundle available, which is used to bind action requests, with granted access rights and provides audit services. An intermediate IP layer acts as a network bridge, linking the OSGi bundles to the physical communication layers of AIM.

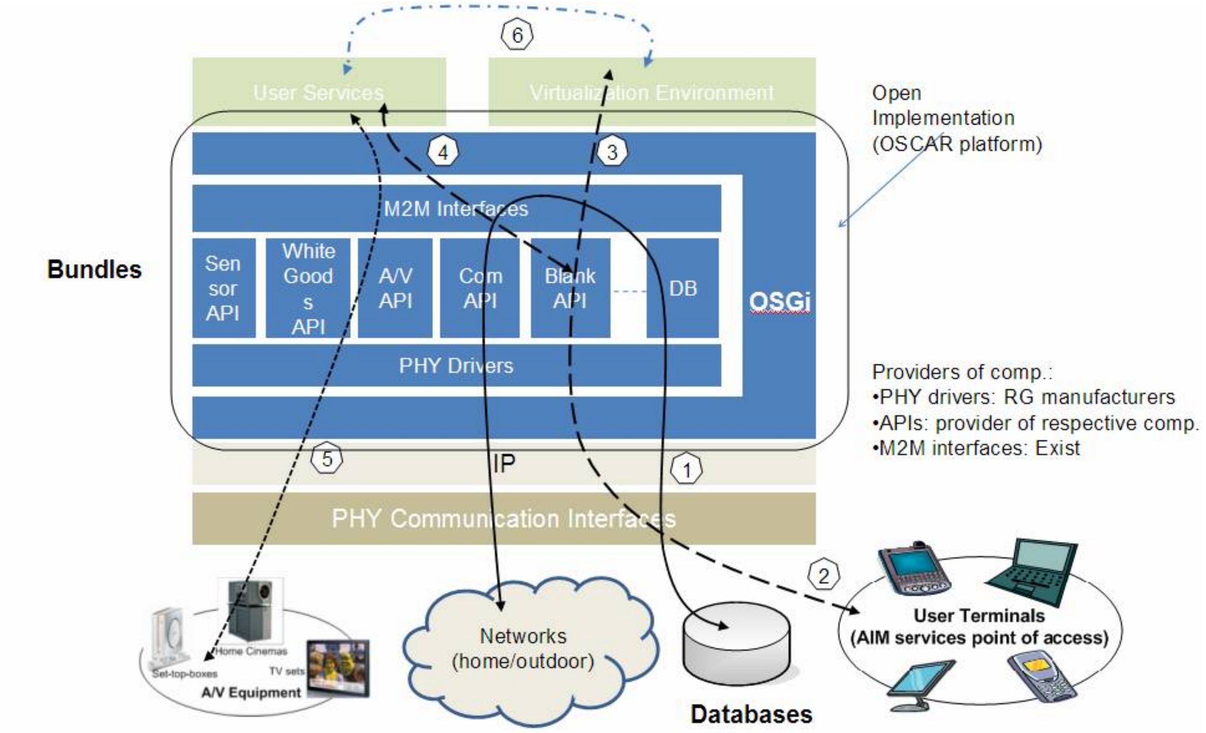


Figure 56: OSGi bundles

5.3 EMD

Networked electrical devices are being slowly introduced to the market. Even if every new sold electrical appliance was networked and manageable, it would take many years till all devices in households would get replaced. Hence, to speed up the process, some intermediate solution must be provided to the markets. This solution is the Energy Monitoring Device (EMD). In the scope of the project, the EMD will provide an energy control interface to household appliances.

An important aspect of the AIM system is management and control. After an energy control point has retrieved a description of the device, the EMD can send action commands to a device's service layer. To do this, an EMD sends a suitable control message. Control messages can also expressed in XML using the Simple Object Access Protocol (SOAP). Like function calls, in response to the control message, the service returns action-specific values. The effects of the actions, if any, are modelled by changes in the variables that describe the run-time state of the power management service.

An important factor in energy expenditure is the Standby mode, also known as phantom power load, which is responsible for an incredibly high amount of electricity consumption. Practically every electronic device that is plugged into a socket continues to consume electricity after it is switched off. Examples include phone chargers, notebook power adaptors, microwave ovens, game consoles, CD, video and DVD players. Worldwide surveys indicate that energy consumed by appliances in standby mode amount to 10% of the total energy consumed in households.

5.3.1.1 White goods and EMD control

White goods belong to the category regarding easily manageable appliances concerning instantaneous energy consumption. However, only some of appliances of this category can benefit from standby energy management. For example, a washing machine having finished its programme or an oven with expired timer can be switched off by the system.

5.3.1.2 A/V and EMD

All A/V appliances have standby modes that they can be switched on and off using a remote control.
Switching between standby and OFF states will be performed by the EMD, taking into account usability factors, such as:

- Presence of users at home;
- time zone & movement of users between rooms;
- on permanent or long term leave.

5.3.1.3 Communication equipment and EMD

Communication equipment usually does not offer a standby mode. Instead, manufacturers encourage users to unplug the devices each time they do not use them. For many devices the active mode is also the standby mode. For example a DECT station in the absence of people at home could be safely switched off without any impact on user communication.

Others, more energy consuming communication devices, such as wireless access points or GRPS/ADSL gateways, recently introduced as a method for integrating mobile communications over fixed operator networks, are said to be in standby mode although they remain active, during nights or user absence periods.

5.3.1.4 The EMD architecture

The EMD shall have a unified architecture, which will feature generic interfaces towards the household appliances, the power network and the home network. Due to its generic architecture, the system can be realized in differing forms, i.e. standalone external box or internal module.

Concerning its buildings blocks, the system offers three **generic-purpose interfaces**: one towards home communications networks; one towards the mains power network; and one for connecting to internal digital control buses of household appliances.

With these three general-purpose interfaces, the system will be able to integrate with virtually any network environment or household appliance and will provide two types of power management logic:

- **Power monitoring:** This consists of power metering functions that are applied to power electronics of the household appliances, an encoding logic that turns measurement results into digital values, and a monitoring logic that buffers the obtained measurements following user configuration commands;
- **Power control:** This consists of control logic, taking into account the user commands as they have been decoded and submitted by the enforcement logic of a given appliance. Based on this information, the system performs selection of one of the several external interfaces to the household appliance.

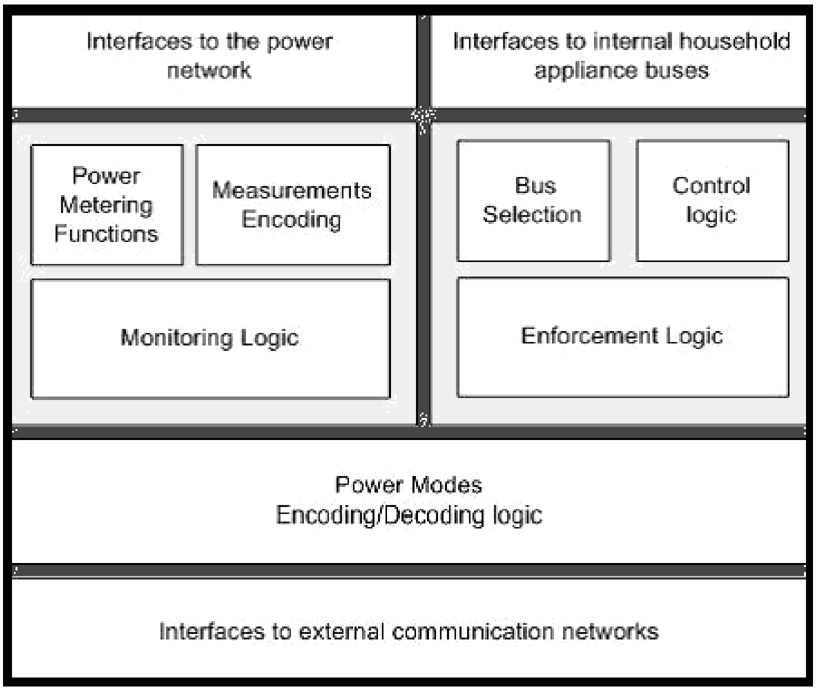

Interfaces to the power network
Interfaces to internal household appliance buses
Power Metering Functions
Measurements Encoding
Bus Selection
Control logic
Monitoring Logic
Enforcement Logic
Power Modes Encoding/Decoding logic
Interfaces to external communication networks

Figure 57 : Indicative internal architecture of the Energy Management Device (EMD)

The EMDs shall be accessible either locally, through the AIM gateway or via external operator networks.

In the indoor communication scenario the EMD will offer power management services to applications hosted on the AIM gateway (flow 1) or on PC terminals through the AIM gateway (flow 2) or directly (flow 3) via short range wireless interfaces or the GPRS network.

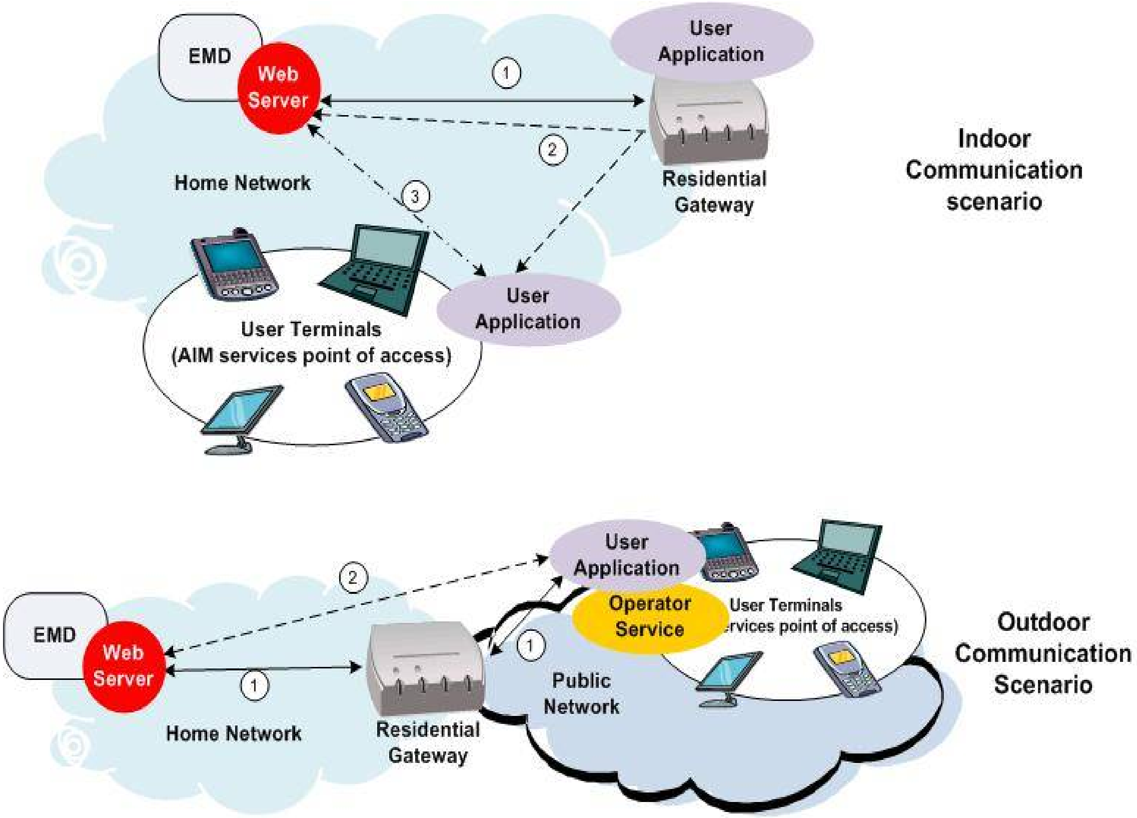


Figure 58 : Indoor and outdoor communication scenario

In the outdoor communication scenario, an EMD will offer its services to users residing in public networks, through operator services running either in cooperation with the AIM gateway (flow 1) or in standalone (flow 2).

Privacy and confidentiality of user data circulated in the outdoor networks will be ensured by the application of proper encryption of messages exchanged between the EMDs and the AIM network.

Encryption will maintain user anonymity in the processing of energy consumption data by third parties, by suppressing user identity. The interfaces the EMD will exhibit to external communication networks will be of generic type, so as to allow connectivity with any type of wired/wireless communication networks, like Zigbee, Bluetooth, Power Line , Ethernet, etc.

5.4 Home network

A home network is a residential local area network and is used to connect multiple devices within the home. Devices are connected together to exchange information and to share common functions, data and equipment. All AIM appliances and sensors will be connected to the home network. Ethernet and power cables are the standard medium for wired networks. Often homes are more difficult to wire than office environments, and special technologies are developed which don't require new wires. Home networking may use Ethernet, WIFI, Coax cable (TV), Power Line and phone wiring. Ethernet, Power Line and WIFI are the most common standards.

The home network operates via the existing home wiring (coax, phone wires and Power Line) and wireless. Home networks may be connected to the internet, directly or via a DSL provider. This external connection can be served by the AIM gateway with server functions.

With the future evolution of networking technology and the realization of AIM results, more electronic devices and home appliances will have Internet ability and become accessible by home network.

Wireless communication is comfortable for the users and easy to apply in the whole household. The wireless access to the AIM home network will be accomplished by access points i.e. provided by the AIM gateway. For wireless communication standards like WIFI, DECT and GSM/GPRS/UMTS are used. Other proprietary wireless communication standards are made for special applications.

The control of the home network will be done with a Home Control Center or via the internet. This can be realized by a fixed installed terminal and by wireless devices like mobile phone or Personal Digital ssistant *(*PDA) or with a Web-Browser.

The standard information exchange will be done by an IP-based protocol. This protocol will be used to monitor and control the home network. The AIM Home network allow connectivity with any type of wired/wireless communication standards like ZIGBee, Bluetooth, powerline , Ethernet, etc.

The information exchange with appliances and sensors will be done mainly via the KNX-Standard. KNX is an open standard for all applications in home and building control. It is arised from the combination of the former European Installation Bus (EIB), BatiBUS and the European Home Systems (EHS). KNX brings a lot of comfort and flexibility to homes and buildings.

More details for different communication standards can be found in section “2.3.1 In-house Communication technologies”.

The home network should be available in the whole household and accessible by multiple monitor and control devices as well as by appliances and sensors. External access to the AIM gateway and the appliances from utilities and service provider will be possible via internet. For this access security features are necessary (password, firewall, data encryption, etc.).

The home network should offer functionalities for energy control and monitoring, like:

- security features;
- multiple user levels for any kind of user;
- automatic recognizing of new or removed appliances or sensors;
- multiple overviews for the energy consumption of all connected appliances, price, $CO_{2;}$
- tables and diagrams of each appliance with actual and historical power consumption;
- switch and control function for the entire household and each appliance;
- standard overlay profiles for normal use;
- special functions for holidays, special events, energy saving;
- remote access via internet for selected users.

5.5 The User interface

The user interface of a system like AIM is always a major point which can influence the success of a solution dramatically. The main challenge is to provide a simple, yet intelligent, efficient and easy to use interface to the people who should operate the system. The broad span of possible users raises the requirements additionally. On the other hand the user interface is also strongly depending from the kind of service which should be controlled.

A complete energy profiling application including several automation steps and different possible scenarios would require more parameters and programming than a simple remote control of a shutter. So, one basic requirement is that the user interface should be always kept as simple as possible. Nevertheless one basic rule should be that the information which is relevant for controlling the different services should always be available for the user interface.

The following sections describe the mapping of user interfaces on different devices, and the aspects that relate to the nature of these devices. Device-independent user interface functionalities are described in section 4.

5.5.1 Users outside the home

These users will access the service by way of a mobile handset (typically a smartphone with standard web browsing capabilities) that will connect to the service platform.

The corresponding interface will be classical and adapted to the constraints of both the device itself and the portability across devices. Adaption of content to mobile aspect ratios seems the best option in this case.

5.5.2 Users inside the home (fixed-mobile)

Three interface modes could be proposed for users inside the home:

5.5.2.1 Fixed classical interface

This interface would correspond more or less to a large screen version of the mobile interface and it can be accessed anywhere from a desktop web browser.

5.5.2.2 Fixed dedicated & distributed interfaces

These interfaces are distributed in the home and dedicated either to rooms or devices, where they present information that is specific to this room or device. There is a possibility to use various ambient features such as the position of the user, user presence in rooms, etc.

5.5.2.3 Mobile interfaces

These interfaces use a mobile device that can be carried either inside or outside the home environment. Users will be able to control the energy consumption of home environment by means of using a web browser that gives access to the functions of household appliances through the AIM logic.

6 Network architecture

The analysis of the communication and networking protocols selected for the AIM architecture is described thoroughly in this section. More specifically, first we describe existing home networking technologies, while we also outline how these can be leveraged on the AIM architecture. Next we present a concrete analysis of the particular subset of technologies that were selected for this project. Subsequently, we focus on analysing potential system communications technologies that could be adopted at the higher layers of the protocol stack. Selection of technologies at this level is described in the final document section.

6.1 Available home networking technologies

In the international markets there are numerous home networking technologies on offer, like ZigBee, Z-Wave, Insteon, Bluetooth, Wibree, LonWorks, HomePlug, EIB/KNX, X10, RS485, Modbus; being applied over many network technologies, standards and by industry consortiums like UPnP, IGRS, DLNA, SPIA, HGI, NMRP, Zwave, X.10, LonWorks, and CEBus. We are going to list some additional information on the most important technologies on offer in international markets.

6.1.1 ZigBee

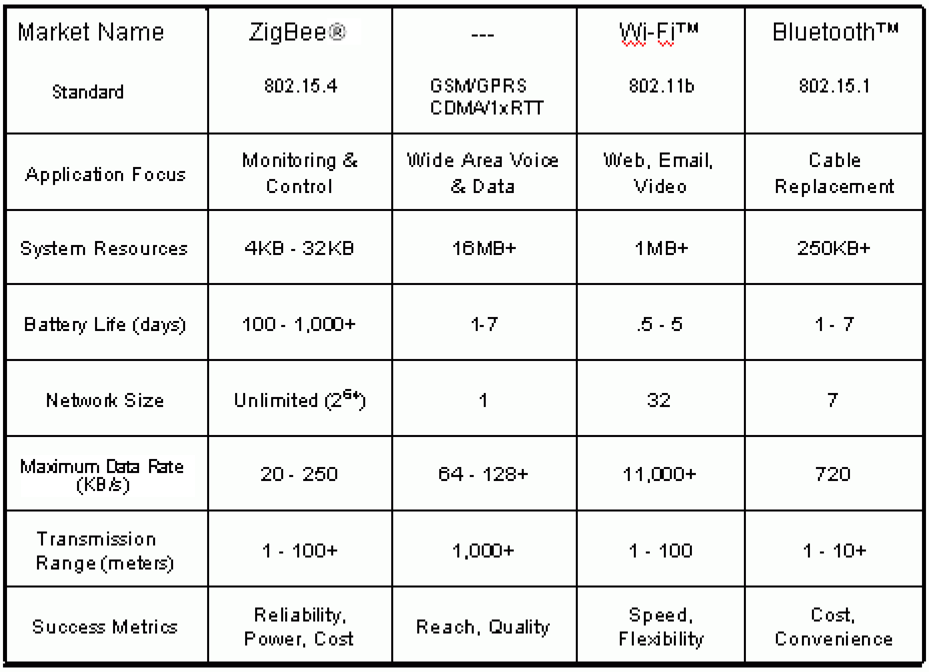
The ZigBee Alliance is a global ecosystem of companies creating wireless solutions for use in residential, commercial and industrial applications. The ZigBee Alliance companies work together to enable reliable, cost-effective, low-power, wirelessly networked, monitoring and control products based on an open global standard. The ZigBee Alliance membership comprises of technology providers and original equipment manufacturers worldwide. Membership is open to all.

ZigBee technology is suited to a wide range of energy management and efficiency, building automation, industrial, medical, home automation applications. Essentially, applications that require interoperability and/or the RF performance characteristics of the IEEE 802.15.4 standard would benefit from a ZigBee solution. Examples include:

- Demand Response;
- Advanced Metering Infrastructure;
- Automatic Meter Reading;
- Lighting controls;
- HVAC control;
- Heating control;
- Environmental controls;
- Wireless smoke and CO detectors;
- Home security;
- Blind, drapery and shade controls;
- Medical sensing and monitoring;
- Universal Remote Control to a Set-Top Box which includes Home Control;
- Industrial and building automation.

ZigBee is a wireless standards-based technology that addresses the needs of remote monitoring and control, over sensory network applications. It enables broad-based deployment of wireless networks with low cost, low power solutions and provides the ability to run for years on inexpensive primary batteries for a typical monitoring application.

6.1.1.1 Basic ZigBee attributes



Market Name	ZigBee®	---	Wi-Fi™	Bluetooth™
Standard	802.15.4	GSM/GPRS CDMA/1xRTT	802.11b	802.15.1
Application Focus	Monitoring & Control	Wide Area Voice & Data	Web, Email, Video	Cable Replacement
System Resources	4KB - 32KB	16MB+	1MB+	250KB+
Battery Life (days)	100 - 1,000+	1-7	.5 - 5	1 - 7
Network Size	Unlimited (2^{64})	1	32	7
Maximum Data Rate (KB/s)	20 - 250	64 - 128+	11,000+	720
Transmission Range (meters)	1 - 100+	1,000+	1 - 100	1 - 10+
Success Metrics	Reliability, Power, Cost	Reach, Quality	Speed, Flexibility	Cost, Convenience

Figure 59: Comparison between different short range wireless communications technologies

ZigBee battery powered devices can ‘sleep’ for hours or days. The duty cycle of battery powered nodes within a ZigBee network is designed to be very low, resulting in very low average power consumption. Once associated with a network, a ZigBee node can wake up and communicate with other ZigBee devices and return to sleep. Representative time cycles are listed bellow:

- 30 ms (typical) = new slave enumeration;
- 15 ms (typical) = sleep slave to active;
- 15 ms (typical) = active slave channel access.

While battery life is ultimately a function of battery type, capacity and end-use application, ZigBee was designed to support very long life battery applications. Users can expect multi-year battery life when using standard, alkaline batteries in a network supporting a typical application. In applications that are powered from the mains, the ZigBee energy consumption is trivial.

ZigBee was designed for the hostile RF environments that routinely exist in mainstream commercial and industrial applications. Utilizing Direct Sequence Spread Spectrum with features including collision avoidance, receiver energy detection, link quality indication, clear channel assessment, acknowledgement, security, support for guaranteed time slots and packet freshness.

ZigBee's addressing scheme is capable of supporting over 64,000 nodes per network and multiple network coordinators can be linked together to support extremely large networks. The logical size of a ZigBee network ultimately depends on which frequency band is selected, how often each device on the network needs to communicate and how much data loss or retransmissions can be tolerated by the application.

6.1.1.2 Insteon

Insteon network basic attributes

- Dual band (RF and Power-line);

- Peer-to-peer networking is supported;
- Mesh topology net;
- Unsupervised network operation (no routing tables).

Protocol

- All devices are two-way repeaters;
- Messages are acknowledged;
- Broadcast retry if a message is not acknowledged;
- Synchronized to Power Line;
- It can bypasses wall, floor and ceiling obstacles (RF).

Device Installation

- Plug-in;
- Wire-in;
- Battery operated.

X10 Compatibility

- INSTEON-compatible devices can send and receive X10 commands;
- INSTEON-compatible devices do not repeat X10 commands.

Security

- Encrypted message payload.

6.1.2 X10

X10 is an international and open industry standard for communication among electronic devices used for home automation, also known as *domotics*. It primarily uses Power Line wiring for signalling and control, where the signals involve brief radio frequency bursts representing digital information. A wireless radio based protocol transport is also defined.

X10 was developed in 1975 by Pico Electronics of Glenrothes, Scotland, in order to allow remote control of home devices and appliances. It was the first general purpose domotic network technology and remains the most widely available.

Although a number of higher bandwidth alternatives exist including KNX, INSTEON, BACnet, and LonWorks, X10 remains popular in the home environment with millions of units in use worldwide, and inexpensive availability of new components.

6.1.3 LonWorks

LonWorks is a networking platform specifically created to address the unique performance, reliability, installation, and maintenance needs of control applications. The platform is built on a protocol created by Echelon Corporation for networking devices over media such as twisted pair, Power Line, fibre optics, and RF. It is popular for the automation of various functions within buildings such as lighting and HVAC.

6.1.3.1 LonWorks origins and uptake

LonWorks platform has its origins with chip designs, Power Line and twisted pair, signalling technology, routers, network management software, and other products from Echelon Corporation. In

1999 the communications protocol (then known as LonTalk) was submitted to ANSI and accepted as a standard for control networking (**ANSI/CEA-709.1-B**). Echelon's Power Line and twisted pair signalling technology was also submitted to ANSI for standardization and accepted. Since then, ANSI/CEA-709.1 has been accepted as the basis for IEEE 1473-L (in-train controls), AAR electro-pneumatic braking systems for freight trains, IFSF (European petrol station control), SEMI (semiconductor equipment manufacturing), and in 2005 as EN 14908 (European building automation standard). The protocol is also one of several data link/physical layers of the BACnet ASHRAE/ANSI standard for building automation.

China ratified the technology as a national controls standard, GB/Z 20177.1-2006 and as a building and intelligent community standard, GB/T 20299.4-2006; and in 2007 CECED, the European Committee of Domestic Equipment Manufacturers, adopted the protocol as part of its Household Appliances Control and Monitoring – Application Interworking Specification (AIS) standards.

6.1.3.2 LonWorks usage

By 2006 approximately 60 million devices were installed with LonWorks technology. Manufacturers in a variety of industries including building, home, transportation, utility, and industrial automation have adopted the platform as the basis for their product and service offerings. Statistics as to the number of locations using the LonWorks technology are scarce, but it is known that products and applications built on top of the platform include diverse functions such as embedded machine control, municipal and highway street lighting, heating and air conditioning systems, intelligent electricity metering, subway train control, stadium lighting and speaker control, security systems, fire detection and suppression, and newborn location monitoring and alarming.

6.1.3.3 LonWorks technical details

Two physical layer signalling technologies, twisted pair "free topology" and Power Line carrier, are typically included in each of the standards created around the LonWorks technology. The two-wire layer operates at 78 kbit/s using differential Manchester encoding, while the Power Line achieves either 5.4 or 3.6 kbit/s, depending on frequency.

Additionally, the LonWorks platform uses an affiliated IP tunnelling standard -- ANSI/CEA-852 -- used by a number of manufacturers to connect the devices on previously deployed and new LonWorks -based networks to IP. Most LonWorks based control applications are being implemented with some sort of IP integration, either at the UI/application level or in the controls infrastructure. This is accomplished with web services or IP-routing products available on the market.

An Echelon designed 8-bit processor, the "Neuron chip", was initially the only way to implement a LonTalk node and is used in the large majority of LonWorks based hardware. Much later, the protocol was made available for general purpose processors: a port of the ANSI/CEA-709.1 standard to IP-based or 32-bit chips. However, this was a relatively recent development and has not been widely adopted.

6.1.4 Z-Wave

Z-Wave is a low-power wireless technology designed specifically for remote control applications. Unlike Wi-Fi and other IEEE 802.11-based wireless LAN systems that are designed primarily for high-bandwidth data flow, the Z-Wave RF system operates in the sub Gigahertz frequency range and is optimized for low-overhead commands such as on-off (as in a light switch or an appliance) and raise-lower (as in a thermostat or volume control).

Because Z-Wave operates out of the 2.4 GHz frequency of 802.11 based wireless systems, it is largely impervious to interference from common household wireless electronics, such as Wi-Fi routers, cordless telephones and Bluetooth devices.

As a result of its low power consumption and low cost of manufacture, Z-Wave can be easily embedded in consumer electronics products, including battery operated devices such as remote controls, smoke alarms and security sensors. Z-Wave is currently supported by over 200 manufacturers worldwide and appears in a broad range of consumer products in the U.S. and Europe.

Z-Wave is a mesh networking technology, where each node or device on the network is capable of sending and receiving control commands through walls or floors, around household obstacles or radio dead spots that might occur inside the home. Z-Wave devices can work one-at-a-time or in groups. Some common applications for Z-Wave include:

6.1.4.1 Remote home control and management

By adding Z-Wave to home electronics such as lighting, climate and security systems, it is possible to control and monitor these household functions via remote control, based on manual or automated decisions. The control can be applied to a single device or group of devices, in a single room or zone or throughout the entire home. Z-Wave devices can also be monitored and controlled from outside of the home by way of a gateway that combines Z-Wave with broadband Internet access.

6.1.4.2 Energy conservation

Z-Wave is envisioned as a key enabling technology for energy management in the green home. As an example, Z-Wave enabled thermostats are able to be raised or lowered automatically based on commands from Z-Wave enabled daylight sensors. Grouped scene controls can ensure that unnecessary energy consumption is minimized by various on/off states for systems throughout the home such as lighting, appliances and home entertainment systems.

6.1.4.3 Home safety and security systems

Since Z-Wave can transceive commands based on real time conditions, it is able to control devices in intelligent groupings, and it allows novel extensions on traditional home security concepts. For example, the opening of a Z-Wave enabled door lock can de-activate a security system, turn on lights when children arrive home from school, and send a notification to a parent's PC or cell phone via the Internet. Opening a Z-Wave enabled garage door can trigger exterior and interior home lights, while a Z-Wave motion detector can trigger an outdoor security light and a webcam, which would allow the end user to monitor the home while away.

6.1.4.4 Home entertainment

Z-Wave's ability to command multiple devices under a unified event makes it well suited for home audio and video applications. For example, a simple "Play DVD" command on the remote control could turn on the needed components, set them to the correct inputs and even lower motorized shades or dim the room lights.

6.1.5 KNX/EIB

KNX Association is the creator and owner of the **KNX** technology – an open STANDARD for all applications in home and building control, ranging from lighting and shutter control to various security systems, heating, ventilation, air conditioning, monitoring, alarming, water control, energy management, metering as well as household appliances, audio and lots more. The technology can be used in new as well as in existing home and buildings.

KNX is a global standard for home and building control with:

- A single, manufacturer independent design and commissioning tool (ETS);
- A complete set of supported communication media (Twisted Pair, Power-line, Radio Frequency and IP);
- A complete set of supported configuration modes (system, easy and auto mode).

KNX is approved as European Standard (CENELEC EN 50090 and CEN EN 13321-1).

- International Standard (ISO/IEC 14543-3);
- Chinese Standard (GB/Z 20965);
- US Standard (ANSI/ASHRAE 135);
- This standard is based upon more than 15 years of experience in the market including its predecessors, EIB, EHS and BatiBUS.

6.1.6 HomePlug

HomePlug is an industry trade group for Power Line communication. This organization of about 50 companies defines Power Line communication specifications. HomePlug 1.0 and AV are the two versions of the specification for home networking technology that connects devices to each other through the Power Lines in a home.

HomePlug certified products connect PCs and other devices that use Ethernet, USB, and 802.11. Many devices have HomePlug built in, and to connect them to a network all one has to do is to plug the device into the wall of a home. Since surge protectors and similar devices may interfere with the high-frequency signals used by HomePlug, the directions included with HomePlug devices recommend plugging them directly into the wall outlets without using extension cords or outlet strips.

6.1.6.1 HomePlug operation

Since the signals may travel a short distance outside the user's residence or business, like many other network standards, HomePlug includes the ability to set an encryption password. As with many other networking products, most HomePlug devices are "secure by default". The HomePlug standards require that all devices are set to a default out-of-box password. Users should change this password.

To simplify the process of configuring passwords on a HomePlug network, each device has a built-in master password, chosen at random by the manufacturer and hard-wired into the device, which is used only for setting the encryption passwords. A printed label on the device lists its master password. The data at either end of the HomePlug link is not encrypted (unless an encrypted higher-layer protocol such as TLS or IPSEC is being used); only the link between HomePlug devices is encrypted. Since HomePlug devices typically function as transparent network bridges, computers running any operating system can use them for network access. However, some manufacturers only supply the password-setup software in a Microsoft Windows version; in other words, enabling encryption requires a computer running Windows. Once the encryption password has been configured, Windows will no longer be needed, so in the case of a network where all computers run other systems, a borrowed laptop could be used for initial setup purposes.

In residences and small businesses with Split phase wiring (common in North America), roughly half the 120-volt outlets in the building will be on each hot phase and HomePlug signals may or may not be able to get from one side to the other. If one is unlucky, this may prevent some rooms from being connected via HomePlug.

Among other things, HomePlug brings back the ability to use Ethernet in bus topology. This is achieved by use of advanced OFDM modulation that allows co-existence of several distinct data carriers in the same wire. The use of OFDM also allows turning off (masking) one or more of the sub-carriers which overlap previously allocated radio spectrum in a given geographic region. In North America, for instance, HomePlug AV only uses 917 of 1155 sub-carriers.

6.1.7 CEBUS

CEBus, short for Consumer Electronic bus, also known as **EIA**-600, is a set of electrical standards and communication protocols, which allow electronic devices to transmit commands and data. It is suitable for devices in households and offices, and might be useful for utility interface and light industrial applications. In 1984, members of the Electronic Industries Alliance (EIA) identified a need for standards that would provide more functions than the defacto home automation standard X10. X10 provided blind transmission of the commands ON, OFF, DIM, BRIGHT, ALL LIGHTS ON, and ALL UNITS OFF over a Power Line carrier, later infrared and short range radio mediums. Over a six year period, engineers representing international companies met on a regular basis and developed a proposed standard. They called this standard CEBus (pronounced "see bus"). The CEBus standard was released in September 1992. CEBus is an open architecture set of specification documents which define protocols for products to communicate through Power Line wire, low voltage twisted pair wire, coax, infrared, RF, and fibre optics.

6.1.7.1 CEBUS Power Line carrier

The CEBus standard includes such things as spread spectrum modulation on the Power Line. Spread spectrum involves launching a modulation at one frequency, and altering the frequency during its cycle. The CEBus Power Line standard begins each burst at 100 kHz, and increases linearly to 400 kHz during a 100 microsecond duration. Both the bursts (referred to as "superior" state) and the absence of burst (referred to as the "inferior" state) create similar digits, so a pause in between is not necessary.

A digit 1 is created by an inferior or superior state that lasts 100 microseconds, and a digit 0 is created by an inferior or superior state that lasts 200 microseconds. Consequently, the transmission rate is variable, depending upon how many of the characters are *one* and how many are *zero*; the average rate is about 7,500 bits per second. A 400 microsecond burst is an *end of frame* indicator and also saves time. For example, if the 32-bit destination address field has some of its most significant bits zero, they need not be sent; the *end of frame* delimits the field and all receiving devices assume the un-transmitted bits are zero.

CEBus transmissions are strings or packets of data that also vary in length, depending upon how much data is included. Some packets can be hundreds of bits in length. The minimum packet size is 64 bits, which at an average rate of 7,500 bits per second, will take about 1/117th of a second to be transmitted and received.

6.1.7.2 CEBUS other media

Other media besides Power Line carrier are specified: coaxial cable, infrared, radio frequency, and optical fibre. The initial offerings supported only a Power Line carrier.

6.1.7.3 CEBUS addresses

The CEBus standard involves device addresses that are set in hardware at the factory, and include 4 billion possible combinations. The standard also offers a defined language of many object oriented controls, which include commands such as volume up, fast forward, rewind, pause, skip, and temperature up or down 1 degree.

6.1.8 BACNet

BACnet, an ASHRAE building automation and control networking protocol, was designed specifically to meet the communication needs of building automation and control systems for applications such as heating, ventilating, and air-conditioning control, lighting control, access control, and fire detection systems and their associated equipment. The BACnet protocol provides mechanisms by which computerized building automation devices can exchange information, regardless of the particular building service they perform. As a result, the BACnet protocol may be used by head-end workstation, general-purpose direct digital controllers, and application specific or unitary controllers with equal effect.

6.1.8.1 BACNet history

The development of the BACnet protocol began in June, 1987, in Nashville, Tennessee, at the inaugural meeting of the Standard Project Committee (SPC). The first meeting produced a list of desirable attributes of a good protocol, and what the BACnet protocol eventually became: Interoperability, Efficiency, Low Overhead, Highest Common Multiplier, Compatibility with other applications and networks, Layered OSI model Network, Flexibility, Extensibility, Cost Effective, Transmission Reliability, Apply to real-time processes, Maximum Simplicity, Allow priority schemes, Medium access fairness, and Stability under realistic loads.

BACnet had an almost immediate impact on the HVAC controls industry, which by 1996 was dominated by Siemens Building Technologies. Although several manufacturers had developed BACnet devices, in 1996 a smaller company, Alerton, announced a complete BACnet product line for HVAC controls, from the operator's workstation down to small VAV controllers. Automated Logic Corporation and Delta Controls soon followed suit. Other current examples of suppliers offering full lines of BACnet building automation products are Siemens Building Technologies, Johnson Controls, Inc., Teletrol Systems, TAC, KMC Controls, Contemporary Controls Ltd, Reliable Controls and PRIVA. Carrier has plans to transition completely over to BACnet in the next few product cycles.

BACnet is an entirely non-proprietary system. This means that there are no proprietary chip sets or protocols used. Information regarding the comparison of BACnet and LonWorks (a protocol technology often compared to BACnet) is contained in an online white paper from BACnet International (1996) and an online white paper from Strata Resource Inc.(2006).

6.1.8.2 The Development of BACnet

For many years, as building automation systems became popular, more and more users were demanding alternatives to proprietary systems, which prevented competitive bidding or serviceability. They objected to being "locked in" to one particular manufacturer. A consensus and industry attitude has been developing to respond to this need.

Most solutions providing interoperability are proprietary gateways or converters. For instance, one particular manufacturer may have found a way to read the code of another manufacturer and produce a device that lets the two systems communicate. Sometimes the development is a cooperative effort; other times it is not. The end result, however, is that one manufacturer could provide either a new or different operator's terminal or global controller for a different manufacturer's existing system.

There were other control-network protocols in existence before -- and coinciding with -- the development of BACnet but they didn’t meet all of the desired criteria at the time: primarily, that the standard had to be technically sound, be able to handle buildings data, be truly non-proprietary, and be easy to implement.

6.2 Adopted technologies and rationale

The communication between the AIM gateway and the EMDs can be constituted using a wide variety of protocols and technologies. Our selection was based on cost factors, easiness of implementation, commercial availability, popularity between appliance manufacturers, energy consumption and compliance to regulations use of wireless/mobile devices in home environments. In our project we used the following communication sets:

- KNX Power Line communications;
- KNX wired communications;
- ZigBee wireless communications;
- Wifi 802.11g.

The AIM gateway offers middleware services, which are in essence protocol independent and agnostic, since additional protocols can be augmented in our platform according to market demand and technology shifts. AIM devices are virtualised as well. The above standards are used widely and enjoy substantial market penetration in Europe, thus the rationale of using them as communication means in our project.

6.2.1 Basic ZigBee advantages

ZigBee is a wireless standard; ZigBee devices are so low powered that a typical battery-powered node can wake up, check in, send data, and shut down in less than 30 ms. This attribute leads to an extremely long battery life or extremely low mains power consumption. For devices with a 30-s check-in period or more, the battery's shelf life will expire before the battery capacity runs out. If a node is configured for use with a beacon frame and a guaranteed time slot, then on-air time is reduced to 3 ms. This can be achieved with only one transceiver IC incorporating the Physical and some MAC layer functions and a light-weight task running on the same medium-powered 8-bit microcontroller used for the application.

The flash memory requirement for a ZigBee device ranges from 16 to 60 KB, depending on the device's complexity, the required stack features and whether or not it is an RFD or FFD device. This is about a quarter of Bluetooth's requirements. AES 128-bit security and a sophisticated MAC layer supporting CSMA-CA, clear channel assessment, link quality indication, optional acknowledgement, and packet freshness are built in. An addressing scheme can support more than 64,000 nodes per coordinator. Multiple network coordinators can be linked, which means extremely large networks are possible.

6.2.2 Wi-Fi Advantages

The Wi-Fi LAN has a broad application nowadays. Because of its comfortable and quick installation people often replace old wired LANs with Wi-Fi. Such a connection allows us to move an AIM device around the place without losing TCP/IP connection or other network resources.

The typical Wi-Fi range of 50-75 meters (inside the buildings) is quite adequate to our project's scope. Building a Wi-Fi network is often the cheapest way to achieve the desired connection with the surroundings. The price of a single wireless adapter is decreasing almost every day, so making a large network area by means of Wi-Fi is the most reasonable way. You will not need to arrange all the wires around and you will profit by the minimal installation time. Most of the Wi-Fi adapters have user-friendly configuration and diagnostic tools which can help you to adjust or change your WLAN settings or even can do everything for you (plug and play).

6.2.3 KNX advantages

The KNX certification process ensures that different products of different manufactures used in different applications operate and communicate with each other. This ensures a high degree of flexibility in the extension and in the modification of installations. Product compliance is checked at neutral laboratories (third parties). KNX is the only home and building control open standard running global certification schemes for products, training centres (vocational and private institutions) and even for persons (electrical contractors, building designers).

KNX supports several communication media. Each communication medium can be used in combination with one or more configuration modes, allowing each manufacturer to choose the right combination for the targeted market segment and application. KNX, as multi-mediated protocol, suites the following different information propagation media:

- **Twisted pair (KNX TP):** KNX is transmitted across a separate bus cable, hierarchically structured in lines and areas;
- **Power-line (KNX PL):** KNX is transmitted on the existing main network;
- **Radio frequency (KNX RF):** KNX is transmitted via radio signals. Devices can be uni- or bidirectional;
- **IP/Ethernet (KNX IP):** This widespread communication medium can be used in conjunction with the ‘KNXnet/IP’ specifications, which allow the tunnelling or routing of KNX frames encapsulated inside IP frames.

KNX can be coupled to other systems. Several KNX manufacturers offer gateways to other networks, i.e. to other building automation systems, telephone networks, multimedia networks, IP networks, etc. KNX systems can be mapped to BACnet objects (as documented in the international standard ISO 16484-5) or offer the possibility to interface with the DALI technology. KNX is independent from any hard- or software technology and can be realized on any microprocessor platform.

6.3 System level communication solutions for services implementation

There are several options in use for implementing communication services. Among the most popular options are JINI, CORBA, WSDL and XML/SOAP. Each comes with its own strong points. The communication between the AIM residential gateway and the AIM user applications will be constituted using a Web / XML-SOAP communication flow. Our entire messaging will be XML/SOAP based. Bellow a brief overview of each available technology is listed.

6.3.1 CORBA

CORBA is a mechanism in software for normalizing the method-call semantics between application objects that reside either in the same address space (application) or remote address space (same host, or remote host on a network).

CORBA uses an interface definition language (IDL) to specify the interfaces that objects will present to the outside world. CORBA then specifies a “mapping” from IDL to a specific implementation language like C++ or Java. Standard mappings exist for Ada, C, C++, Lisp, Ruby, Smalltalk, Java, COBOL, PL/I and Python. There are also non-standard mappings for Perl, Visual Basic, Erlang, and Tcl implemented by object request brokers (ORBs) written for those languages.

The CORBA specification dictates that there shall be an ORB, through which the application interacts with other objects. In practice, the application simply initializes the ORB, and accesses an internal Object Adapter which maintains such issues as reference counting, object (& reference) instantiation policies, object lifetime policies, etc. The Object Adapter is used to register instances of the generated code classes. Generated Code Classes are the result of compiling the user IDL code which translates the high-level interface definition into an OS- and language-specific class base for use by the user application. This step is necessary in order to enforce the CORBA semantics and provide a clean user process for interfacing with the CORBA infrastructure.

Some IDL language mappings are "more hostile" than others. For example, due to the very nature of Java, the IDL-Java Mapping is rather straightforward and makes usage of CORBA very simple in a Java application. The C++ mapping is not "trivial" but accounts for all the features of CORBA, e.g. exception handling. The C-mapping is even stranger (since it's not an Object Oriented language) but it does make sense and handles the RPC semantics just fine. (Red Hat Linux delivers with the GNOME UI system, which used to have its IPC built on CORBA, now replaced by DBus).

A "language mapping" requires the developer ("user" in this case) to create some IDL code that represents the interfaces to his objects. Typically, a CORBA implementation comes with a tool called an ‘IDL compiler’ which converts the user's IDL code into some language-specific generated code. A traditional compiler then compiles the generated code to create the linkable-object files for the application. This diagram illustrates how the generated code is used within the CORBA infrastructure:

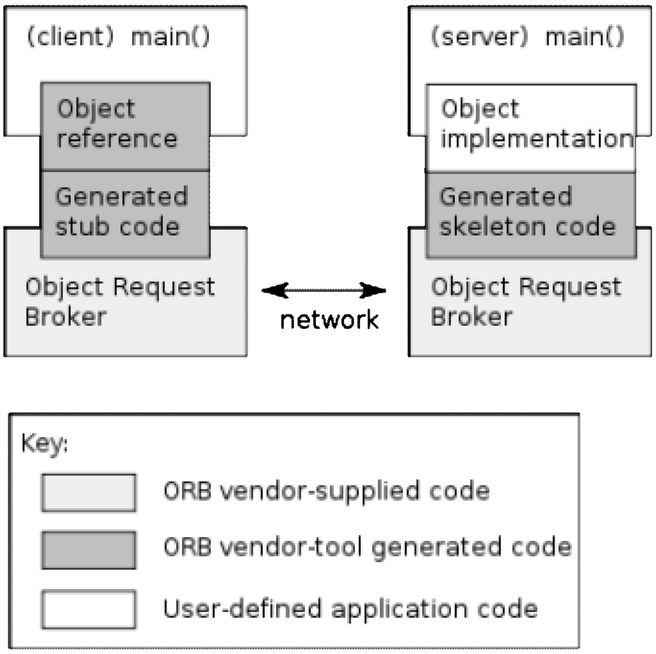


Figure 60: The CORBA mechanism

6.3.1.1 CORBA strong points

CORBA brings to the table many benefits that no other single technology brings in one package. These benefits include language- and OS-independence, freedom from technology-linked implementations, strong data-typing, high level of tunability and freedom from the details of distributed data transfers.

Language Independence

CORBA at the outset was designed to free engineers from the hang-ups and limitations of considering their designs based on a particular software language. Currently there are many languages supported by various CORBA providers, the most popular are Java and C++. There are also C-only, SmallTalk, Perl, Ada, Ruby, and Python implementations, just to mention a few.

OS Independence

CORBA's design is meant to be OS-independent. CORBA is available in Java (OS-independent), as well as natively for Linux/Unix, Windows, Sun, Mac and others.

Freedom from Technologies

One of the main implicit benefits is that CORBA provides a neutral playing field for engineers to be able to normalize the interfaces between various new and legacy systems. When integrating C/C++, Java, Fortran, Python, and any other language/OS into a single cohesive system design model, CORBA provides the means to level the field and allow disparate teams to develop systems and unit tests that can later be joined together into a whole system. This does not rule out the need for basic system engineering decisions, such as threading, timing, object lifetime, etc. These issues are part of any system regardless of technology. CORBA allows system elements to be normalized into a single cohesive system model.

For example, the design of a Multitier architecture is made simple using Java Servlets in the web server and various e time, C++ legacy code can talk to C/Fortran legacy code and Java database code, and can provide data to a web interface.

Strong Data Typing

CORBA provides flexible data typing, for example an "ANY" datatype. CORBA also enforces tightly coupled datatyping, reducing human errors. In a situation where Name-Value pairs are passed around, it's conceivable that a server provides a number where a string was expected. CORBA Interface Definition Language provides the mechanism to ensure that user-code conforms to method-names, return-, parameter-types, and exceptions.

High Tune-ability

There are many implementations available e.g. OmniORB (Open source C++ and Python implementation), that have many options for tuning threading and connection management features. Not all implementations provide the same features.

Freedom From Data Transfer Details

When handling low-level connection and threading, CORBA provides a high-level of detail in error conditions. This is defined in the CORBA-defined standard exception set and the implementation-specific extended exception set. Through the exceptions, the application can determine if a call failed for reasons such as "Small problem, so try again", "The server is dead" or "The reference doesn't make sense." The general rule is: Not receiving an exception means that the method call completed successfully. This is a very powerful design feature.

Compression

CORBA marshals its data in a binary form and supports compression.

6.3.1.2 CORBA problems and criticism

While CORBA promised to deliver much in the way code was written and software constructed, it was much criticized during its history.

Some of its failures were due to the implementations and the process by which CORBA was created as a standard, while others reflect problems in the politics and business of implementing a software standard. These problems led to a significant decline in CORBA use and adoption in new projects. The technology is slowly being replaced by Java-centric technologies.

Location transparency

CORBA's notion of location transparency has been criticized; this means that objects residing in the same address space and accessible with a simple function call are treated the same as objects residing elsewhere (different processes on the same machine, or different machines). This notion is flawed if one requires all local accesses to be as complicated as the most complex remote scenario. However, CORBA does not place a restriction on the complexity of the calls. Many implementations provide for recursive thread/connection semantics. I.e. Obj A calls Obj B, which in turn calls Obj A back, before returning.

Design and process deficiencies

The creation of the CORBA standard is also often cited for its ‘design by a committee’ property. There was no process to arbitrate between conflicting proposals or to decide on the hierarchy of problems to tackle. Thus the standard was created by making a union of the features in all proposals with no regard to their coherence.[2] This made the specification very complex, prohibitively expensive to implement entirely and often ambiguous.

A design committee composed largely of vendors of the standard implementation, created a disincentive to make a comprehensive standard. This was because standards and interoperability increased competition and eased customers' movement between alternative implementations. This led to much political fighting within the committee, and frequent releases of revisions of the CORBA standard that were impossible to use without proprietary extensions.

Problems with implementations

Through its history, CORBA was plagued by shortcomings of its implementations. Often there were few implementations matching all of the critical elements of the specification, and existing implementations were incomplete or inadequate. As there were no requirements to provide a reference implementation, members were free to propose features which were never tested for the usefulness. Implementations were further hindered by the general tendency of the standard to be verbose, and the common practice of compromising by adopting the sum of all submitted proposals, often created APIs that were incoherent and difficult to use, even if the individual proposals were perfectly reasonable.

Working implementations of CORBA have been very difficult to acquire in the past, but are now much easier to find. The SUN Java SDK comes with CORBA already. Some poorly designed implementations have been found to be complex, slow, incompatible and incomplete. Commercial versions can be very expensive. This changed significantly as commercial-, hobbyist-, and government-funded high quality free implementations became available.

Firewalls

CORBA (more precisely, IIOP) uses raw TCP/IP connections in order to transmit data. However, if the client is behind a very restrictive firewall/transparent proxy server environment that only allows HTTP connections to the outside through port 80, communication may be impossible, unless the proxy server in question allows the HTTP CONNECT method or SOCKS connections as well.

At one time, it was difficult even to force implementations to use a single standard port — they tended to pick multiple random ports instead. Due to such problems , some users have made increasing use of web services instead of CORBA. These communicate using XML/SOAP via port 80, which is normally left open or filtered through a HTTP proxy inside the organization, for web browsing via HTTP. Recent CORBA implementations, though, support SSL and can be easily configured to work on a single port.

Most of the popular open source ORBS, such as TAO and JacORB also support bidirectional GIOP, which gives CORBA the advantage of being able to use callback communication rather than the polling approach characteristic of web service implementations. Also, more CORBA-friendly firewalls are now commercially available.

6.3.2 JINI

Jini provides facilities for dealing with some of the Fallacies of Distributed Computing, problems of system evolution, resiliency, security and the dynamic assembly of service components. Code Mobility is a core concept of the platform and provides many benefits including non-Protocol dependence.

One of the goals of Jini is to shift the emphasis of computing away from the traditional disk-drive oriented approach, to a more network oriented approach. Thus resources can be used across a network as if they were available locally. Jini is based on Java, and is similar to Java Remote Method Invocation but more advanced. Jini allows more advanced searching for services, through a process of discovery of published services (making Jini more similar to the Service-oriented architecture concept). There are three main parts to a Jini scenario. These are the client, the server, and the lookup service. The service is the resource which is to be made available in the distributed environment. This can include physical devices (such as printers or disk drives) and software services (for example a database query or message service). The client is the entity which uses the service.

6.3.2.1 Using a JINI service

The first step in creating a Jini service is for the service to find the lookup service (LUS) - a process called discovery. Once the LUS is found, it returns a Service Registrar object to the service, which is used to register the service in the lookup (the join process). This involves providing information about the service to be provided, such as the ID of the service, the object which actually implements it and other attributes of the service.

When a client wishes to make use of a service, it too uses discovery to find the LUS - either by unicast interaction, when it knows the actual location of the LUS, or by dynamic multicast discovery. After contacting the LUS, the client is returned a Service Registrar object, which it uses to look up a particular service. It does this by consulting the lookup catalogue on the LUS and searching based on the type, name or description of a service.

The LUS will return a Java proxy, specifying how to connect directly to the service. This is one of the ways in which Jini is more powerful than RMI, which requires the service to know the location of the remote service in advance. Using the Proxy, the client may connect directly to the service implementation (without further interaction with the LUS), and use it as if it were a local service. However, there are some differences to the event model, in that the order of events occurring across a network cannot be guaranteed.

Services in Jini will not necessarily be permanently available, which leads to the concept of leasing. When a service registers with a LUS, a lease is granted, having a certain duration. Leases will need to be periodically renewed, to check if a service is still 'alive', which means that if a service fails or becomes unreachable, it can be timed out.

Jini uses serialization to send Java objects across the network. This means an entire Java object can be saved and sent, and used remotely as if it were local, as opposed to creating a specific format for sending data in each new implementation. Jini services can be grouped together, to allow a client to search for specific groups. A group of services in Jini is called a federation.

6.3.2.2 JINI limitations

Jini uses a look-up service to broker communication between the client and service. Many falsely believe that, because of this, it is essentially a centralized model (though the communication between client and service can be seen as decentralized) and that it does not scale well to very large systems. In a Jini network, one scales-up the look-up service by running multiple instances that listen to the same multicast group. As such, the look-up service is, indeed, scalable. Since Jini is implemented in Java, many applications require a Java Virtual Machine to be present.

6.3.3 WSDL

The Web Services Description Language (WSDL) is an XML-based language that provides a model for describing Web services.

The current version of the specification is 2.0. By accepting binding to all the HTTP request methods (not only GET and POST as in version 1.1) WSDL 2.0 specification offers better support for RESTful web services, and is much simpler to implement. However support for this specification is still poor in software development kits for Web Services which often offer tools only for WSDL 1.1.

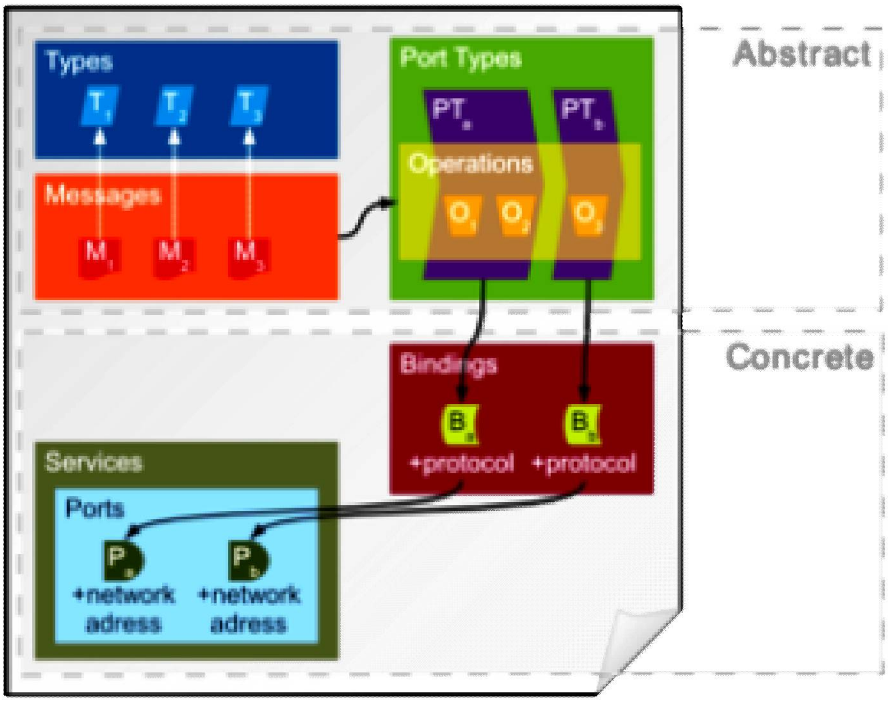


Figure 61: A representation of concepts defined by a WSDL 1.1 document.

The WSDL defines services as collections of network endpoints, or ports. The WSDL specification provides an XML format for documents for this purpose. The abstract definition of ports and messages are separated from their concrete use or instance, allowing the reuse of these definitions. A port is defined by associating a network address with a reusable binding. A collection of ports define a service. Messages are abstract descriptions of the data being exchanged, and port types are abstract collections of supported operations. The concrete protocol and data format specifications for a particular port type constitutes a reusable binding, where the operations and messages are then bound to a concrete network protocol and message format. In this way, WSDL describes the public interface to the web service.

WSDL is often used in combination with SOAP and XML Schema to provide web services over the Internet. A client program connecting to a web service can read the WSDL to determine what functions are available on the server. Any special data-types used are embedded in the WSDL file in the form of XML Schema. The client can then use SOAP to actually call one of the functions listed in the WSDL. XLang is an extension of the WSDL such that "an XLANG service description is a WSDL service description with an extension element that describes the behaviour of the service as a part of a business process". Resources or services are exposed using WSDL by both Web Services Interoperability (WS-I Basic Profile) and WSRF framework.

6.3.4 SOAP[3]

The AIM SOAP specification is using XML documents as messages, usually over HTTP to a Web Service. The AIM SOAP Specification contains:

[3] The original acronym Simple Object Access Protocol has been dropped.

- A syntax for defining messages as XML documents, which are referred to as SOAP messages;
- A model for exchanging SOAP messages;
- A set of rules for representing data within SOAP messages, known as SOAP encoding;
- A guideline for transporting SOAP messages over HTTP;
- A convention for performing remote procedure calls (RPC) using SOAP messages.

An AIM SOAP message contains the following required elements:

- An Envelope element that identifies the XML document as a SOAP message. This element defines a framework for describing what exists inside a message. The Envelope element serves as a container for the other elements of the SOAP message. As it is the top element, the Envelope is the message. SOAP messages indicate their version by the namespace of the Envelope element;
- The Body element contains the message payload. In the case of a request message the payload of the message is processed by the receiver of the message and is typically a request to perform some service and, optionally, to return some results. In the case of a response message, the payload is typically the result of some previous request or a fault.

An AIM SOAP message may also contain the following optional elements:

- The Header element namespace serves as a container for extensions to SOAP. If this element is present it must be the first child of the Envelope element;
- A Fault element that provides information about errors that occurred while processing a SOAP request. This element only appears in response messages.

The following figure illustrates the contents of an AIM SOAP message:

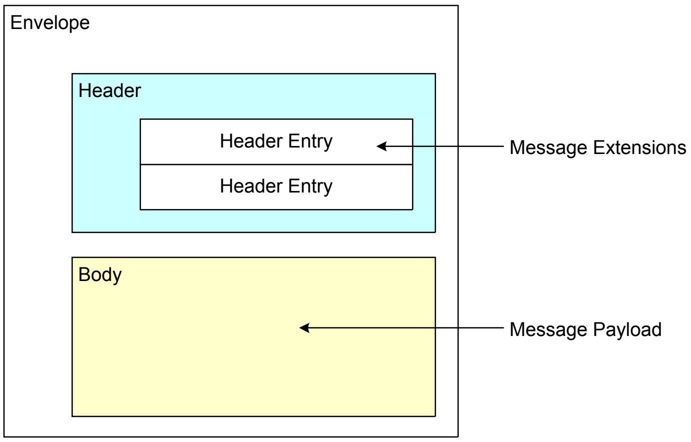


Figure 62: SOAP message

These elements are declared in the default namespace of the SOAP Envelope, which is the root element of a SOAP message and defines the XML document as a SOAP message. An example of an actual SOAP message is the following:

```
<soap:Envelope xmlns:soap='http://schemas.xmlsoap.org/soap/envelope/'
      soap:encodingStyle='http://schemas.xmlsoap.org/soap/encoding/'>
 <soap:Header>
      <!-- extensions go here -->
 </soap:Header>
 <soap:Body>
      <!-- message payload goes here -->
 </soap:Body>
</soap:Envelope>
```

AIM SOAP messages rely on XML Namespaces. As can be seen from the example above. all elements are prefixed with the namespace prefix soap, which is associated with the namespace URI http://schemas.xmlsoap.org/soap/envelope/. All the elements in the message that are associated with the soap namespace are standard elements of the SOAP message, as are the attributes. Any other elements are either related to the message extensions or the message payload.

The basic rule that governs an AIM SOAP message is that it must be encoded using XML; the message must use the SOAP Envelope namespace; it must use the SOAP encoding namespace, it must not contain a DTD reference and it must not contain XML processing instructions.

In order for a network node to be able to perform service requests or provisions, it must be able to build, parse a SOAP message, or both. An AIM SOAP server is able to perform both these functions. The following figure portrays the invocation of a service from an AIM service requester:

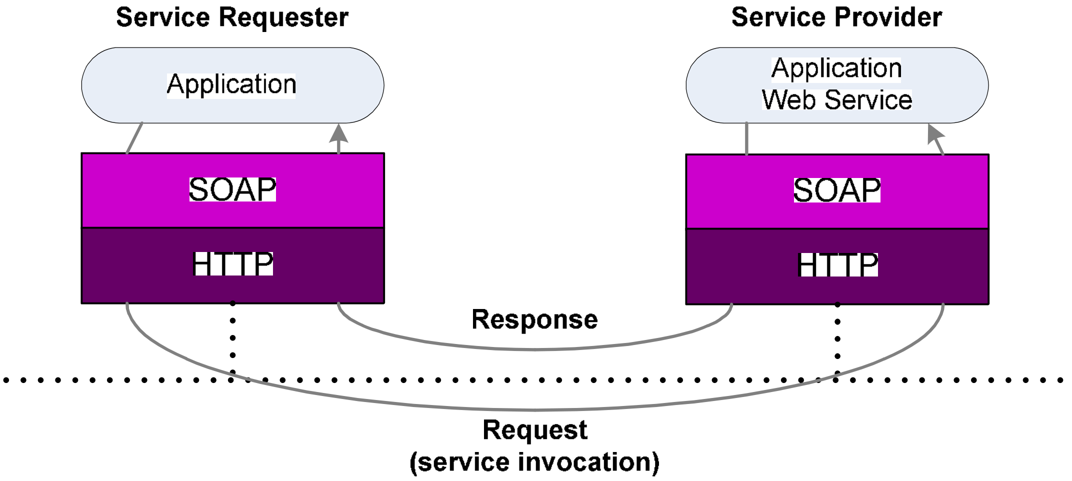


Figure 63: Messaging

The Web server resides inside the AIM gateway, whereas the application is hosted inside an AIM EMD unit or AIM device respectively. The application residing in the service requester creates a SOAP message. This message constitutes the request that invokes the web service operation and is provided by the service provider. The SOAP component (SOAP client) interacts with HTTP to send the AIM SOAP message over the network infrastructure, which delivers the message to the SOAP component on the server side (SOAP server).

The message is then routed to the web service, which is responsible for processing the request message and create a response (also a SOAP message); this response is sent back to the service requester.

AIM SOAP defines a binding to the HTTP protocol. This binding describes the relationship between parts of the SOAP request message and the various HTTP headers. All AIM SOAP requests use the

HTTP POST method and specify at least three HTTP headers: Content-Type, Content-Length, and a custom header SOAP Action. The actual SOAP message is passed as the body of the request or response.

SOAP was chosen as our messaging protocol due to its simplicity, to the fact that it is the standardised enveloping mechanism for communicating messages and remote procedure calls using XML and because it supports the 'publish', 'find' and 'bind' operations mentioned above.

6.3.5 AIM service description and WSDL

Service description is used for describing the public interface of a specific web service. The most commonly used interface format is WSDL. The Web Services Description Language is used to describe the public interface to a web service. It is an XML based service description on how to communicate using a web service, i.e. the protocol bindings and message formats required to interact with the web services listed in its directory. The supported operations and messages are described abstractly and then bound to a concrete network protocol and message format. WSDL is used in combination with SOAP and XML schema.

A client application can read the WSDL schema to determine what functions are available on a server, and subsequently, the client can use SOAP to call the functions listed. The services in a WSDL document are defined as collections of network endpoints (ports). These messages are descriptions of data being exchanged; their port types are collections of operations. The protocol and data format specifications for a particular port type form a binding. A port is defined by associating a network address to a binding. A collection of ports constitutes a service. The following elements are used in defining services:

- **Type.** This element encloses data type definitions that are relevant to the exchanged messages;
- **Message.** A message consists of one or more logical parts. Each message is associated to some kind of type specification from a type system, which uses a message-typing attribute. WSDL defines several message-typing attributes;
- **Operation.** An operation is accessible via the name attribute. An end point can support one of four transmission primitives. These are: one-way, request-response, solicit response, notification;
- **Port Type.** A port type is a named set of abstract operations over the abstract messages involved;
- **Binding Port.** A port defines an individual endpoint by specifying a single address for a binding. A port cannot specify more than one address or any binding information other than address;
- **Service.** A service groups together a set of related ports.

Service discovery

AIM services are grouped into a common registry, which allows network web services to publish their location and description. Service discovery uses UDDI.

UDDI

Universal Description, Discovery and Integration (UDDI) is a global look-up base for locating services in a universal set up to a managed service directory. It is an XML-based registry for Web Services, which allows these services to list themselves, advertise their presence, and define how their related services or applications interact to one another over the Internet. This directory is platform independent and consists of:

- White Pages (address, contact and known identifiers);
- Yellow Pages (categorisations based on standard taxonomies);

- Green Pages (technical information and services exposed).

The UDDI standard specifies protocols for accessing a registry of Web Services, methods for controlling access to the registry, and a mechanism for distributing or delegating records to other registries, i.e. the registry provides a standardised way to locate a service, to invoke that service and to manage metadata about that service. UDDI is designed to be interrogated by SOAP messages and to provide access to Web Services Description Language documents, describing the protocol bindings and message formats required to interact with the web services listed in its directory.

Overview

The following diagram illustrates these protocols in their respective positions in the AIM communication protocol stack:

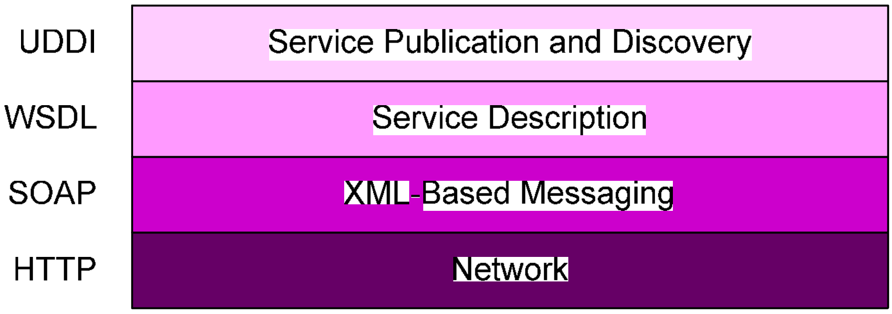


Figure 64: Web services protocol stack

6.3.6 Device profile for Web services

In resource-constrained environments the standard web service stack may be too large from a footprint perspective and too demanding on the CPU. For these reasons, a restricted version of the web service stack (DPWS Device Profile for Web Services) has been defined and is still in the standardisation process. The device profile specifies a number of implementation constraints to enable web service functionality on light-weight devices.

The device profile targets the following requirements:

- Identification of a minimal set of Web service specifications needed to enable secure messaging, dynamic discovery, description, and event handling;
- Simplification of Web services protocols and formats in a way which allows their easy implementation on consumer electronics hardware;
- Specification of the set of minimum requirements for compliance without constraining richer implementations.

From a core functional perspective, the device profile defines a set of Web service specifications, which offer the following features:

- Sending secure messages from and to a Web service;
- Discovering a Web service dynamically (i.e. without an explicit service directory such as UDDI);
- Describing a Web service;
- Subscribing and unsubscribing to events from a Web service.

From this functional perspective DPWS is quite comparable to UPnP, although there are some notable differences both in design philosophy and technical articulation. WSDL is used in service specifications (as opposed to the UPnP device description format). The AIM security concept is based on protocol extensions (as opposed to UPnP's security approach via the so-called security device) and event handling is based on the SOAP protocol (as opposed to UPnP's Gena).

In the current landscape of unmanaged networks both technologies have their place and are expected to coexist for quite a while.

6.4 Adopted system level communication solutions and rationale

The rationale of adopting a SOAP web interface between the AIM gateway and the AIM user applications has to do with the inherent protocol interoperability offered by this approach.

The most compelling feature of SOAP is that it has been implemented on many different hardware and software platforms. This means that AIM SOAP can be used to link disparate systems within and external to the AIM architecture. Many attempts have been made in the past to come up with a common communications protocol that could be used for systems integration, but none of them has enjoyed a widespread adoption like SOAP. SOAP is smaller and easier to implement than most of the previous protocols. For example, distributed computing environment (DCE) and CORBA took years to implement, so only a few implementations were ever released. SOAP, however, can use existing XML Parsers and HTTP libraries to do most of the hard work, so a SOAP implementation can be completed in a matter of months, which is why there are more than 30 SOAP implementations available. SOAP doesn't have all the features found in DCE or CORBA do, but this streamlined approach is what makes SOAP so readily available.

The primary use of AIM SOAP is for different programs and AIM applications, possibly written in different languages and running on different platforms, to communicate with each other. The HTTP transport binding for SOAP makes it attractive for some uses. SOAP fits right in the AIM architecture without the complex changes to the network other protocols require.

SOAP over HTTP can be managed with the same tools that manage other Web applications. Most people use SOAP because it supports interoperability among many different environments and it supports HTTP, which has led to SOAP becoming an industry standard.

6.4.1 SOAP and security

One of the first questions that newcomers to SOAP have usually revolves around how SOAP handles security. Early-on in the development of SOAP, SOAP was seen as an HTTP based protocol, so the assumption was made that HTTP security would be adequate for SOAP. After all, there were thousands of Web applications using HTTP security, so surely it would be adequate for SOAP. For this reason, the current SOAP standard assumes security is a transport issue and doesn't address it.

However, when SOAP expanded to become a more general-purpose protocol that runs on top of a number of transports, security became a bigger issue. Fortunately, the W3C is already working on security for XML documents, so it's probably safe to assume that at some point in the near future, the security issues addressed by the W3C will be used to define a security implementation for SOAP and this is important for our AIM architecture. In the meantime, SOAP can take advantage of the full range of security options available for HTTP Web applications.

6.4.2 The value of an AIM XML Web service

One of the most compelling uses of SOAP is to enable XML Web services. An XML Web service is a function that is exposed through a SOAP interface so that other SOAP-based application on the Web can call it to take advantage of the service. There are two great advantages to using XML Web services:

- An XML Web service is a standard way to expose services to a large number of other users who need those services;
- XML Web services provide a way to combine services that other entities provide and use them to build one’s own unique application.

7 Interfaces functional specification

In this section we provide the specification of the interfaces in the AIM architecture. A figure that depicts the different interfaces can be seen below.

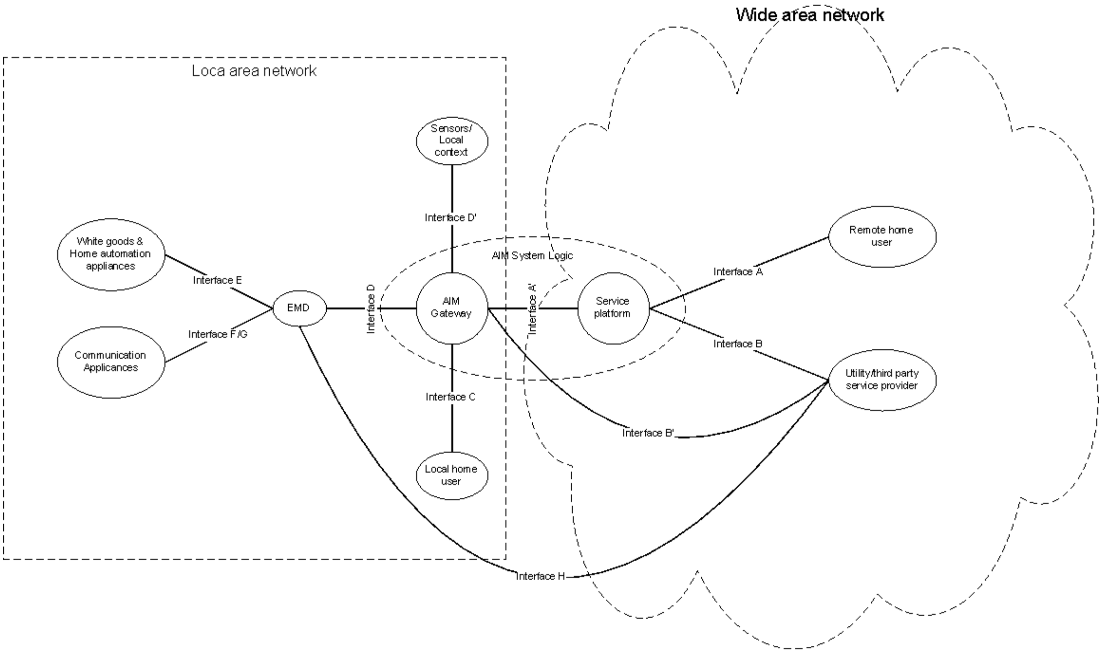


Figure 65 : Interface specifcication

7.1 Interface A

Interface A is a remote access interface that makes it possible for users to access the AIM system for both control and monitoring when they are outside the home network. Interface A will be an http web browser-based interface, as it should be accessible both from a mobile device (supposedly a Smartphone with IP access and regular web browsing capabilities) and also a PC sitting behind a corporate firewall (typically for users who would wish to have access to control and monitoring of their home AIM system functionalities from their office PC, if allowed by their company).

Interface A should give access to all the regular control and monitoring functionalities, with possibility to restrict access to some of these functionalities only to specific categories of users. The most privileged and security-critical administration functionalities could be restricted to the local interface (i.e. interface C).

Interface A' provides a means to transparently traverse the main home network gateway whilst maintaining security, i.e. avoiding to open a permanent backdoor that could be taken advantage of by potential intruders. This possibility is offered through the service platform that acts as both a proxy to functions of the AIM system that reside on the AIM gateway inside the home network, and as a host to other AIM core functions, the trade-off between the two depending on implementations.

7.2 Interface B

Interface B is situated between the Utility and the AIM service Logic. This interface is a logical interface and is independent from the way how the information between both entities is transported. The main function of this interface is to provide the required information between the utility and the household. The information exchange must use a standardized format or protocol (as e.g. ODEL).

Since not all possible services are defined yet and a future proof and open architecture is one of the objectives of the AIM project, Interface B has to be open and extendable (if required).

7.3 Interface C

This interface represents the logical connectivity of the residential user with the services of the home network. It conveys information about the energy management logic contained on the device virtualisation environment (DVE) which the user may use in order to control energy consumption of the home environment.

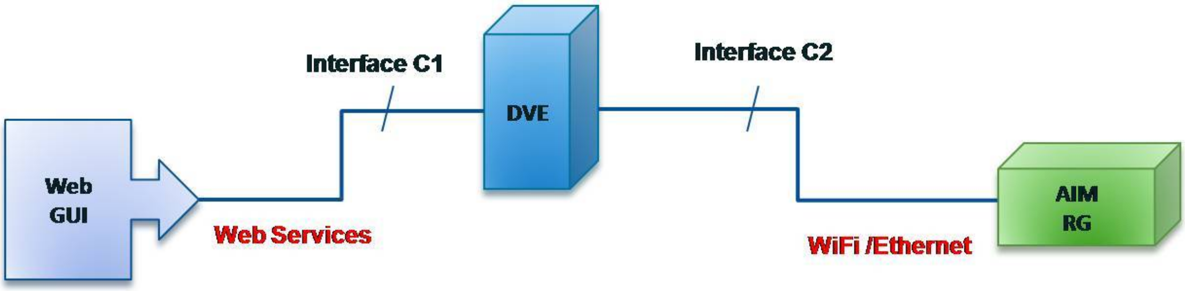
The DVE supports set up and personalisation of user profiles. Home users is abe able of defining energy management scenarios on individual basis and execute them at will and in personalised manner.

Interface C is the **logical** interface between the local users and the AIM Residential Gateway. The users is allowed to alter the behaviour of the AIM topology, using a host of devices like control boxes, PCs, WiFi PDAs and mobile phones.

The interface C is **physically** considered divided in 2 sides. Interface C first side (C1) is between local user and the DVE and the second side (C2) is between the DVE and the AIM Residential Gateway.

The Interface C1 is a Web based Graphics User Interface (GUI) that allow the users to operate on the DVE.

The Interface C2 carried information are channelled to the AIM Residential Gateway using WiFi or Ethernet technologies.



As above, the users are allowed to access the DVE to setup their preferences through a GUI that will be useable by any terminal type available at home; i.e. wireless, PDAs, PCs.

Web Services offer many benefits over other types of IP-based services:

- **Interoperability** - This is the most important benefit of Web Services. Web Services typically work outside of private networks, offering developers a non-proprietary route to their solutions. Services developed are likely, therefore, to have a longer life-span, offering better return on investment of the developed service. Web Services also allow developers to use various programming languages, such as: Java, C++, VBScript, JavaScript, or Perl. In addition, thanks to the use of standards-based communications methods, Web Services are virtually platform independent;
- **Usability** - Web Services allow the business logic of many different systems to be exposed over the Web. This gives your applications the freedom to use the Web Services that they need. Instead of re-inventing the wheel for each client, you need only include additional application-specific business logic into the client-side. This allows you to develop services and/or client-side code using the languages and tools that you want;
- **Reusability** - Web Services provide not only exploitation of the component-based model of application development, but the closest thing possible to zero-coding deployment of such services. This makes it easy to reuse Web Service components as appropriate in other services. It also makes it easy to deploy legacy code as a Web Service;

• **Deployability** - Web Services are deployed over standard Internet technologies; it enables Web Services to be deployed even over the firewall to servers running on the Internet on the other side of the globe. Also due to the use of existing standards, underlying security (such as SSL) is already built-in.

For human initiated actions, security controls is supported through standard procedures such as password checks and SSL links. This is the standard interface, through which a user is subscribing or opting-out of tele-administration and monitoring by the external actor base.

7.4 Interface D

Interface D is the interface between the AIM EMDs and their controlling Gateway.

Since the AIM domestic network is essentially hierarchical, most, if not all, flow control will be governed by an AIM Gateway. The latter is the device that accepts commands from external actors and channels them to specific or grouped EMDs in the system, making the controlled devices comply to the energy consumption pattern requested. Interface D will support multiple wired, wireless or Power Line communication technologies, like Power Line , ZigBee, Wifi etc.

Requirements for the D interface are:

- the interface should be located at a high layer in the OSI stack, and be PHY independent;
- the interface should rely on IP as the common network layer protocol.

Since the home gateway is the AIM central coordination point, it should assume the role of a master, with the connected appliances assuming the role of slaves. Accordingly, the AIM paradigm is that the master issues command messages and slaves reply. For example regular events occurring at slave sites (e.g. statistics counter increment) are sent spontaneously by a slave, and the master must take care to check them out periodically. The exception is only for unpredictable events which need immediate action. Hence these following generic message types should be supported:

- REQUEST: the master sends this message to the slave to ask for any data (single value or value arrays or data structures etc.);
- REPLY: the answer of a slave to a request or to a command;
- COMMAND: the master sends this message to a slave for immediate action (e.g. switch power outlet off, goto low power mode etc.);
- EVENT: this message is sent by the slave to the master in case of unpredictable events (e.g. failure, short circuit, overflow etc.) The master might reply with a request (e.g. send error counter).

If it is assured that each message is acknowledged by another message (e.g. REQUEST-REPLY), hence the simpler RTP protocol can be used. Otherwise the FTP protocol would assure that for example a COMMAND message has been received by a slave.

The message catalogue should be extensible in future. As a consequence a slave or master should not issue errors or fail in case of reception of an unknown message type.

The messages should be human readable. It is recommended that each "D-capable" slave understands at least one message pair, for example the <REQUEST device ID>. The ID is returned via a REPLY message.

7.5 Interface E

Interface E is the interface between the AIM EMD Device and the white good. White goods usually have their own proprietary interface which are not AIM conform. The EMD communicate with AIM gateway over a standard AIM protocol and translate the information from and to the AIM Gateway in the proprietary protocol of the white good. Depending on the manufacture different protocols and commands may exist. Usually there are commands for power- and function-control. There are also multiple hardware interfaces which will be transformed to standard AIM interfaces. In the AIM project white goods offers hardware interfaces like RS232 and I²C. ZigBee and Power-line is also planed as an interface for white goods.

7.6 Interface F

Interface F is the interface between the AIM EMD Device and A/V (Audio/Video) equipment like radio and TV sets. Radio and TV sets have multiple interfaces for the interconnection with the EMD. Depending on the A/V equipment there is TCP/IP Ethernet/WIFI and Infrared (IR) interfaces with proprietary command sets for power-control and program-selection. For the realisation of power measurement and saving features sometimes additional devices are necessary. In the AIM Project these devices will be connected to the EMD via a ZigBee connection. – The EMD translate the proprietary commands of the A/V devices into AIM commands. The data exchange between the EMD and the AIM gateway will be done with the AIM protocol.

7.7 Interface G

Interface G is the interface between the AIM EMD Device and Com devices like phones, router, FAX-machines, and so on. COM devices have multiple interfaces to communicate among themselves and between other devices. Main communication interfaces of COM devices are Ethernet, WIFI, DECT and Bluetooth. AIM features are accessible via Ethernet/WIFI or DECT. The commands to control COM devices are proprietary. The EMD translate the proprietary commands of the COM devices into AIM commands. The data exchange between the EMD and the AIM gateway will be done with the AIM protocol.

7.8 Interface H

Interface H is an option to connect the EMD directly to the service providers for when there is no possibility to have a gateway with interface for remote control installed at the home network.

8 Validation plan

The process by which the AIM architecture will be validated is split in three phases, all of which are to be hosted in WP5:

The first phase will pertain to the integration of the AIM components, work to be performed in WP5, task 5.1, and will involve realization of interoperability tests among the components of the architecture, that is, the EMD, the appliances, the home network, the virtualization logic and the user applications, with the objective to prove components' compliant operation with respect to the initial requirements. In this process design malfunctions and operational problems observed in individual components will be traced down and will be resolved via regressive development in the context of the WPs in which each component has been designed.

The second phase pertains to the functional testing of the integrated AIM architecture. Prior to evaluation experiments, the functionality of the AIM architecture will be tested in its entirety in standalone fashion, whereby operation of the allotted AIM components will be tested in laboratory environment. In this phase work will involve definition and realization of test cases using dedicated, project-made, test devices. In combination with these devices, supplementary test probes, such as logging and trace files and logic execution breakpoints, will have to be implemented on every major component of the architecture to allow for consistent measurement of the operation of the entire AIM architecture. This phase shall also be performed in the context of WP5, in task 5.1 and will result in regressive development activities in the frame of the design WPs (3 and 4).

The third phase pertains to the evaluation of application usability aspects, through the deployment and exploitation of the AIM architecture in real household environments. In this phase validation of the integrated AIM architecture will be performed, whereby the services and applications designated in WP3 and 4 will be used in pilot operation, with the objective to prove platform's operation against the specification of the three use-cases drawn up in the technical annex (for residential users, utilities and network operators). Tracing of performance bottlenecks and malfunctions shall be captured in the context of real user applications with the help of test probes set for this purpose. The phase will be hosted in WP5, task 5.2 and will accommodate regressive developments in conjunction to task 5.1 in order to eliminate any potential malfunctions that will be diagnosed. In the context of this final validation phase, use-cases realization is planned to happen in two procedures:

- In the first procedure, the fully fledged system will be installed and tested in a prototype "virtual home environment" that is offered by France Telecom with real users (around 50 in total) of various profiles who will be invited to test several usability aspects, for a time interval of two months. The objective of this use-case is to measure the ease in using the system by inexperienced users and its usefulness to assist users in their daily life.
- In the second procedure, replicas of the fully fledged system will be installed in 3 households in Greece with real appliances that will be provided by the 3 appliance manufacturers. The objective of this use-case is to prove the efficiency of the system to perform energy saving by 20% as has been targeted in the technical annex. To prove this figure, utility bills paid prior to system installation will be compared with those that will be obtained after the system installation for the same time period.

9 Conclusions

In this document we described in detail a new system architecture, proposed by AIM project consortium, which intends as its major objective to reduce the energy consumption in a residential setting. The focus is on the appliances that consume electricity. To this aim, we developed an architecture that utilises ICT components and described several functional components that are needed in order to realise this architecture. The proposed architecture is centred on the concept of an Energy Management Device (EMD) that exercises the necessary monitoring and control functions when it interacts with individual appliances. The EMD can also be interfaced with a residential gateway that hosts all the services and applications that will drive the behaviour of the EMD. Users of such a system can be both utility and telecom operators that may easily deploy services remotely. Finally, we presented a potential realization of the proposed architecture that consists of actual hardware and software components. One of our main conclusions is the importance of the EMD which plays a central role in the AIM architecture. The EMD is one of the major differentiators that AIM introduces and its careful hardware design is critical for achieving real benefits and reducing energy consumption. In the future we expect that such components would be part of intelligent devices since there will be a need for them to manage their energy consumption in relation to their environment.

Annex A

A.1 Related research projects description

A.1.1 The DINAR project

The DINAR (Decentralised Renewable Energy Supply Plants: Technical and Economical Integration in the Grid Operation and Adaptation of Basic Conditions) project aims at defining an energy management interface through which home users may select the source of the energy they consume judging on its real time price on the market.

The main goal of the project is the investigation and formulation of strategies for the integration of decentralised power plants into the control of the distribution network. Technical as well as economical aspects are considered within the project.

An economical model will be developed in order to calculate economical consequences of different integration strategies. Parallel to the economical investigations a Bidirectional Energy Management Interface (BEMI) will be developed which fulfils requirements regarding energy management as well as communication.

A.1.2 The DEHEMS project

The Digital Environmental Home Energy Management System (DEHEMS) project aims to improve the current monitoring approach to levels of energy being used by households, with an overall aim of reducing CO2 emissions across Europe.

DEHEMS will extend the current state of the art in intelligent meters, moving beyond energy 'input' models that monitor the levels of energy being used to an 'energy performance model' that also looks at the way in which the energy is used. It will bring together sensor data in areas such as household heat loss and appliance performance as well as energy usage monitoring to give real time information on emissions and the energy performance of appliances and services. It will enable changes to be made to those appliances/services remotely from the mobile phone or PC and provide specific energy efficiency recommendations, for the household. The impact will be to personalize action on climate change, and so help enable new policies such as Personal Carbon Allowances as well as supporting the move towards increased localized generation and distribution of energy.

A.1.3 The Beaware project

The project aims to contribute to the reduction of energy consumption, a societal challenge of first order that requires combination of technical, economical, and social means. So far, energy conservation has focused on new often proprietary technologies and automation, treating users as passive consumers. However, strong evidence suggests that users can adapt actively their behaviour to energy saving with suitable feedback, support, and incentives, reducing significantly and cost-effectively energy use without impacting adversely their comfort.

At present, energy information flows are slow, aggregated, and hidden, being operated by a market lacking incentives and proper service models. The opaqueness discourages users to learn and apply conservation strategies in their everyday lives. However, novel ICT's offer opportunities for removing this bottleneck. In particular, ubiquitous interfaces and web services, combined with low-cost sensors, support real-time information from energy networks and consumption, empowering users to learn and share conservation strategies.

The project studies how ubiquitous information can turn energy end users into active players by developing: 1) ambient and mobile interfaces to integrate energy use profiles into users' everyday life; 2) an open and capillary infrastructure sensing wirelessly energy consumption at appliance level; 3) value added service-based platforms and models where consumers can act on ubiquitous energy information while energy producers and other stakeholders gain new business opportunities. The expected impact focuses on 1) grounding the conservation potential to users' cognitive constraints and practices, 2) ubiquitous computing applications for sensing wirelessly energy use and enabling users to act, and 3) value added service models to innovate a new energy and multi-utility market.

A.1.4 The Beywatch project

Targeting environmental sustainability, energy efficiency and new power distribution business models, BeyWatch aims to design, develop and evaluate an innovative, energy-aware, flexible and user-centric solution, able to provide interactive energy monitoring, intelligent control and power demand balancing at home, block and neighbour level. The system will interconnect legacy professional/consumer electronic devices with a new generation of energy-aware white-goods in a common network, where multilevel hierarchic metering, control, and scheduling will be applied, based on power demand, network conditions and personal preferences.

Moreover, BeyWatch will optimize and integrate an innovative hybrid photovoltaic/solar (HPS) system, which will provide a) hot water for white goods (such as dishwasher, washing machine) in order to strongly decrease the energy consumption and the CO2 emissions at home by reducing/removing the heating operational cycles and b) generate electrical energy from Renewable Energy Sources (RES), which can be utilised at home, and during peak periods even fed to the electricity network in a reverse power generation/ distribution business model. Information from HPS system will be shared in the BeyWatch network and used for a new set of energy management rules in order to maximize energy savings and environmental savings at home, block and neighbour level.

A.1.5 The AMI-MOSES project

The AmI-MoSES project will develop an (ambient) intelligent monitoring system for energy consumption, dedicated to manufacturing SMEs, to provide comprehensive information about the energy use, and knowledge-based support for improvements in energy efficiency. Existing energy consumption data will be complemented by different information from AmI systems (e.g. AmI systems for interactions between human operators and machines/processes etc.) and process related measurements (e.g. specific manufacturing line temperatures) and fed to the SOA based platform. The platform will allow to build different SW services, using the measured and processed data, such as On-line diagnostics of energy related problems in an SME, Continuous improvement of energy consumption etc. The services will, among other functionalities, interactively provide suggestions of the appropriate actions for problem elimination and energy efficiency increase.

The decision making support for the energy efficiency increase will be also environmentally based, meaning that the problem elimination suggestions will always take care about the environmental performance from the manufacturing SME sectors, reducing the need for natural energy sources. The consortium SMEs will provide industrial testing environments, some of the major technical inputs including the energy measurement equipment, energy consumption monitoring, energy auditing, and energy saving expertise.

A.1.6 The DIADEM project

The resulting methods and tools will support environmental management in industrial settings. In particular, the resulting system will support seamless and efficient integration of:

- Robust and efficient gas monitoring systems;
- Advanced decision support/planning systems which facilitate rapid, high-quality decision making based on rich domain expertise and large quantities of relevant information.

The resulting systems will contribute to safer and healthier environment in industrialized areas in different, complementary ways:

- Mitigation of consequences of catastrophic chemical incidents through quick and reliable gas detection, monitoring and extremely efficient decision making processes;
- Prevention of catastrophic chemical incidents and reduction of chemical pollution through planning based on collaboration of many experts and efficient use of advanced tools;

- Prevention of chemical air pollution in industrial areas. By being able to quickly detect and discover the sources of pollution, the environmental protection agencies will able to enforce stringent regulations upon the industry.

This will be achieved through a unique combination of:

- Advanced approaches to information fusion and gas distribution models;
- A service oriented approach to modular information processing;
- Seamless integration of human-based and automated reasoning techniques supported by multi criteria decision analysis and advanced human machine interfaces;
- And different existing tools will be integrated into various processing modules.

A.1.7 The E4U project

E4U aims at fostering world-leadership in ICT enabled energy efficiency in the EU through accelerating research and development for energy-efficient ICT systems. It will achieve this through the creation of a strategic research roadmap for power electronics in alignment with the national, EU, and international policy framework. E4U will create impact through targeted interaction with the research community, leading European industry, and RTD policy makers at the national and European level. E4U will also advertise the benefits of power electronics and ICT for energy efficiency to the broad public.

A.1.8 The GENESIS project

So far, several EU funded projects and other initiatives have taken up the challenge of Promoting sustainable development, Ensuring security and diversity of energy supply, Improving industrial competitiveness, Enhancing economic and social cohesion; furthermore, very valuable research work has been carried out in the past, but the gap to the market(s) and to the full inclusion of the nowadays technologies is still the main obstacle hindering the deployment of its economic potential. In this context GENESIS project consortium will collect and analyse research results on efficiency and energy management systems (EMS) and identify opportunities for integration and applications to further complex or cross cutting areas.

The main aim is to provide the guidelines for economical sustainability of the industrialisation of solution based on RandD current results to be mapped through two main steps:

- An analysis of the technical and scientific basis;
- And a further improvement of features following the cutting-edge technologies and the market requirements.

The current proposal therefore aims to improve the RandD activities on technologies to make content more intelligent and self-adaptive and therefore to improve the EMS environments by:

- Bringing together researchers and industrial partners of the EMS fields, to explore potential synergies, joint exploitation or the identification of further shared research paths among past and/or ongoing projects in the domain;
- Defining a draft agenda that will outline the envisaged steps needed to let the RandD results potentialities comply as much as possible with the real applications needs;
- To favour the market exploitation of identified/supported technologies through the access to private capital and other available financial products.

A.1.9 The INTUBE project

The energy consumption in the operational phase of buildings is one of the major contributions to energy use in Europe. The improvement of energy efficiency only in the renewed stock (new and renovated buildings) is too slow considering the ambitious goal to improve the energy efficiency by 20% before 2020.

IntUBE will lead to increased life-cycle energy efficiency of the buildings without compromising the comfort or performance of the buildings by integrating the latest developments in ICT-field into

Intelligent Building and Neighbourhood Management Systems (IBMS and NMS) and by presenting new ICT-enabled business models for energy-information related service provision.

By using the existing building stock more efficiently with the help of the new tools and business models developed in IntUBE, the potential to reach the goal is considerably increased. The solutions will also be applicable to new buildings.

The results of IntUBE will benefit many actors in the building sector like the owners, the users, the energy service providers, maintenance service providers, etc in form of well-performing buildings that use the natural resources (especially energy) optimally, resulting in less environmental effects and reduced life-cycle costs of energy.

The IntUBE consortium consists of universities, research centres and companies from Southern to Northern Europe. They all have established dissemination channels, and the SMEs of the consortium will be able to extensively exploit the results in their business.

Annex B

B.1 Mapping of user requirements to design elements

The table below provides a mapping between the requirements set out in D2.1 and the elements of the AIM architecture that implement them.

Requirements by category	Partner flagged the requirement	Design elements
Requirements for the overall system		
Non_functional-020-M	CFR	The user applications and the DVE (system availability 24h/7)
Non_functional-030-M	CFR	The user interface as provided by the three application categories (for residential users, the utilities and the network operators)
Non_functional-040-M	CFR	The gateway and the DVE (user identification and authentication)
Non_functional-050-M	CFR	Applicable on all architecture components (safety)
Non_functional-060-M	CFR	User applications (system usability)
Local_Users-040-M	CFR	User applications and the DVE
Utility-0030-M	PPC	The EMD
Utility-0110-M	PPC	The user interface as provided by the three application categories (for residential users, the utilities and the network operators)
White_goods-0040-M	IND	The Gateway
White_goods-0060-O	IND	The EMD
White_goods-0080-O	IND	The M2M APIs of the Gateway and the EMD (appliances control functions)
White_goods-0090-M	IND	The Gateway
Requirements for the network		
Local_Users-030-M	CFR	The gateway and the user applications
Operator-0070-M	FT	The Gateway
Operator-0120-M	FT	The Gateway
Operator-0130-M	FT	The Gateway, The DVE and the user applications
Operator-0140-M	FT	The Gateway, The DVE and the user applications
Operator-0150-M	FT	The Gateway
Operator-0160-M	FT	The Gateway

Operator-0170-M	FT	The home network
Operator-0180-M	FT	The EMD
Utility-0050-M	PPC	The Gateway
Utility-0060-M	PPC	The Gateway
Utility-0080-M	PPC	The Gateway
Utility-0090-M	PPC	The Gateway
Utility-0100-M	PPC	The Gateway
White_goods-0010-M	IND	EMD and the database of the gateway
Gateway-0010-M	KEL, DOE	The protocols of the gateway
Gateway-0020-M	KEL, DOE	The physical communication interfaces of the gateway
Gateway-0030-M	KEL, DOE	The logic of the gateway (profiling, databases, identity management)
EMD-0090-M	KEL, DOE	The physical interfaces of the EMD
InterfaceA-0010-M	KEL, DOE, FT	The gateway and the user applications of network operator
InterfaceA-0020-M	KEL, DOE, FT	The communication interface between the utility and the network operator
InterfaceA-0030-M	KEL, DOE, FT	The gateway (security)
InterfaceA-0040-O	KEL, DOE, FT	The network (physical communication interfaces)
InterfaceA-0050-M	KEL, DOE, FT	The M2M APIs of the gateway
InterfaceB-0010-M	KEL, PPC	The DVE (appliances control logic)
InterfaceB-0020-M	KEL, PPC	The DVE (logic for the definition of energy strategy)
InterfaceB-0030-M	KEL, PPC	The gateway (the high level communication interfaces)
InterfaceB-0040-O	KEL, PPC	The applications for utilities
InterfaceC-0010-M	KEL, CFR	The physical communication interfaces of the gateway
InterfaceC-0020-M	KEL, CFR	The interface between the EMD and the Gateway
InterfaceC-0030-M	KEL, CFR	The M2M APIs of the gateway
InterfaceC-0040-M	KEL, CFR	The gateway (security protocols)
InterfaceC-0050-M	KEL, CFR	The user terminals
InterfaceC-0060-M	KEL, CFR	The DVE and the identity management functions of the gateway
InterfaceC-0070-M	KEL, CFR	The protocols of the gateway

InterfaceC-0080-M	KEL, CFR	The protocols of the gateway
InterfaceD-0010-M	BCT	The EMD
InterfaceD-0020-M	BCT	The EMD, the gateway and the network (physical communication interfaces)
InterfaceD-0030-M	BCT	The protocols of the EMD
InterfaceD-0040-M	BCT	The protocols of the EMD and the gateway
InterfaceD-0050-M	BCT	The protocols of the gateway
InterfaceD-0060-M	BCT	The protocols of the gateway
InterfaceE-0030-O	DOE, IND	The protocols of the gateway and the EMD
InterfaceH-0020-M	KEL, FT	The M2M APIs of the gateway
InterfaceH-0030-M	KEL, FT	The EMD
Requirements for internal architecture logic		
Local_Users-070-M	CFR	The use of a sensor network as a means of tracing user behaviour
Local_Users-080-M	CFR	The DVE
Operator-0030-M	FT	Gateway protocols
Operator-0050-M	FT	Operator applications
Operator-0080-M	FT	Applications for the residential user
Operator-0100-M	FT	The identity management protocols of the gateway
Operator-0110-M	FT	The DVE
Operator-0190-M	FT	The home network
Operator-0200-M	FT	The protocols of the gateway
Operator-0220-M	*FT*	The protocols of the gateway
Operator-0230-M	*FT*	The DVE
Utility-0070-M	PPC	Utility applications
Utility-0120-M	PPC	The UPnP functionality of the gateway
White_goods-0030-M	IND	The DVE
White_goods-0050-M	IND	The EMD
White_goods-0070-M	IND	The EMD and the Gateway
White_goods-0150-M	IND	The EMD
White_goods-0160-M	IND	The appliances
White_goods-0170-M	IND	The EMD and the appliances
White_goods-0180-O	IND	The EMD
White_goods-0190-M	IND	The EMD
Audiovisual-0010-M	PHI	The EMD and the appliances
Audiovisual-0020-M	PHI	The EMD and the gateway

Audiovisual-0030-M	PHI	The EMD
Audiovisual-0060-M	PHI	The EMD
Audiovisual-0070-M	PHI	The EMD
Audiovisual-0110-O	PHI	The audiovisual appliance and the EMD
Gateway-0040-M	KEL, DOE	The protocol stack of the gateway
Gateway-0050-M	KEL, DOE	The protocols of the gateway and the EMD
EMD-0010-M	KEL	The EMD
EMD-0011-M	KEL	The APIs of the gateway
EMD-0020-M	KEL	The EMD
EMD-0030-M	KEL, DOE	The EMD
EMD-0040-M	KEL, DOE	The EMD
EMD-0050-M	KEL, DOE	The EMD (metering capability)
EMD-0060-M	KEL, DOE	The EMD (control capability)
EMD-0070-M	KEL, DOE	The EMD (protocols)
EMD-0080-M	KEL, DOE	The EMD (protocols security)
EMD-0100-M	KEL, DOE	The EMD (protocols)
EMD-0110-M	KEL, DOE	The EMD (high level functions)
EMD-0120-M	KEL, DOE	The EMD (functions for standby devices)
EMD-0130-M	KEL	The EMD (protocols)
EMD-0140-M	KEL	The EMD (protocols)
EMD-0150-M	KEL	The EMD (physical interfaces functions)
EMD-0160-M	KEL	The EMD and the gateway
InterfaceE-0010-M	DOE, IND	EMD and Gateway protocols
InterfaceE-0020-M	DOE, IND	EMD and Gateway protocols
InterfaceF-0010-M	DOE, PHI	EMD and Gateway protocols
InterfaceF-0020-O	DOE, PHI	EMD and Gateway physical communication interfaces
InterfaceG-0010-M	DOE, IFX	EMD and Gateway protocols
InterfaceG-0020-O	DOE, IFX	EMD and Gateway protocols
InterfaceH-0010-M	KEL, FT	EMD and Gateway physical communication interfaces
Requirements for the appliances		
Local_Users-050-M	CFR	Applications for residential users
White_goods-0020-M	IND	White good appliances
White_goods-0100-O	IND	The protocols of the gateway
White_goods-0110-O	IND	The washing machine appliances
White_goods-0120-O	IND	The EMD

White_goods-0130-M	IND	The control logic of the gateway
White_goods-0140-O	IND	The EMD and the gateway control function
Audiovisual-0040-M	PHI	The EMD
Audiovisual-0050-M	PHI	The audiovisual appliances
Audiovisual-0080-M	PHI	The EMD
Audiovisual-0090-M	PHI	The audiovisual appliance
Audiovisual-0100-M	PHI	The audiovisual appliance
Communication_Equipment-0010-M	IFX	The EMD
Communication_Equipment-0020-M	IFX	Communication appliances
Communication_Equipment-0030-M	IFX	Communication appliances
Communication_Equipment-0040-M	IFX	The EMD
Requirements for the users		
Non_functional-010-M	CFR	User terminals
Local_Users-010-M	CFR	User terminals
Local_Users-020-M	CFR	The user interface
Local_Users-060-M	CFR	The protocols of the user applications
Operator-0010-M	FT	Operator applications
Operator-0020-M	FT	Operator applications and the gateway
Operator-0040-M	FT	The gateway
Operator-0060-M	FT	The gateway
Operator-0090-M	FT	The gateway protocols for user authentication
Operator-0210-M	FT	User applications portability
Operator-0220-M	FT	The communication protocols of the EMD and the gateway
Operator-0230-M	FT	The DVE
Utility-0010-M	PPC	Utility applications
Utility-0020-M	PPC	Communication protocols of the gateway with outdoor networks
Utility-0040-M	PPC	Utility applications