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Project Full Title

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Authors:	Anke Weidlich (SAP), Stamatis Karnouskos (SAP), Jan Ringelstein (ISET), Patrick Selzam (ISET), Aris Dimeas (ICCS-NTUA), Vally Lioliou (PPC), Cor Warmer (ECN), Koen Kok (ECN), Stefan Drenkard (MVV), Dejan Ilic (SAP), Martin Griesemer (SAP), Per Goncalves da Silva (SAP)		
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Abbreviations

ADSL	Asymmetric Digital Subscriber Line
AMI	Advanced Metering Infrastructure
BEMI	Bi-directional Energy Management Interface
BPL	Broadband over Powerline
CECED	European Committee of Domestic Equipment Manufacturers
Cenelec	Comité Européen de Normalisation Electrotechnique
CSI	Customer site integration
DPWS	Devices Profile for Web Services
DR	Demand response
DSI	Demand side integration
DSL	Digital Subscriber Line
DSO	Distribution system operator
ESMIG	European Smart Metering Industry Group
ETSI	European Telecommunications Standards Institute
FIPA	Foundation for Intelligent Physical Agents
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HSPA	High Speed Packet Access
HEM	Home energy management
HV	High-voltage
ICT	Information and communication technologies
IEC	International Electrotechnical Commission
IETF	Internet Engineering Task Force
IIOP	Internet Inter-ORB Protocol (ORB = Object Request Broker)
IP	Internet protocol
ISDN	Integrated Services Digital Network
IT	Information technologies
KEMA	Consulting and testing association for the energy industry
LAN	Local Area Network
LON	Local Operating Network
LV	Low-voltage
MAS	Multi-Agent System
MID	Measuring instruments directive

MV	Medium-voltage
OPC-UA	OLE for Process Control Unified Architecture (OLE = Object Linking and Embedding)
PLC	Powerline Communication
PPC	Public Power Corporation
PSTN	Public switched telephone network
REST	Representational State Transfer
SCADA	Supervisory Control and Data Acquisition
SGAD	Smart Grid Automation Device
SMS	Short Message Service
SOA	Service-Oriented Architecture
SOAP	Simple Object Access Protocol
SOHO	Small office / home office
TCP/IP	Transmission Control Protocol/Internet Protocol
TSO	Transmission system operator
UMTS	Universal Mobile Telecommunications System
VPP	Virtual power plant
WELMEC	Western European Legal Metrology Cooperation
WAN	Wide Area Network
WLAN	Wireless Local Area Network

1. Technological Overview in the Context of Smart Houses and Smart Grids

The general infrastructure to be used in order to accommodate the scenarios considered in the SmartHouse/SmartGrid document D1.1 "High-Level System Requirements" is abstractly shown in Figure 1. A key issue is the integration of devices, communication between devices, and integration/communication with the enterprise systems. Information generated at the point of action (device level) is used by other devices, by higher level systems that aggregate and process them, as well as by global services. A more detailed presentation of the appropriate architecture for realizing the SmartHouse/SmartGrid business cases has been provided in the deliverables D.2.1, D2.2, D2.3, D2.4, D3.1 and D3.2.

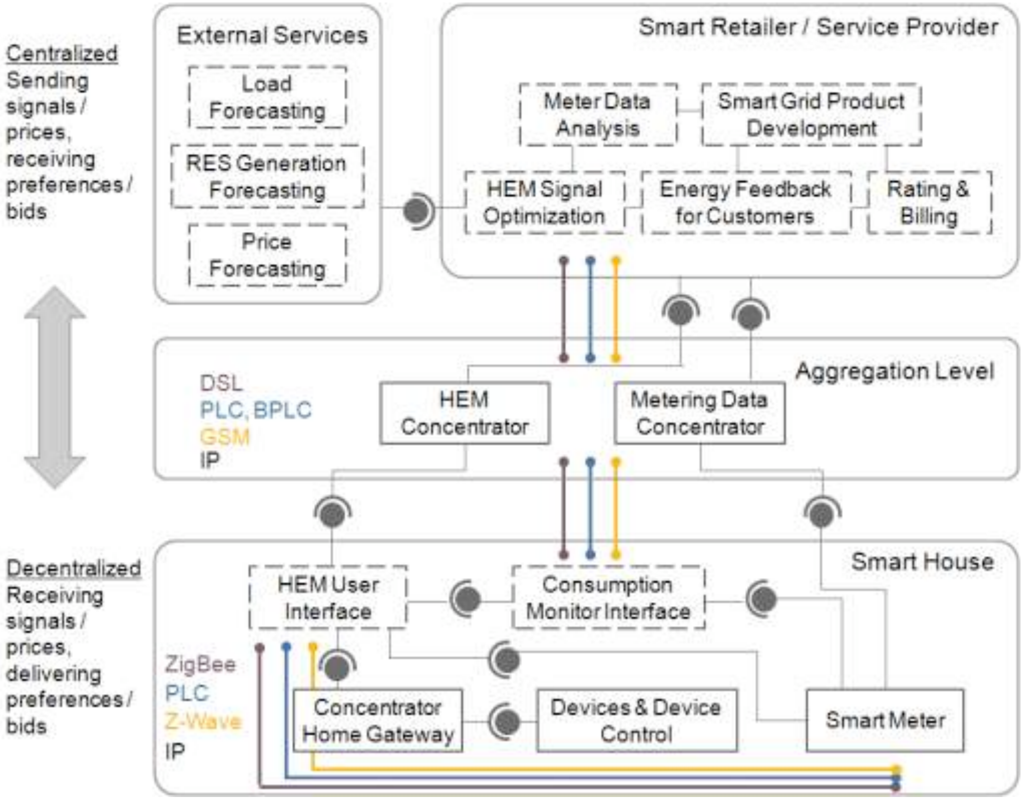

Figure 1: Overview of the SmartHouse/SmartGrid ICT infrastructure

In this document, the information representation and communication standards relevant and necessary to the integration of smart houses and smart grids are investigated. Within the interaction of smart houses with smart grids, three main categories of technologies can be distinguished. These are briefly summarized in the following subsections, and the state-of-the-art of the according technologies is described in Section 3:

- In-house technologies: These technologies are used mostly for monitoring, control and management of devices within the smart house itself, as well as for extraction and usage of internal and external information for the smart house. These include mostly monitoring, but also control capabilities. The technological concepts for in-house technologies within the SmartHouse/SmartGrid project have been discussed in deliverable D2.1. Possible communication technologies and their current development status are discussed in Section 3.2.
- House-to-grid technologies: These are mostly used to interconnect houses, and to connect houses to grid operators and utilities, thus enabling an information exchange among them. They also include monitoring, but mostly take over control capabilities. Wide-area communication technologies that facilitate house-to-grid interaction are reviewed in Section 3.1.

- House/grid-to-enterprise technologies: These are mainly used to couple the information generated within the smart house or the smart grid with enterprise services. As such, the nature of these technologies primarily targets monitoring, while it also supports the management of the infrastructure via decision support functionality that can be used to apply control strategies. SmartHouse/SmartGrid concepts for house/grid-to-enterprise communication have been described in deliverable D2.4; the required underlying wide-area communication technologies are basically the same as for house-to-grid, as reviewed in Section 3.1.

The primary concept in this research project is the decentralization of control. This means that according to the market status, local decisions are taken that affect the nearby consumers. It is therefore necessary to define the key control mechanisms and IT solutions to be adopted in order to exploit the benefits of the SmartHouse/SmartGrid combination. Appropriate monitoring and control mechanisms must be capable of balancing the stakes of the different actors in the system. In the context of this project, the focus is placed on the concepts of Multi-Agent Systems (MAS), device to business integration and Service-Oriented Architectures (SOA). These concepts and their application to SmartHouse/SmartGrid scenarios are analyzed in Section 4. An in-depth discussion of the SmartHouse/SmartGrid approach to decentralized coordination and control of loads and generation is provided in deliverable D2.2.

2. Smart Metering and Demand Response Deployment in Europe

2.1. Smart Metering

The availability of detailed data on the energy consumption of households is an important prerequisite for SmartHouse/SmartGrid concepts. However, the advancement of smart metering in Europe is quite unequal among different states. This section gives a brief overview of smart metering deployment in Europe, focusing on some advanced countries (i.e. Italy, France and Sweden) and on the three countries in which field tests are carried out within the SmartHouse/SmartGrid project.

Two recent European Directives, one about energy efficiency and energy services (ESD) [EC 2006][5] and the measuring instruments directive (MID) [EC 2004][6], demonstrate the importance of installing metering and billing systems that allows the end-consumers to regulate and manage precisely their electricity consumption. According to the EC, at least 80% of all the European end costumers should be covered by the new smart metering technology to achieve the energy saving objectives [EC 2009].

The Berg Insight consulting company predicted that smart metering will continue his deployment with an annual grow of 16% to reach in 2014 a rate of 80% of the European households. Besides, political authorities start to provide interoperability rules for these new metering systems. To go on with the transformation from a monopoly structure to a structurally unbundled market, the new smart meters need to follow standards (on a scale as large as possible: country, continent or worldwide). A lot of companies work on norms, for example in the European Smart Metering Industry Group (ESMIG) or within projects encouraged and financially assisted by the European Commission. Some of these initiatives are reviewed in Section 3.3. Nevertheless, for a fast European wide deployment, a unique standard is still missing. According to many experts, more coordination is required in all smart metering projects.

During the last year, the deployment of this technology has continued and a large majority of the EU15 countries are in "full swing" and near from this state. Following the different national and European regulatory policies, each country launched different actions. They are all at different steps of smart metering deployment process (from nearly nothing to a full running smart metering network).

- Standardizing process in Germany or Greece
- Medium scale testing in France and in the Netherlands
- Full nation wide deployment and running in Sweden and in Italy

The current status of smart metering deployment in Europe is given in Figure 2. A more detailed description of the smart metering status in selected countries is provided in the following paragraphs.

[5] The Directive on energy end-use efficiency and energy services [EC 2006] obliges the Member States to make national energy efficiency action plans. The plans shall describe how the countries will realize a 9% reduction in final energy consumption compared with business as usual until 2016.

[6] The Directive on measuring instruments [EC 2004] aimed at creating a single market for measuring instruments across the EU. The fundamental principle is that meters which receive an MID approval can be used in any other EU country irrespective of where in the EU that approval was granted. The MID covers ten instrument types, including gas, electricity and water meters.

Figure 2: Regulation and implementation status of smart metering in Europe[7]

2.1.1. Italy

Italy is the most advanced European country in the smart metering deployment. The Italian DSO Enel, in cooperation with IBM, has begging to introduce smart meter in by end residential customer in 2001. The aim of the project Telegestore was to create an advanced meter management network for 30 million residential customers that helps to manage peak demand and that allows to better cope with bad payers.

Now the system is completed. 32 millions of smart meters and the corresponding concentrators and infrastructure are installed, which allow for remote management of the electrical connection contract and for hourly measurements of the consumption in all Italian households.

Figure 3: Enel's smart meter

Since these new meters have been installed, new tailored tariffs have appeared on the Italian electricity market. For example, Enel has created new tariff offers that allow for a price reduction between 7:00 pm and

[7] Shargal 2009

1:00 am or reductions during weekends or a reduced tariff for all times of consumption that is not on weekdays between 7:00 am and 8:00 pm. 1.6 million of such contracts have been signed in the year 2008. Some larger Italian cities like Rome or Milan are currently extending smart metering projects for water and gas distribution networks.

2.1.2. Sweden

In 2003, the Swedish parliament passed regulations requiring all electricity meters for the more than five million Swedish utility customers to be read on a monthly basis by mid-2009. With this obligation, the manual reading became impossible, particularly in the North of the country where the density of population is very low. A cooperation of more than 30 independent energy companies, which has been formed to purchase new metering hardware in order to comply with the new legislation, opted for Echelon's Networked Energy Services (NES) as a metering system. It is based on the LonWorks network protocol. Also, the two major utilities Vattenfall and E.ON Sverige deploy Echelon's NES as a smart metering system, and have already widely installed the new meters at their customers' sites.

Unlike in Italy, where the DSO Enel is a state owned company, in Sweden the government stimulated smart metering through strong legislation, which made the country become the first one to achieve almost 100% penetration of smart metering by July 2009, at the time where monthly bills became mandatory.

2.1.3. France

The biggest French TSO, ERDF[8], has launched his smart metering efforts in 2007. This project is called Linky and has the objective to deploy an Advanced Metering Infrastructure in the whole country until 2017, for more than 35 million French households as well as for all industrial and commercial buildings. The deployment of these new meters will be divided into three phases:

- The first was a research and development period which began in 2007. All parts of the network were studied (meters, transformers, concentrators etc.). Atos Origin France conducted the project in collaboration with other partners like Landis + Gyr, Itron (Actaris), Iskraemeco and Trialog.
- Since 2009, a middle scale deployment and test period has begun in two distinct regions; an urban area in the city of Lyon and its suburbs and a rural area in the Indre-et-Loire. During these two years of experimentation 300,000 meters will be installed and the new information system software will be tested; 1% of all French end costumers will thus be equipped with smart meters.
- After all the experiences received during the second phase, these new smart meters will be generalized to replace all the old French electricity meters.

Figure 4: French smart meter

[8] Electricité Réseau Distribution France, http://www.erdfdistribution.fr/

In the new smart meter (see Figure 4), lot of new technologies were introduced, such as powerline communication or an USB port to provide new services to the end costumer. But the most significant differences of this meter are the new characteristics linked with decentralized generation. Before, the generation of PV panel, for example, was directly subtracted from the consumption, making it difficult to know the actual generation and consumption quantities. The new Linky smart meter allows for separating between the two data series and makes both pieces of information directly available.

2.1.4. The Netherlands

Several utilities and network operators have performed a pilot roll-out of smart meters for residential customers since 2006. Oxxio, a Dutch utility, has been very active in this field and already has integrated automatic meter reading on its billing processes. The network operator Alliander (former Continuon) had a massive pilot, called InfoStroom, including over 80,000 smart meters, focusing on operational issues with ICT, communication and efficiency in installation processes. Other companies had smaller pilots with smaller numbers of smart meters.

In the Netherlands early 2006, an effort has been started by the Dutch Standardisation Institute NEN to define a pre-standard for smart meters in the Netherlands, the NTA 8130. The NTA 8130 defines a minimal set of functions for smart metering, focusing besides metering on better handling of customer switching, better fraud detection and improved customer energy efficiency. A lot of discussion arose on privacy concerns and the fact that the standard was not future proof. According to some parties the standard lacked functionality to facilitate transition towards Smart Grid solutions. Nevertheless the House of Representatives of the Netherlands passed a law stating that starting April 1, 2009, all Dutch households should be provided with a smart meter, the first two years being a test period in which only new and retrofit buildings will be required to install a smart meter. Additional features were planned in a second generation NTA 8130 plus, making the smart meter even smarter. A schematic overview of the global planning for smart meter roll-out can be seen in Figure 5.

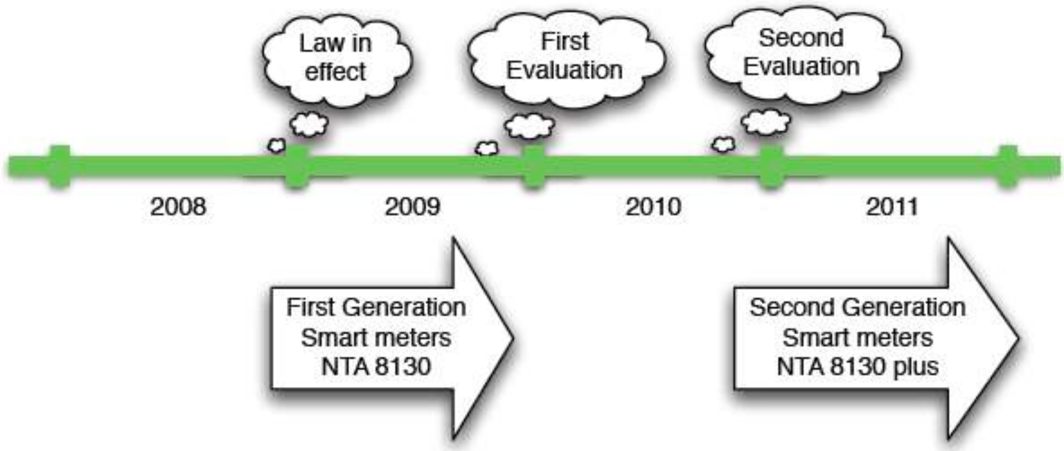

Figure 5: The smart meter roll-out planning, as initially accepted by the Dutch parliament

After the publication by the Dutch Consumer Organisation (Consumentenbond) of a study by the Tilburg University on privacy concerns the Dutch Senate were force to turn down the law in April 2009. The metering precision of 15 minutes gives a lot of information about the consumer's habits (e.g. when they sleep or when they are away). A fear that this data could be sent to insurance or other companies exists by the Dutch citizens. As a result smart meters can now only be rolled out on a voluntary basis.

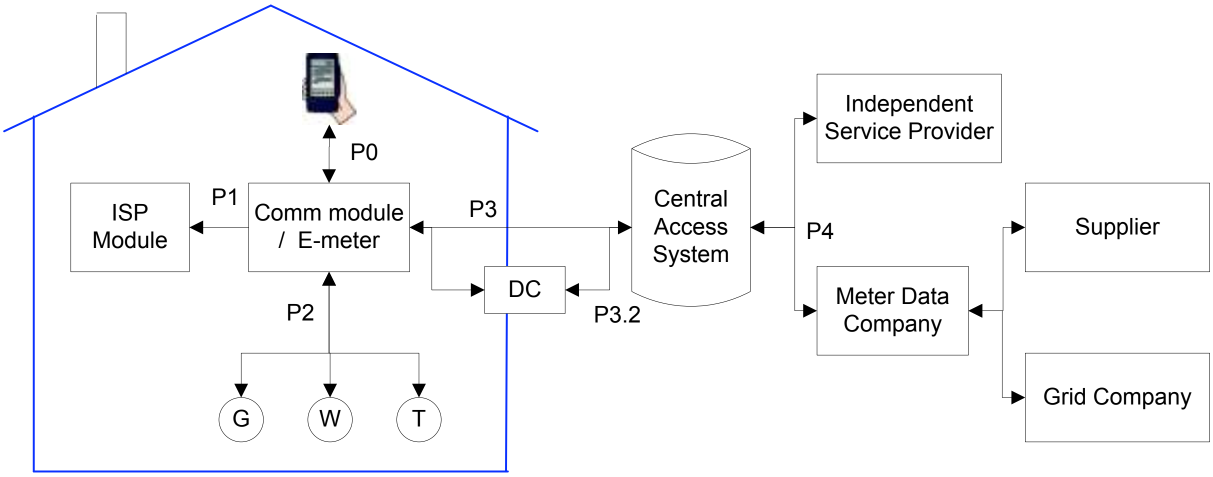

Figure 6: The Dutch smart metering system architecture

KEMA and TNO-ICT have been assigned the task to evaluate the concerns about the NTA 8130. The overall conclusion is that, with some minor changes, the roll-out can continue. A new amendment was supposed to be handled by the House of Representatives in the spring of 2010, but has been postponed after the fall of the Dutch Government. Core of the amendment is that by default the automated meter readings are restricted to 6 times per year. And the consumer can decide to disable the communication, thus turning the smart meter into a conventional meter. The large scale roll-out is expected to start in the second half of 2011.

2.1.5. Germany

Large-scale deployment of smart meters has still not started in Germany. A couple of field tests have been carried out by utilities, in which usually the use of advanced pricing schemes was tested (see Section 2.2.3). Besides, one notable initiative was the SELMA project[9], in which a legally compliant security concept for smart meters and the data transfer of metering data was developed. The SELMA concept considers the whole metering process chain from calibration and installation, to measurement and billing. Existing international standards for communication and security were used wherever possible. The measurement data signature can be used to easily validate measured consumption data anywhere in the process (up to and including invoicing). It also makes it possible to automate the maintenance process for measuring devices by downloading validated and certified software packets, thereby considerably lowering maintenance costs. The project ended in 2005, and a transition towards mass application was envisaged.

Due to new legislation, customers will have the right to choose the metering service provider independently from their power supply contract. The owner of the meter, the meter reading company, the grid operator and the retailer are all different actors in the new setting, so every one of these four stages of the value chain can be delivered by different companies. Another piece of legislation became effective from 2010 onwards. It gives all German electricity consumers the right to demand the installation of a smart meter by their energy supplier. Besides, smart meters are obligatory in new and completely renovated buildings. Customers also have the right to demand a semi-annual, quarterly or monthly bill for their real consumption. From the 30th of December on, suppliers will have the obligation to propose energy tariffs to their customers that reflect the time of consumption and provide incentives to save energy; this can be interpreted as time varying tariffs.

Recently, the first players have started to offer smart metering services in order to differentiate themselves from their competitors (e.g. EnBW Cockpit[10], Yello Sparzähler[online11]; see Figure 7 for a picture of the smart

[9] SELMA Project (Sicherer ELektronischer Messdaten-Austausch - secure electronic measurement data exchange), http://www.selma-project.de/
[10] http://www.enbw.com/content/de/privatkunden/produkte/strom/enbw_isz/cockpit/index.jsp

meter). It can be expected that smart metering will, thus, experience a considerable push in the near future. Up to now, the largest deployment of smart meters has been conducted by RWE, the German North West TSO, involving 100.000 smart meters in Mülheim an der Ruhr.

Figure 7: The Yello smart meter

2.1.6. Greece

All high voltage (HV) and the total of the 9,300 medium voltage (MV) consumers and renewable energy producers in Greece nationwide are automatically remotely metered. AMR is achieved via GSM/GPRS modems. The project of total budget 3.1 M€ was realized by the consortium PROTASIS SA – ITF/EDV GmbH.

Smart Grid / Smart Metering MV Pilot Project

The first smart grid system installed on the medium voltage level covers more than 100 km of MV network with applications ranging from load management to fault detection and automatic meter reading. The smart grid network is installed in two medium voltage lines starting from the ultra-high voltage substation of PPC just outside the city of Larissa. These two lines named R-240 and R-250 feed both agricultural loads and villages in the area.

Larisa is one of the major cities in northern Greece with a population of about 250,000 people. Its major role in the Greek society and economy includes the vast agricultural production. PPC has undertaken the task to electrify this agricultural region in a way that the demand will meet the supply under the harsh Greek summer conditions. This task is not easy, as it involves the management of a wide spread medium roltage network with huge amounts of power delivered peaking at summer, a season most difficult for PPC when temperatures reaching up to 40 degrees Celsius bring the air-conditioning loads in Greece to their peak.

Siemens and Amperion designed and implemented for PPC this smart grid network solution featuring embedded telecommunications on the medium voltage lines based on the Amperion patented BPL technology and a vast array of end devices including switches and power quality measuring sensors. The network installed is comprised by 105 BPL units installed on the MV network thus creating a backbone of connectivity to the substation. The units are installed starting at the first pole outside of the ultra-high voltage substation (KYT) and one is installed every 700 to 800 meters until the end of the MV lines. The first

[11] http://www.yellostrom.de/privatkunden/sparzaehler/index.html

unit, called the injector unit, is connected to the substations control centre via Wi-Fi and then to the Internet / PPC intranet via and HDSL provided by the fibber optics POP in the substation.

Each of the following units, called repeaters, extend the signal for the next hop and create a wireless hotspot around them for users and devices to connect to the main network. The Wi-Fi is under the IEEE 802.11 a, b and g and the security methods used are both WPA2-PSK and MAC authentication for the network devices. The wireless is also used for backup purposes between units in case of cable failure. In this way, a meshed wireless connectivity area of approximately 100 km² is created, where load switching units and other installed equipment (sensors, meters etc) can seamlessly connect to any of the units.

As far as switching devices are concerned, 200 are connected in customers that PPC indicated and are remotely monitored from the control centre via OPC and over the BPL backbone and Wi-Fi last mile connection. This reduces the cost of installation significantly and reduces that complexity of expanding to more switches (or any other devices) in the area since the coverage and backbone network are already installed. Apart from the switching equipment, 45 remotely operated meters are installed at the consumers' in the villages of Halki and Mellia in order for PPC to evaluate the AMR opportunity over BPL. They, too, are connected via the Wi-Fi network on the BPL backbone.

From a telecommunications point of view, two surveillance cameras are also installed in the network to secure sensitive parts of the network and ten VoIP networks are handed out to PPC personnel to use instead of mobile phones while in the area of coverage. Wi-Fi Internet connectivity is also available to authorised PPS personnel, but not to the public in the villages covered, since PPC has decided not to engage in that market, as of today.

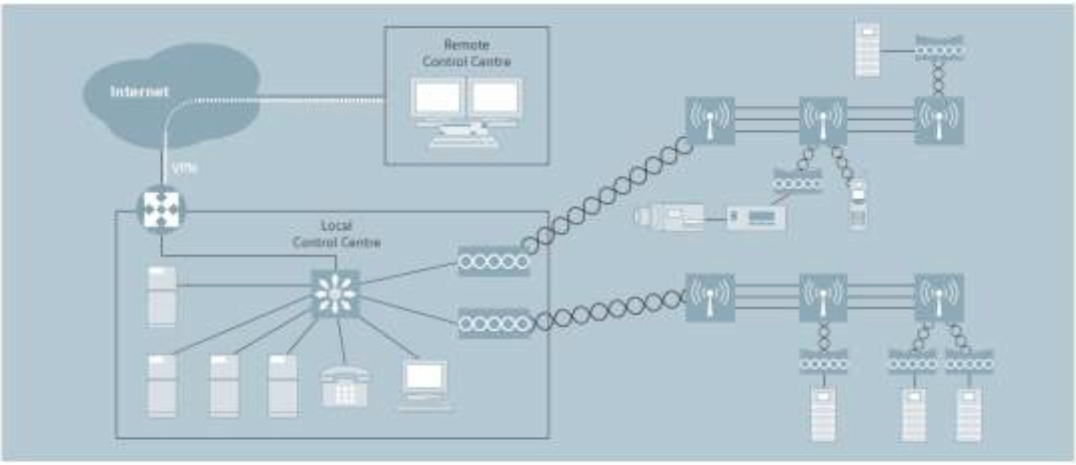

Figure 8: Network diagram of Greek smart grid pilot project

The applications delivered in the context of the described pilot project include:

- Load management (remote control switches that control the agricultural loads within milliseconds)
- AMI (automatic meter infrastructure)
- RF noise level measurements (fault prediction)
- Wireless cameras surveillance
- Measurement on the LV grid (voltage, current, and temperature)
- Telecom applications (VoIP, Internet etc.)

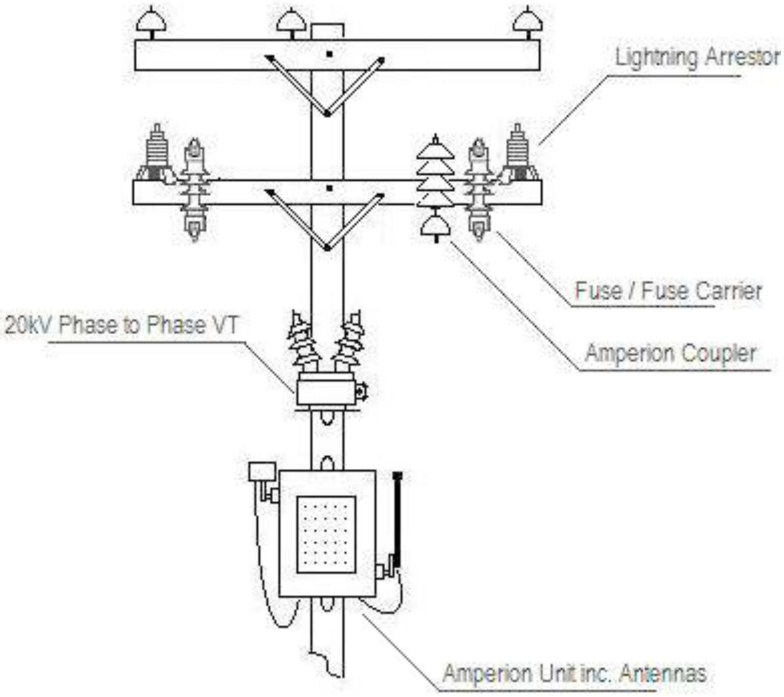

Figure 9: Unit installation within Greek smart grid pilot project

Within the described pilot project, a few problems came up concerning the transmission of the data from the meters to the control centre. The data was being transferred at lower speed than the nominal one. The nominal data transfer speed for such a BPL communication architecture is 250 MBps. However, such transfer speed was impossible to be reached in the real field. The real speed of the data transmission was between 100 and 150 MBps. These delays can be explained by the high noise that exists in the MV lines. The increased level of harmonic distortion in the MV lines limits the maximum speed of data transfer. In some other rare occasions, loss of information was noticed due to communication failures. Fuse failures to the BPL communication resulted in losing the continuity of the communication between the metering devices and the control centre and that was the reason for losing data.

Smart metering LV pilot project

Apart from the experience gained from the smart metering MV pilot project in Larissa, PPC has initiated three smart metering LV pilot projects in different areas within the prefecture of Attiki. In each project, smart meters from different vendors have been implemented. However, the adopted communication architecture was similar for all the projects. The data from the meters was gathered by a concentrator located at the respective substation through LV PLC communication (supported by DLMS protocol).

The first pilot project was developed in the area of Neo Faliro and Rentis. The scope of this project was the telemetering of some LV consumers being connected to two different substations. Both single and three phase meters were installed. The single phase meters were ACE 4000 produced by Actaris and the three phase meters were ZMF120 produced by Landis+Gyr. The concentrator that was installed at the substations was the one developed by Landis+Gyr. The communication between the smart meters and the concentrator was PLC (DLMS protocol). The data transfer speed between meter and concentrator is 1200 bits/s. The communication frequency through PLC is SFSK 63 and 74 kHz.

The second pilot project was developed in the area of Corydalos, The scope of this project was the telemetering of some LV consumers, using PLC communication. ISKRAEMECO is the vendor that supplied the smart meters and the concentrator for this project. Both single and three phase meters were installed. The single phase meters were ME371 and the three phase meters were MT371. The concentrator that was installed at the substation was the P2LPC. The data transfer speed between meter and concentrator is 1200 bits/s. The communication frequency through PLC is SFSK 83 & 93 kHz.

The third pilot project was developed in the area of Kalithea. The scope of this project was also the telemetering of some LV consumers using PLC communication (DLMS protocol). SAGEM is the vendor that supplied the smart meters and the concentrator in this project. 22 CX-100 single phase smart meters and eight CX2000 three phase smart meters were installed. The concentrator installed at the substation was the XP3000. The data transfer speed between meter and concentrator is 1200 bits/s. The communication frequency through PLC is SFSK 80 & 90 kHz.

A common smart metering architecture was developed for the three pilot projects. Figure B.3 presents the common smart metering concept using PLC communication supported by DLMS protocol. The data signal of each smart meter is transmitted through LV lines to the concentrator located in the substation. The concentrated data is sent via GSM network to the central control room where it is stored in a database for further analysis.

The strength of the data signal from a smart meter is inversely proportional to the distance between the smart meter and the concentrator of the substation. This means that the data signal that is emitted from distant meters may be too weak and not readable by the concentrator. The signal of distant meters should somehow be boosted in order to not losing any information. This signal boost is succeeded by the adjacent meters. Each meter operates as a repeater for the previous ones in order to amplify the signal.

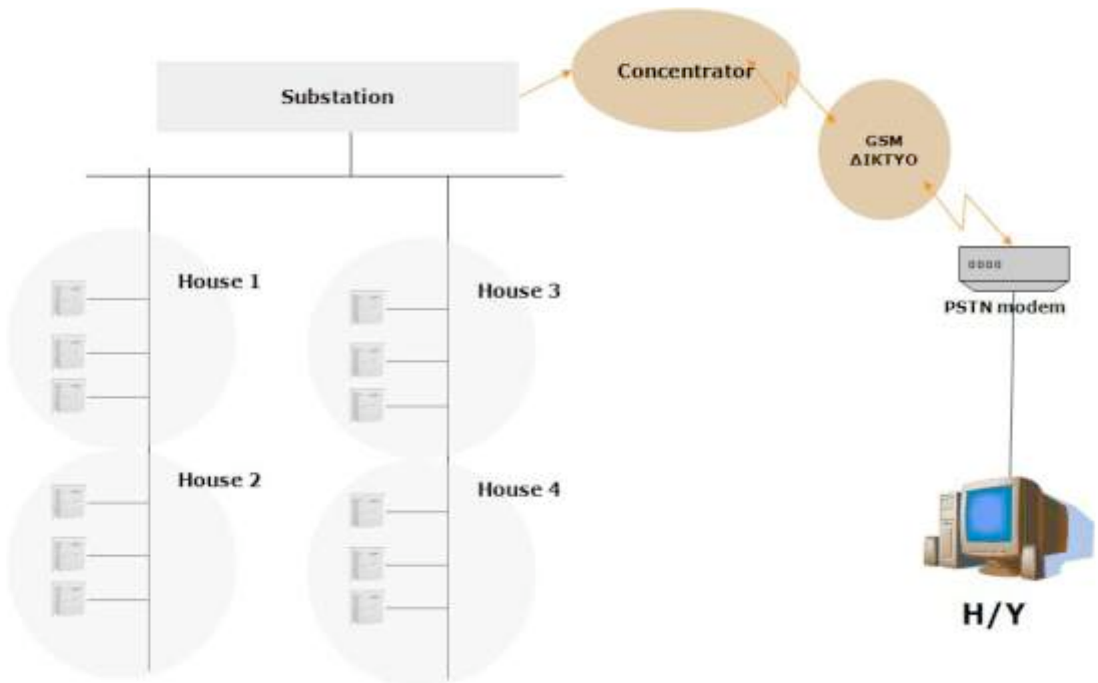

Figure 10: Common communication architecture for the three PPC LV pilot projects

The PLC communication requires dense networks since each smart meter acts also as a repeater for the previous ones. This means that the distance between two successive meters should be predefined according to the technical specifications of the meters. This requirement should be considered especially when smart metering pilot projects are being developed due to the limited number of meters that are installed. The average distance between two successive meters in the three pilot projects was about 100 meters in order to avoid data loss. However, in case of a massive smart metering application, especially in urban areas, this obstacle can be overcome by the fact that the distance between houses is less than 50 meters.

2.2. Demand Response

Demand response (DR) can be described as a means to increase the demand side participation in the competitive electricity market. The customer adjusts her electricity consumption in response to an external signal. This signal can be price-based, by setting up special retail pricing tariffs, or program-based, in which customers are given other forms of incentives to adjust their loads [U.S. DOE 2006].

In the last years, a third DR scheme is arising, in which the demand side not just receives a price signal, but is actually involved in the price forming process. Large consumers already can become part of the market, either as separate party or bundled with other parties. For small end-users, this is not yet an opportunity, although several European projects address the issue of aggregation of large numbers of small consumers into virtual power plants. Since in this scheme the end-user demand is really integrated into the electricity market, this type of DR is also called Demand Side Integration (DSI). With the introduction of distributed generation, demand response is no longer bound to end-user electricity consumption but may comprise end-user electricity production as well. Hence more terminology is introduced: Customer Site Integration (CSI).

Sections 2.2.1, 2.2.2 and 2.2.3 give an overview of different approaches. The deployment of demand side management in Europe, with a focus on The Netherlands, Germany and Greece, is summarized in Section 2.2.4.

2.2.1. Price-Based Demand Response Programs

With time-varying retail tariffs, the price of electricity to be paid by the customer fluctuates, to varying degrees, in accordance with variations in the electricity price on the wholesale markets. Customers on time-varying tariffs can reduce their electricity bills if they respond by adjusting the timing of their electricity consumption to take advantage of lower-priced periods and/or avoid consuming when prices are higher.

Typical time-varying tariffs include the following three options:

- Time of use: energy prices usually vary for different times of the day in order to reflect typical supply and demand situations in fixed time intervals.
- Critical peak pricing: usually the same as Time of Use, with the exception that extraordinary prices can be charged in extreme (peak) situations.
- Real-time pricing: prices vary according to a given reference, e.g. wholesale exchange prices

2.2.2. Incentive-Based Demand Response Programs

Incentive-based demand response programs represent contractual arrangements designed by grid operators and utilities or retail electricity suppliers to elicit demand reductions from customers at critical times. The corresponding programs give participating customers incentives to reduce load that are separate from, or additional to, those customers' retail electricity rate, which may be fixed or time-varying. The incentives may be in the form of explicit bill credits or payments for pre-contracted or measured load reductions. Customer enrolment and response are voluntary, although some demand response programs levy penalties on customers that enrol but fail to respond or fulfil contractual commitments when events are declared. In order to determine the magnitude of the demand reductions for which consumers will be paid, demand response programs typically specify a method for establishing customers' baseline energy consumption (or firm service) level against which their demand reductions are measured.

- Direct load control: utilities can directly control single loads – not employed in Germany
- Interruptible/curtailable load: usually deployed for large customers – some loads can be curtailed in peak situations
- Demand bidding / buyback programs: consumers can submit bids for curtailing loads in peak situations
- Emergency demand response programs

2.2.3. Distribution Site Integration

Demand response programs described in the previous paragraphs are characterized by the initiation by the utility, and depend on voluntary participation of end-users. Typically, the state of the electricity grid leads to control decisions at a central level, after which customers are approached to resolve the problem.

The future electricity network, having a large share of decentralized generation, and having more and more all-electric infrastructure (e.g. electrical vehicles) will require distributed control concepts for local grid support. The role of generation and consumption is more in balance, and a logical step is to look for market-based solutions for control, having active customers as market participants. This leads to dynamic responses, with proactive action in case of critical circumstances. End-users no longer react to price changes but are participating in the price formation process. The outcome of the market can be fixed in "real-time" contracts.

This concept, leading to true integration of end-users into the process of delivering electricity, is implemented in the PowerMatcher technology [AAMAS 2005] that will be applied in several of the scenarios of the SmartHouse/SmartGrid project.

2.2.4. Deployment of Demand Response Schemes in Europe

<u>Greece</u>

PPC currently evaluates several scenarios related to the development of a new service portfolio, by introducing new products in its supply division, aiming at introducing versatile tools for the demand side management, which is of the utmost importance for defending its supply market share.

The products examined include:

- New pricing schemes
  - Fixed / indexed price
  - Discounts schemes
- Enhanced features
  - Multiple tariff, interruptible tariffs, prepaid schemes
  - Green energy, loyalty
- Web services
  - Information
  - Sale / after sale services
- Energy saving / efficiency
  - Consulting
  - Project management
  - Energy audits
- Automated energy management systems

The existing regulating environment imposes important hurdles for the implementation of many of the above products, especially the ones related to tariffs.

PPC is currently offering night time tariffs, with lower prices for residential customers during the night. Under negotiation are also several tailor-made tariff schemes with MV and HV customers, in order to allow smoothing of their demand curve by time-shifting loads from peak hours to valleys. In the summer, where Greece during the last few years is experiencing a shortage of power, there are incentives for MV and HV customers to allow power cuts, with the benefit of price discounts. Under development is also a scheme of cooperation with local authorities for energy savings and better energy control related to street lighting and municipal buildings lighting.

Germany

Typical time-varying tariffs in Germany are offered for customers who have night storage heaters, where the tariff during night hours is considerably lower than during daytime. Real-time pricing is deployed only in some small-scale field tests (cp. "Energiebutler" by MVV). Other small-scale examples are e.g. a demand side management program provided by a public services company in Saarbrücken, who shuts off contracted deep-freezers and refrigerators in supermarkets for 1-2 hours when load is high. These cooling devices cool down deeper in times of lower load. Another example is a chemical factory in Wilhelmshaven. Here, the utility can deliver up to 30 MW less power for a certain duration that has been agreed upon beforehand. Up to now, there are only singular demand side management programs in Germany, and few initiatives to deploy this rationale on a large scale.

Besides these small scale activities and field trials, a larger series of field trials is currently in the preparation phase or has already started in the framework of six model regions within the E-Energy research scheme[12] co-funded by the national ministry for economics. The projects continue until the end of 2012 and much experience will be available by then.

The Netherlands

Small consumers can apply for a double tariff meter to be installed. During off-peak time (night, weekend), a much lower tariff is offered to the end-user, giving him the incentive to shift electricity use to these periods. Main appliances that are affected are washing and drying devices.

In a [SenterNovem 2004] study, the total potential for demand response in Dutch households is estimated at 700–1,200 MW. This is 2.5–5% of the total maximum power demand in the Netherlands. The main obstacles for demand response are a lack of proper technology (e.g. smart metering and communications) and incentive structures (e.g. consumers only see a peak and off-peak price). The introduction of smart meters may lead to some DR initiatives based on capacity restriction and prepay services. Small consumers are not enthusiastic about DR, because the security of supply in the Netherlands is very high.

Another report by Deloitte studies the potential of DR in the Dutch liberalised electricity market. The potential in the wholesale sector is 1,730 MW, of which 1,200 MW is industrial and 425 MW in the horticulture sector [Deloitte 2004]. A total of 1,000 MW is already utilized, 700 MW remains unexploited. Another almost unexploited capacity is in emergency generators, estimated at 1,400 MW.

In order to optimally utilize demand response, commercial users should be flexible with respect to buying and selling electricity. Since acting on the electricity wholesale market introduces operational costs and risks, in many cases the energy management is redirected to utilities or energy service providers.

In the Netherlands, the horticulture sector has a large share of CHP installed. Fed by gas, they produce heat, light, CO_2 (for plant growth) and electricity. By installing large heat buffers and CO_2 tanks, a lot of flexibility is available for electricity production. Although the capacity for each party is relatively small, as an aggregated group this flexibility is already utilized in today's wholesale market.

Future residential demand response potential is expected to come from plug-in hybrid electric vehicles, electric heat pumps and air conditioning. A recent study from the ITM project revealed that 1.5 million heat pumps in 2040 can provide the equivalent of 250 MW regulating power and 1.5 GWh storage. 6.5 million PHEV can provide 36 GWh of storage. Together, this is sufficient to compensate most of the short term differences between predicted versus realised output of 10 GW wind farm, thus contribute highly to integration of intermittent renewable [ITM 2009].

In Belgium VITO, in cooperation with Group Machiels, has announced to set up a virtual power plant service. ECN's PowerMatcher technology will be used to utilize the demand response potential of a cluster of producers and consumers.

[12] http://www.e-energy.de/

3. Information Representation and Communication in Energy Systems

For SmartHouse/SmartGrid systems, both in-house and remote communication is necessary in order to transmit relevant data among devices, between the grid and Smart Houses, and between enterprise systems and Smart Houses or the Smart Grid. Therefore, technologies and data formats allowing bi-directional communication over long distances (Section 3.1) and local communication over short distances (Section 3.2) are reviewed in the following. Section 3.3 gives a brief overview about standardisation efforts in the data exchange protocols and Sections 3.4 and 3.5 add a discussion about how to ensure security and privacy in smart house communications.

3.1. Wide Area Communication

In order to allow a transmission/distribution system operator (TSO/DSO) or a commercial aggregator to send price signals or other relevant information to the end-user/prosumer, remote communication with the electricity meter must be possible. This section reviews options for Wide Area Network (WAN) communication with the customer interface, including the meter.

3.1.1. Fixed Network Communication

Existing public networks such as telephony (over landline) networks can be used to provide communications between meters and utilities. One key advantage of these systems is their ability to deploy an Advanced Metering Infrastructure across a wide area and thus possibility lower upfront cost of deployment since the utility can make use of existing infrastructure. Some remote meter reading systems rely on paging networks while others rely on landline telephone networks. However, these systems have limitations since they are subject to the coverage provided by the public networks, potentially disruptive protocol changes and high operational costs.

The deployment costs of AMI systems based on these public networks are limited to installing the new endpoint and setting up the service they offer. Therefore, utilities are not required to install any communication infrastructure, which significantly speeds up the deployment process.

As for their rather low capacity demand, metering and consumption data could, in principle, be transmitted via narrowband network communication systems such as Public Switched Telephone Network (PSTN) or Integrated Service Digital Network (ISDN); however this requires the sending device to dial a switched connection every time it wants to transmit data. Typically, there is only one customer phone line and dial-in charges would be paid by the customer which leads to additional costs. Since in Europe today every house is connected to the PSTN via at least one twisted pair, the advantage of the PSTN is attractive for remote meter reading and related applications. Additionally the data rates achievable with PSTN would be adequate for these purposes.

Another problem with the analogue phone line would occur if both customers and AMI on same line may lead to conflicts if the PSTN is frequently accessed. On the other hand, the ISDN technology provides (at least) two independent channels at higher speed (than PSTN), but the ISDN technology is not available in every household.

In contrast with telephony infrastructure, the number of broadband connections with flat-rate tariffs (xDSL, TV broadband cable) are growing in many European countries, these connections would allow the sending of energy-related data without additional costs [wik-Consult/FhG Verbund Energie 2006]. This possibility makes this technology an interesting candidate in an AMI concept. An important fact is that data carried by the ADSL is typically routed over the telecom operator data networks and the Internet. For the reason of DSL's widespread availability and low cost of transmitting additional data, the first electricity suppliers in Germany who are offering smart metering services and real-time energy consumption to their customers (e.g. EnBW Cockpit, Yello Sparzähler^{online}, see also Section 2.1.5) rely on this technology and require their smart metering customers to have a DSL connection at their home.

Additional option would be Fibre to the Premises (FTTP). This is a form of fibre-optic communication delivered directly onto the customer's premises. This contrasts with other fibre-optic communication delivery strategies such as Fibre to the Node (FTTN), Fibre to the Curb (FTTC), or Hybrid Fibre-Coaxial (HFC) that depend upon more traditional methods such as coaxial cable or copper wires for "last mile" delivery. Some companies (e.g. telecom or electricity) have already started to invest in this new technology. For further reading about the wired technologies that could be involved in an AMI concept, the reader is referred to Open-Metering project deliverable D2.1.

3.1.2. Mobile Network Communication

Existing mobile public networks, e.g. paging, satellite, cellular telephony networks, as well can be used for communications between meters and utilities. The mobile network solution's gives enables the deployment of Advanced Metering Infrastructure across a wide area while sparing the utility the cost of building a private communication infrastructure. These remote meter reading systems may rely on paging networks while others rely on cellular telephone networks, or satellite communications might be used. Three key limitations include: being subject to the provided signal coverage of the public networks, involved protocols (this is especially true in the cellular segment) and operational costs.

With AMI systems based on mobile public networks (if there is coverage at the customer location) will limit the installation costs to the value of the new endpoint and setting up the service. Since utilities are not required to install additional communication infrastructure, deployment time will be minimized.

One possible mobile solution is Wavenis Wireless Technology that was created as a proprietary technology by Coronis Systems in 2001. This is a 2-way wireless system designed to operate in UHF ISM bands. The main features of Wavenis are:

- Low data rate communications (in the range from 4.8 kbps to 100 kbps) that fulfils requirements for the metering applications,
- Ultra-low power consumption in devices (smart meters). With such a low level of consumption the battery-powered devices could reach multi-year operation,
- High link budget to attain large radio reach and in-house signal penetration.

The Wavenis technology is currently applied in telemetry, industrial Automation, AMI and Automatic Meter Reading (AMR), utility meter monitoring, home comfort, etc.

Another example is the radio-based system called EverBlu. This technology uses a wireless mesh point-to-multipoint communication infrastructure. It is a wireless mesh technology with ultra-low-power, bi-frequency and long-range ability (around 300m). As EverBlu is a long-range mesh radio network, it is convenient for urban, suburban and rural environments.

In need for the higher speed transmission (up to 72 Mbit/s) in mobile communication, the WiMAX (Worldwide Inter-operability for Microwave Access) technology would also be taken in consideration. This is a Wireless Broadband Access (BWA) based on the IEEE 802.16 series standard. It has been designed to provide high transmission speeds in both directions and supports point-to-point and point-to-multi-point network topologies.

WiMAX was intended as a wireless alternative to xDSL and other wired local access solutions in rural areas, suburban or urban areas (like EverBlu). Today, WiMAX technology provides broadband services to mobile or semi-mobile (nomadic) users, as such is also competing with 3G mobile networks in some areas. The technology itself can support robust transmissions, but for reduced speed trade-off. This is valid to a certain extent, for non-line-of-sight (NLOS) conditions and indoor coverage.

However, it is not likely that the deployment of a dedicated WiMAX network solely for the purpose of an AMI can be justified. In other words, it may principally be an option for AMI in those areas where public WiMAX services are available (e.g. municipal networks).

Beside all mentioned technologies, the most diffused one are 2G/2.5G cellular mobile networks. The coverage of public cellular mobile networks is approaching 100% of civilised areas (at least in Europe). Today, mobile services are available almost everywhere making the cellular infrastructure extremely valuable e.g. for meter reading. Additionally, the packet-oriented data services can be provided with GPRS or EGPRS (EDGE) enhanced GSM networks. These services provide even higher speeds depending on the link quality.

Similarly to 2G/2.5G technologies, the 3G/UMTS technologies are principally able to provide data-only services suitable for telemetry and metering applications. Mentioned services are normally IP based and packet oriented. For metering applications it is important to mention that operators could offer 3G data services at more economical conditions than 2G services.

Even so, the deployment of today's 3G networks is still far behind 2G, particularly in less populated or rural areas. This may however change in future, since 3G/UMTS is considered a strong candidate to provide broadband Internet access in those areas currently not served by xDSL and cable. This makes the 3G technology a potential candidate for AMI.

An alternative solution might be the use of satellite systems for metering and energy related end-user services. This solution could be suitable in areas where there is no terrestrial communication infrastructure. However, this solution would require a number of satellite systems offering low speed data services, thus more attractive alternative solutions may be easily found. For further reading on mentioned mobile technologies the reader is referred to the Open-Metering project deliverable D2.1

3.1.3. Hybrid Network Communication

In comparison to fixed network communication systems, mobile network communication systems such as GSM or UMTS are less dependent on an already existing infrastructure. In some regions, in which fixed network based broadband solutions are not economically viable, mobile networks can be an alternative for the transmission of energy-related data between a smart meter and a utility. There are already smart meters on the market which are equipped with an integrated radio module for sending meter data via mobile network communication, such as the GSM or GPRS standard ([wik-Consult/FhG Verbund Energie 2006]; they name the example of EMETRION IQ-GSM/GPRS[13]).

However, if there is a need to extend communication infrastructure, wireless communication in the fixed networks is always an attractive solution. This they do not require additional wiring and a wireless network infrastructure could be used e.g. WiMAx networks. On the other hand, a fixed network may not be justified in certain areas. However, even a wireless communication might have an obstacle in European countries e.g. where radio-based solutions could be distorted by solid walls or meter can be placed in the basement. Therefore it is of main importance to have smart metering system composed as a hybrid system, where both (fixed and mobile communication) solutions are involved.

3.1.4. Powerline Communication

Powerline communication (PLC) uses the existing power lines within a home, building or an outdoor power distribution network to transmit data from one device to another. With a well-designed power line solution, devices should be able to communicate using the existing wiring infrastructure, without any rewiring or modification. This makes powerline communication one of the most cost-effective means for networking devices.

PLC systems send data through power lines by injecting information into either the current, voltage or a new signal. This can be accomplished by slightly perturbing the voltage or current signal as it crosses the zero point, or by adding a new signal onto the power line. The system normally has equipment installed in utility

[13] http://www.goerlitz.com/fileadmin/Dokumente/PDB/EMETRIONIQ-GPRS_PDB_DE.pdf

substations to collect the meter readings provided by the endpoint, and then the information is transmitted using utility communications or public networks to the utility host centre for the PLC system.

PLC systems are particularly well suited to rural environments, but have also been successfully used in several urban environments. For utilities with both rural and suburban areas in their service territory, PLC provides an option for using one automated metering technology for the entire service territory for electric meters.

PLC systems initially targeted residential and small commercial metering, but are now able to read for larger customers as well. Any electrical devices connected to the power line can be networked to communicate with each other. Some examples of applications include:

- Intelligent electricity meters: This solution enables utilities to network all of their electricity meters and to read them from a remote central location. A Powerline smart transceiver-based meter can also enable utilities to remotely switch on/off power to a facility as well as to detect any tampering of meters or unauthorized power consumption.
- Networked home appliances: Every device in a home can now communicate with each other as well as with the local electricity meter. These devices could include the refrigerator, washer/dryer, AC/heating, lighting system, security system, pool heating, etc. As a result, utilities and consumers can monitor and manage power consumption more effectively (demand response, see also Section 0) thereby increasing cost savings and convenience.
- Power lines were designed to carry power and not data. This means it takes a very sophisticated transceiver to reliably communicate over power lines. Many electrical devices connected to the power lines adversely impact the data that is being transmitted. The quality of the signal that is transmitted over power lines is dependent on the number and type of the electrical devices connected to the power lines and switched on at any given time. The quality of the signal is also dependent upon the wiring distance (not physical distance) between the transmitter and the receiver as well as the topology (wiring architecture) of the power line infrastructure in the home/building. All of the above impediments could vary between buildings, neighbourhoods, and the power grids in various countries, making a universal solution very difficult.

There are several powerline communication technologies, both standardized and non-standardized, for narrow and broadband communications currently in existence. Since, it is of key importance to enable AMI technologies going forward, the scalability of PLC technology on the data throughput is required. As the number of smart devices in the home increase, there will be an increase in the information volume being transmitted through the (power-line) wire. For this reason, narrowband PLC (e.g. Echelon, PRIME, ZIV, etc...) should not be considered as candidates for AMI communication infrastructure.

Another important consideration for the smart house is the ability of devices, from different vendors, to communicate with other devices. This would save additional costs (and wiring) since all these devices could communicate over channels that already exist in the house, the power-line. For instance, an electrical appliance would want to communicate its electricity usage to the smart meter independent of their relative vendors. If these vendors could make feasible for these electrical devices to communicate in between each other, the efficient energy usage (of the occupant's available power) all the communication could be done through the power-line. Thus, any employed PLC system should be based on open standards to guarantee the interoperability of devices from different vendors. Two good examples of the broadband PLC technology standards are IEEE 1901 and ITU-T G.hn.

3.1.5. Broadband Over Powerline Communication

Currently, broadband Internet access is offered to residential and small-business customers through DSL, cable-modem, wireless, optical fibre, and satellite technologies. Broadband over Powerline, or BPL, is another mode of broadband access. BPL deployment remains in the developmental stage in most areas where it is available.

BPL utilizes electric power distribution wires for the high-speed transmission of data by transmitting high-frequency data signals through the same power distribution network used for carrying electric power to household users. In a common form of BPL, the broadband connection is provided over the electrical wires that enter a house; a customer can obtain Internet access by plugging a BPL modem into any residential electric outlet served by the BPL system. In another form of BPL, Internet access is provided using a wireless device (such as a Wireless LAN (WLAN) access point) connected to a BPL distribution system outside of the house that communicates with the customer's computer or other equipment inside the house.

It is important to note that BPL technology, in its current form, is not suitable for carrying broadband signals over long distances. The broadband communication channel must be brought into a neighbourhood by other means, and then BPL can be used as the distribution mechanism to reach individual homes or businesses.

Carrier-current systems have been used for many years to conduct low-speed data over power lines. Because of the inherent impedance and attenuation variations of power lines, as well as noise from dimmer switches, motorized electrical appliances, computers switching on and off, and other devices, reliable high-speed communication over power lines has been difficult to achieve. However, the recent availability of faster digital processing technologies and the development of sophisticated modulation schemes have produced new designs that overcome these technical obstacles. These new designs have led to the development of new BPL systems that use spread-spectrum or multiple-carrier techniques and that incorporate adaptive algorithms to overcome the problems associated with noise in the power lines.

BPL works by modulating high-frequency radio waves with the digital signals from the Internet. These high frequency radio waves are fed into the utility grid at specific points, often at substations. They travel along MV circuits and pass through or around the utility transformers to subscribers' homes and businesses. Sometimes the last leg of the journey, from the transformer to the home, is handled by other communication technologies, such as WLAN.

Figure 11 illustrates a basic BPL system, which can be deployed in cell-like fashion over a large area served by existing MV power lines by installing multiple injectors, repeaters, and extractors.

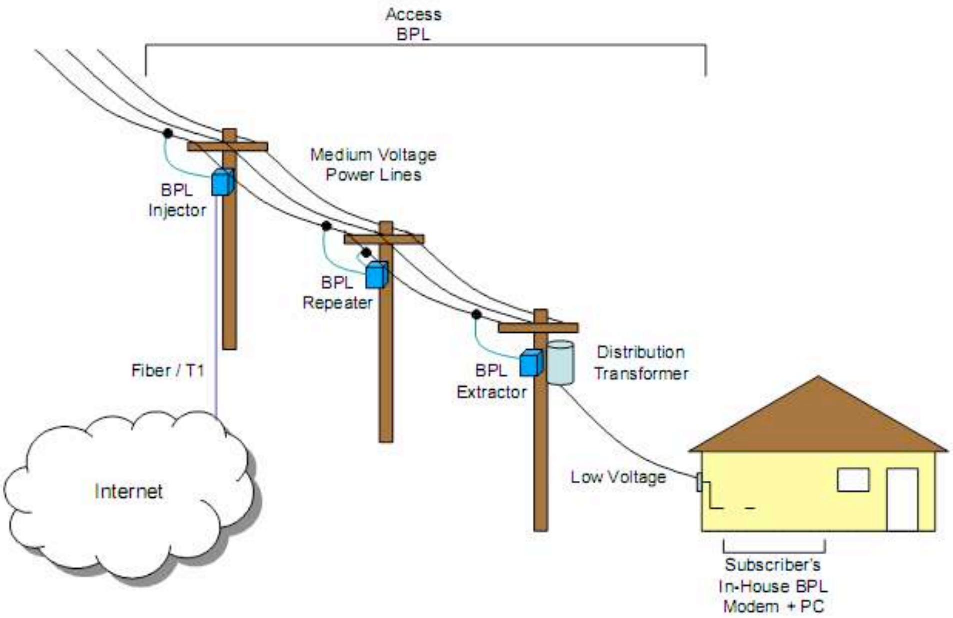

Figure 11: Schematic representation of a broadband over powerline system

The main advantages of BPL technology in building the communications backbone that will enable Smart Grids are the ability to touch, reach and digitize the physical grid. Creating the most robust communication network requires that it touches the key nodes, like transformers on the physical grid, and tackle the true complexities of the grid at the outset.

Drawbacks with using BPL to backhaul data are cost of fibre, installation labour cost and the fact that, should a fault occur on the conductor that the BPL services are provided, all data would be cut off and the communication will be rendered useless.

3.1.6. IEC 61850

The standard IEC 61850 was first introduced for substation communication, but is now preferred by IEC as the "seamless telecontrol communication architecture" for the future communication within the electrical energy supply [Schwarz 2002]. One of the most important features of this standard is the separation of the definition of data models (specifying what content is transmitted and what it means) and the underlying protocols defining how the data shall be transmitted. This concept allows for the extension of the standard to new applications by defining the appropriate data models quite easily. Data models as part of the IEC 61850 family have been approved for wind power plants (IEC 61400-25) and hydro power (IEC 61850-7-410). IEC 61850-7-420 for communication to distributed generation units will probably be available as approved standard within the first half year of 2009. This new chapter also defines basic data models for energy management including operational modes, set point curves and price profiles for electricity production and demand as well as ancillary services.

3.2. Communication for Home Automation and In-House Interconnectedness

In a Smart House, real-time information about the electricity system status (consumption, prices, renewable energy production etc.) needs to be delivered to the customer or to home appliances. This information can either be transmitted via WAN communication options (web sites, SMS or others), or via local network communication.

Besides the communication between the customer site on the one hand and the DSO and the electricity trader on the other hand, communication also has to be possible between the customer interface and the devices installed at the customer's premises (see Figure 12). Moreover, communication between the customer interface and the user display takes place within the Smart House. This communication needs to transmit measurement and status information to the customer interface and switching commands as well as other settings to the devices. Also real-time information about the electricity system status (consumption, prices, renewable energy production etc.) needs to be delivered to the customer display.

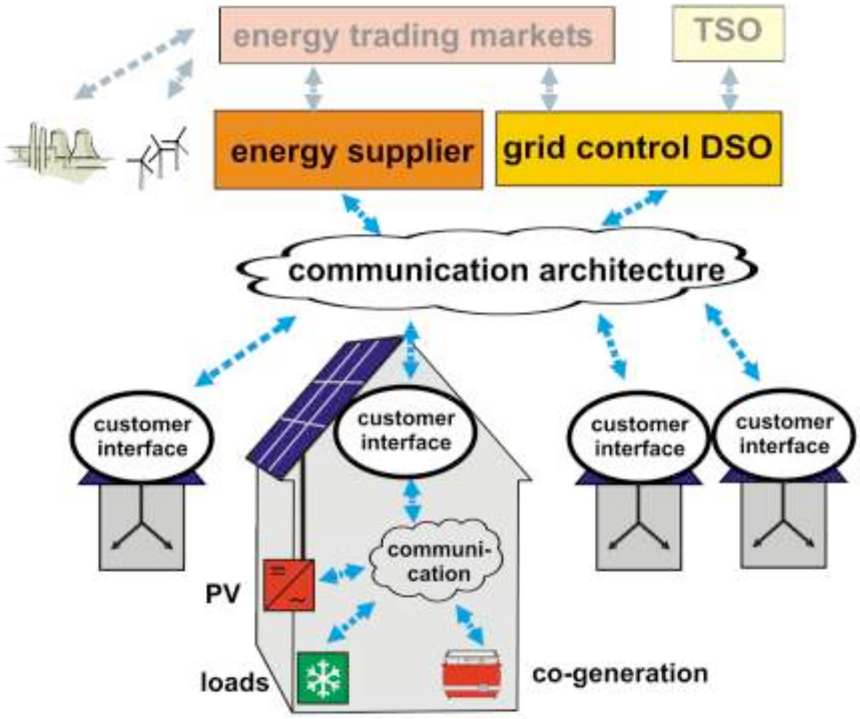

Figure 12: Smart House communication structure

Today building automation is mostly installed in commercial buildings using automation bus systems like KNX or LON. Building automation in private households has not been established in Europe, though. In contrast, TCP/IP-based computer and telecommunication networks are widely used also in private households and small businesses today. The main barriers regarding home automation, which means building automation for small/private customers, are still the cost and the requirement to install the systems in existing buildings. To overcome this situation, it is important to use home automation systems that do not need additional cables, which means signal transmission via radio or the existing electrical cabling. To make home automation feasible for mass market, it will also be necessary to allow for the installation of small systems with limited functionality to start with. These systems should not primarily be designed to provide critical functionality that could affect the usability of the building as a whole when programmed faultily. With this limitation the system can be configured by the customer himself. This approach is also used for most private computer networks in Europe today for those types of customers who prefer to accept occasional disturbances over the cost of professional installation and service. Furthermore, customers who are most interested in using advanced technology in their home are also interested in being able to configure and to control these systems themselves.

3.2.1. W-LAN

Wireless LAN uses the 2.4 GHz, 3.6 GHz and 5GHz frequency bands for signalling according to the IEEE 802.11 standard. In Europe, this frequency band is open to public use, and is divided into 13 channels. The W-LAN technology is used widely in computer networks. Current W-LAN systems can provide data rates of typically 11 Mbit/s for 2.4 GHz band, 54 Mbit/s for 5 GHz frequency band. But, the W-LAN rates might go even up to 600 Mbit/s with the latest IEEE802.11n specification. For use in home automation systems, other standards are more suitable, however. ZigBee uses the same frequency band as W-LAN, but in contrast also specifies auto-routing of information packages from one node to any other node allowing reaching devices within the entire building, as long as all nodes can contact any other node of the network. For using W-LAN, direct radio signal connectivity between all nodes (clients) and the central access point is required unless special repeaters are used. This would increase cost and power consumption of the system. For this reason, W-LAN is not further considered for home automation in this project. W-LAN can be very helpful for the connection between the customer interface and the display, however.

3.2.2. Bluetooth

Bluetooth is an industrial specification for wireless personal area networks (IEEE 802.15.1). It enables connections and information exchange between devices such as laptop computers, PCs, mobile phones, printers or digital cameras via a secure short-range radio frequency. As for its intended use for personal area networks, the range of communication via Bluetooth is rather low, approximately ten meters in most implementations. This makes it unsuitable for a communication with a smart meter. For this reason, it is not further considered in this project.

3.2.3. Specialized Home Automation Systems

Several innovative radio and PLC-based home automation systems that fulfil the requirements explained in the introduction to this section are currently coming to the market. Most of them are proprietary systems of one vendor, however. Until now, solutions to home automation challenges have been sought through the development of better sensor networks. Although they are very important parts of Smart House solutions, no single sensor network technology can solve the challenges in this field. Z-Wave, ZigBee, and Digitalstrom are attempts to define a common command language for home networks. So far, none of them has achieved the status of a de facto standard of home networks. Hence, it can be assumed that a future home will use several different technologies. The three named standards are evaluated in more detail below: ZigBee, Z-Wave and Digitalstrom. Table 1 gives an overview on most important characteristics of these standards.

	ZigBee	**Z-Wave**	**Digitalstrom**
Promoter / origin	ZigBee Alliance www.zigbee.org	Z-Wave Alliance www.z-wavealliance.org Zensys (DK)	Digitalstrom-Allianz www.digitalstrom.org ETZ Zürich Aizo GmbH, Wetzlar
Areas of application	All kinds of sensor / actor networks	Home automation	Home automation
Medium / frequency	Radio 2.4 GHz	Radio 868 MHz	PLC 50 Hz
Bit rate	250 kBit/sec	40 kBit/sec	Approx. 100 Bit/sec
Batteries	Some years, in case of no WLAN interference	Some years	--
Coverage of entire building	Auto-routing	Auto-routing	Robust PLC signal
Home automation standardization	Smart Energy Profiles (2008)	Part of core specification	In progress
Home automation available products	Approx. 10 (mostly smart meters, display), not installable by users	More than 200, no smart meters, mostly installable by users	--
Standardization process and usage	Spec: members of alliance, usually years per edition	Spec: members of alliance, extensions possible in 8-12 months	Not clear yet, so far only members of alliance
Product development	Free	Members of alliance	Members of alliance

Certification	Possible	Mandatory	Not clear yet
Manufacturer-independent compatibility	Not clear yet	Tested success fully at ISET, high priority	--
Potential interferences discussed	WLAN	--	--

Table 1: Comparison of ZigBee, Z-Wave and Digitalstrom as home automation systems

3.2.4. Systems for Connecting to Household Appliances

Several manufacturers of white goods have created own proprietary systems which allow connecting to their appliances such as washing machines, refrigerators and ovens. Most of these systems can be controlled via a user display or via a gateway from a local PC, and send their communication signals via PLC. Examples for these systems are Miele@home (by Miele). Some white goods manufacturers are also extending the scope of these systems to support load shifting and other smart grid related control operations.

A new standard for household appliances interworking has been prepared by CENELEC, with the support of the European association of manufacturers of household appliances CECED. The standard EN 50523 describes the necessary control and monitoring for interworking appliances. It defines a set of functions of household and similar electrical appliances which are connected together and to other devices by a network in the home. It has been released in 2009. The intention was not primarily related to smart grid; however, its use in this context is promising.

In the U.S., the government menaced that it might mandate standards for making household appliance ready for smart grid applications if the manufacturers don't agree on protocols to exchange data from appliances and devices around the home and to the smart grid. Currently, the regulation pushes towards the development of a single standard for these smart grid applications. An alternative would be to have gateways that mediate the data traffic coming from the devices and that support a range of protocols and standards. As these gateways would have to be highly secure, expert judge it unlikely that broadband routers in people's homes today could take over the gateway tasks; instead, pay-TV set-top boxes are possible candidates. These discussions are currently undergoing. One outcome, however, is very likely, i.e. that using internet protocol [IPv6] will be a common basis.

3.2.5. REST

Representational State Transfer (REST) is a software architectural style for distributed hypermedia systems like the World Wide Web. The term originated in a 2000 doctoral dissertation [Fielding 2000] and has quickly passed into widespread use in the networking community. REST is an architectural style for building large-scale networked applications. REST describes a networked system in terms of data elements (resource, resource identifier, representation), connectors (client, server, cache, resolver, tunnel), and components (origin server, gateway, proxy, user agent). The RESTful approach could provide an integration approach for the devices in the SmartHouse/SmartGrid context. Several efforts already experiment with REST for smart meters or plan to do so (e.g. FP7 NOBEL[14]). It is expected that the REST approach may be more lightweight than the typical SOAP based implementation of web services.

3.2.6. OPC-UA

The OPC foundation actively develops the OPC Unified Architecture (OPC-UA)[15], with the goal to advance the OPC communications model (namely COM/DCOM) towards service-oriented architectures and

[14] http://www.ict-nobel.eu/

[15] OPC-UA: http://www.opcfoundation.org/UA/

introduce a cross-platform architecture for process control. OPC-UA is a set of specifications applicable to manufacturing software in application areas such as field devices, control systems, manufacturing execution systems and enterprise resource planning systems. These systems are intended to exchange information and to use command and control for industrial processes. OPC Unified Architecture defines a common infrastructure model to facilitate this information exchange. OPC-UA is used today in industry (e.g. monitoring wind parks) and may coexist with DPWS as the FP7 SOCRADES project demonstrated[16].

3.2.7. WS-DD

The Web Services Discovery and Web Services Devices Profile (WS-DD) Technical Committee of OASIS has adopted a standard (June 2009) that defines:

- A lightweight dynamic discovery protocol to locate web services that composes with other Web service specifications;
- A binding of SOAP to UDP (User Datagram Protocol), including message patterns, addressing requirements, and security considerations; and
- A profile of Web Services protocols consisting of a minimal set of implementation constraints to enable secure Web service messaging, discovery, description, and eventing on resource-constrained endpoints.

Devices Profile for Web Services (DPWS) is attempting to fully integrate devices with the web service world. DPWS defines a minimal set of implementation constraints to enable secure web service messaging, discovery, description, and eventing on resource-constrained devices. DPWS is an effort to bring web services on the embedded world taking into consideration its constrained resources. Several implementation of it exist in Java and C[17], while Microsoft has also included a DPWS implementation (WSDAPI) by default in Windows Vista and Windows Embedded CE.

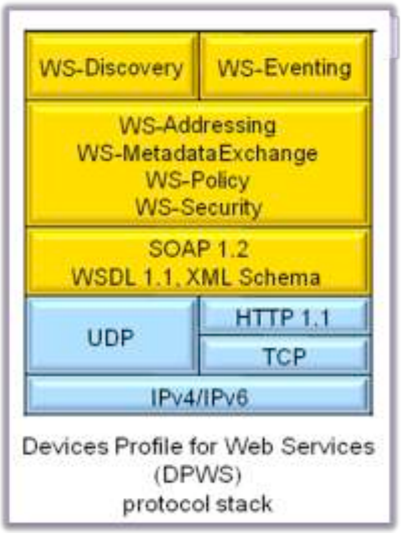

Figure 13: DPWS protocol stack

The DPWS stack supports the following web service standards: WSDL 1.1, XML Schema, SOAP 1.2, WSAddressing, WS-MetaDataExchange, WS-Transfer, WSPolicy, WS-Security, WS-Discovery and WS-Eventing. As a result, dynamic device and service discovery can be realized, while the metadata exchanged can provide detailed information about the devices and its functionality. This is well supported in DPWS with the inclusion of the main data discovery and transfer protocols such as WSDL, SOAP, WS-Transfer etc. Therefore, not only custom made device drivers can be eliminated to a large extend, but also these devices

[16] http://www.socrades.eu/
[17] www.ws4d.org, www.soa4d.org

can now be easier and better used by enterprise resource planning applications via widely used technologies such as web services.

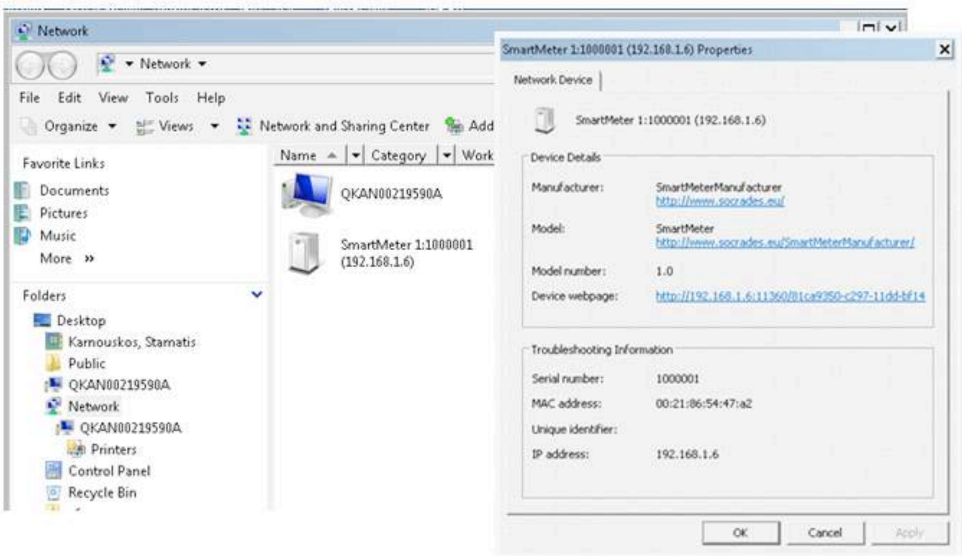

Figure 14: Dynamic discovery of smart meters in MS Windows VISTA

Microsoft has also included a DPWS implementation (WSDAPI) by default in Windows Vista and Windows Embedded CE. Therefore, one can dynamically discover devices that support it (such as the smart meter in Figure 14) and query their data, e.g. their status, serial number etc. Open source implementations also exist for instance WS4D[18] and SOA4D[19].

3.2.8. IPv6 (6LoWPAN)

6LoWPAN is an acronym of "IPv6 over LoW Power wireless Area Networks", and is the name of the working group in the Internet area of the Internet Engineering Task Force (IETF)[20]. 6LoWPAN is the international open standard that enables building the wireless "Internet of Things". It enables using 802.15.4 and the Internet protocol (IP) together and brings IP to the smallest of devices – sensors and controllers. As described in the IEEE 802.15.4 standard, 6LoWPAN brings following advantages:

- It offer the fundamental lower network layers of a type of wireless personal area network (WPAN) which focuses on low-cost, low-speed ubiquitous communication between devices
- IP protocol advantage has proven as a long-lived, stable and highly scalable technology that supports wide range of applications, devices and underlying communication technologies.

Today there are several TCP/IP stacks, such as:

- uIP stack from the Contiki operating system[21]
- TinyOS-based IPv6 stack[22]
- NanoStack[23]
- lwIP stack[24]

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[18] http://www.ws4d.org/
[19] http://www.soa4d.org/
[20] http://www.ietf.org/html.charters/6lowpan-charter.html
[21] http://www.sics.se/contiki/current-events/uipv6-contiki-is-ipv6-ready.html
[22] http://www.tinyos.net
[23] http://sourceforge.net/projects/nanostack

Their footprint is around ten kilobytes, except for lwIP that is around 20 kilobytes.

For the SmartHouse/SmartGrid context, this implies that devices of any size could run this stack and be interconnected with other co-existing structures such as gateways, other devices etc., over a standardized and widely accepted communication channel. The NOBEL[25] project will experiment with 6lowpan/IPv6 for connecting metering devices with enterprise services.

3.2.9. IPSO Alliance - IP for all Devices

Sensors for light, pressure, temperature, vibration, actuators, and other similar objects evolve; new applications and solutions are being created and implemented. Indeed, the Smart Grid, "smart cities", home and building automation, industrial applications, asset tracking, utility metering etc. are all taking of IP's rich history and adaptability. The IPSO Alliance[26] was formed in August 2008 with the objective of continuously increasing the base to support and supplement the IP on every device. The IPSO alliance will perform interoperability tests, document the use of new IP-based technologies, conduct marketing activities and serve as an information repository for users seeking to understand the role of IP in networks of physical objects. The IPSO goals are:

- Promote IP as the premier solution for access and communication for smart objects.
- Promote the use of IP in smart objects by developing and publishing white papers and case studies and providing updates on standards progress from associations like IETF among others and through other supporting marketing activities.
- Understand the industries and markets where smart objects can have an effective role in growth when connected using the Internet protocol.
- Organize interoperability tests that will allow members and interested parties to show that products and services using IP for smart objects can work together and meet industry standards for communication.
- Support IETF and other standards development organizations in the development of standards for IP for smart objects.

The IPSO alliance has published several papers on IP technologies for embedded devices (including smart meters) as well as energy efficiency e.g. in commercial buildings.

3.3. Standardization and Interoperability

Worldwide many standardisation initiatives try to create this prerequisite for the deployment of smart meter, smart grids and smart houses. In Germany, in the European Union, in America and in other parts of the world, industries helped by the political authorities through sponsored projects or thank to a new legislation try to go forward on this topic.

For example in Germany, an important number of initiatives are currently running in smart metering and smart house standardisation. All the type of smart metering are studied with working groups like ZVEI (for the electricity industries) and Figawa (for the gas and water sector) and all the processes of the new smart network are taken into consideration from the metering technology (with the Open Meter Communication project, see Section 3.3.8) to the grid management (e.g. with the OGEMA project, see Section 3.3.1). In parallel to these smaller initiatives a larger state-supported project called E-Energy develops standards; a first outcome of these activities is a standardization roadmap describing the need for new standards (see Section 3.3.7).

[24] http://savannah.nongnu.org/projects/lwip
[25] http://www.ict-nobel.eu/
[26] http://www.ipso-alliance.org/

In the European Union, some important projects work on standards for smart metering and on system interoperability. KEMA[27] works on some advanced metering infrastructure (AMI), WELMEC[28] on metrology and the DLMS Association on communication standards. Another group including Iskraemeco, Itron, and Landis+Gyr developed standard to achieve the goal to integrate and deploy the interoperable device interface specifications (IDIS).

In the rest of the world, some standardisation works are made for example with the American National Institute of Standardisation and Technology (NIST, see Section 3.3.4) or with the OASIS Blue project which regroups enterprises like IBM or Microsoft (see Section 3.3.5). The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) work also on this problematic and publish many standards studies (see Section 3.3.2).

Some projects are described in the following sections. Different parts of smart energy management standardisation problem are considered.

3.3.1. OGEMA

The Open Gateway Energy Management Alliance (OGEMA) provides an open software platform for energy management which links the customer's loads and generators to the control stations of the power supply system and includes a customer display for user-interaction. In this way end customers will be able to automatically observe the future variable price of electricity and shift energy consumption to times when the price is low. All developers and involved parties can turn their ideas for more efficient energy usage by automation into software for the gateway platform.

Activities for developing the OGEMA specifications further are also run in the framework of the SmartHouse/SmartGrid project. The current status of the work is documented on the alliance website[29], and is also appended to this deliverable.

3.3.2. International and European Standardization Organisations: CENELEC and IEC

CENELEC

The mission of CENELEC is to prepare voluntary electro-technical standards that help develop the single European market for electrical and electronic goods and services removing barriers to trade, creating new markets and cutting compliance costs. For doing this, CENELEC strives to satisfy the needs of the European industry and other stakeholders in the market place in the areas of standardization and conformity assessment in the fields of electricity, electronics and associated technologies. CENELEC supports IEC, the International Electrotechnical Commission, in achieving its mission to be globally recognized as the provider of standards and conformity assessment and related services needed to facilitate international trade in the fields of electricity, electronics and associated technologies.

In the area of smart grid, CENELEC is involved in several standardization initiatives. Some of them are mentioned in the following:

- For smart metering CENELEC has developed standards for smart meter functionalities and communications interfaces for use in Europe for the electricity, gas, heat and water sectors together with CEN and ETSI, in the framework of Mandate M/441.
- The technical committee CENELEC TC 205 prepares standards to ensure integration of control applications and the control and management aspects of other applications in and around homes and buildings, including the gateways to different transmission media and public. TC 205 will not prepare device standards but the necessary performance requirements and necessary hardware and software

[27] http://www.kema.com
[28] http://www.welmec.org/
[29] http://www.ogemalliance.org

interfaces. The standards should specify conformity tests. TC 205 will perform the work in close co-operation with relevant CENELEC TCs and those in CEN and ETSI.

- With the support of the European association of manufacturers of household appliances CECED, CENELEC has developed the standard EN 50523 for household appliances interworking (see also Section 3.2.4. It defines a set of functions of household and similar electrical appliances which are connected together and to other devices by a network in the home.

IEC

The International Electrotechnical Commission (IEC[30]) is the leading global organization that prepares and publishes international standards for all electrical, electronic and related technologies. These serve as a basis for national standardization and as references when drafting international tenders and contracts. Through its members, the IEC promotes international cooperation on all questions of electrotechnical standardization and related matters, such as the assessment of conformity to standards, in the fields of electricity, electronics and related technologies. The IEC charter embraces all electrotechnologies including electronics, magnetics and electromagnetics, electroacoustics, multimedia, telecommunication, and energy production and distribution, as well as associated general disciplines such as terminology and symbols, electromagnetic compatibility, measurement and performance, dependability, design and development, safety and the environment.

The IEC has formed the Strategic Group on Smart Grid (SG 3), which advice on ideas and technologies likely to form the basis for new international standards or IEC Technical Committees (TCs) in the area of smart grid technologies. The working group started its work in April 2009 by writing a road map for the development of a framework to achieve interoperability of Smart Grid systems. Since then, it has submitted a 160-page report that covers the 24 technical committees that have published international standards relating to the smart grid and agreed on a basic set of standards covering interoperability, transmission, distribution, metering, connecting consumers and cyber security. SG 3 is working in close collaboration with NIST (see Section 3.3.4). IEC Standards were recognized as being crucial in the development of the NIST roadmap (including at present approximately ten IEC standards) and IEC agreed to actively support NIST in identified and prioritized action fields.

3.3.3. ESMIG

The European Smart Metering Industry Group (ESMIG)[31] is a newly founded initiative which has the objective to deliver the benefits of smart metering by assisting in the development of national and Europe-wide introduction, rollout and management of smart metering systems. The actions of the group will include recommendations with respect to the introduction of smart metering in the EU legislation and the legislation of the EU Member States.

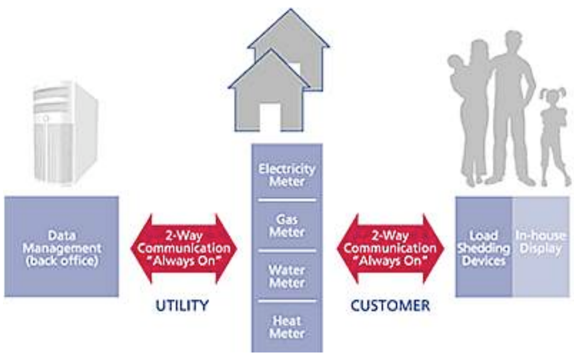

Figure 15: ESMIG scope

30 http://www.iec.ch/

31 http://www.esmig.eu/

3.3.4. U.S. Standardization Approaches: NIST

The mission of the National Institute of Standards and Technology (NIST[32]) is to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology. Based on the mission statement and the scope of projects lead by NIST, the main geographic focus is the U.SA. One of the main roles of NIST is the coordinated tasks for the Energy Independent and Security Act (EISA) and the American Recovery and Reinvestment Act (ARRA). Among others, NIST has a special program for smart grids. In this program, NIST has the primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems. In this program a lot of interesting information is presented about the specification and realization of smart grids. However, NIST is not acting in the development and publication of standards for smart grids; it uses standards and provides input for new standards.

In January 2010, the National Institute of Standards and Technology (NIST) estimated that the smart grid will ultimately require hundreds of standards, specifications and requirements. As expected, some of these are needed more urgently than the others. Therefore, NIST chose to prioritize focus of its work focus on needs identified by the Federal Energy Regulatory Commission (FERC) in its policy statement. The focus includes eight priority areas, but only following three are prioritized by the SmartHouse/SmartGrid project:

- Demand response and consumer energy efficiency
- Advanced metering infrastructure
- Network communications

For demand response and consumer energy efficiency area, mechanisms and incentives for utilities, industrial and residential customers to manage energy usage is in focus. The importance of usage efficiency occurs during times of demand peaks, or when power reliability is at risk. Therefore, for optimizing the balance of power supply and demand, the demand response signals are necessary.

From perspective of NIST, the area of the advanced metering infrastructure (AMI) is currently focused by utilities trying to implement residential demand response and mechanisms for implementing dynamic pricing. The requirement is to create a two-way network between advanced meters and utility business systems. This would enable the necessary data collection and information distribution infrastructure, allowing customers and other parties to be provided with near real-time pricing, or e.g. to help utilities to achieve necessary load reductions.

The area of communication networks if of key importance for the SmartHouse/SmartGrid project since a typical smart house can be surrounded with variety of possible communication channels. Thus, inside the smart grid domains and subdomains (public and private communication networks), the network communication is supposed to be carried out with, both, wired and wireless channels. Given this variety of networking environments, the identification of performance metrics and core operational requirements of different applications, actors and domains (in addition to the development, implementation, maintenance and access controls) is critical to the smart grid.

In following document sections some of these standards will be reviewed with greater details, because of their project relevance. However, some proposed standards (by NIST) could be of importance for future of the smart grid, e.g., one open (and mostly mature) standard that fits SmartHouse/SmartGrid project is ANSI C12.20. This standard specifies metering accuracy, but this is out of scope of this document. Thus, we encourage reader to review [NIST 2010] document.

[32] http://www.nist.gov/

3.3.5. OASIS Blue Initiative

The Organization for Advancement of Structured Information Standards (OASIS) is a non-profit consortium that has been developing open standards for e-business and web services since 1993. Today, it is currently developing over 20 open standards that vary from OpenDocument, a standard for office documents to UDDI, a platform independent web service registry. The OASIS Blue initiative signals OASIS' intent to align their standardization technologies and effort with smart energy. This is intended to be done by leveraging their experience acquired in developing interoperability standards in e-commerce against the requirements of this emerging field. OASIS is divided into several technical comities (TC), each of which attempt to develop and promote standards for a particular area. Of particular interest, are the oBIX, and OASIS Energy Interoperation TCs.

oBIX

Open Building Information Exchange (oBIX) focuses on the interface between the mechanical and electrical control systems and enterprise systems. oBIX aims to offer a public web services interface specification that can be used to acquire data from building management systems, HVAC systems, etc., as such, supporting a vendor neutral method for enterprise connectivity.

OASIS Energy Interoperation

The OASIS Energy Interoperation TC focuses on the interaction between Smart Grids and their end nodes, for instance, smart building, industry, and more importantly homes. Furthermore, it aims to develop communication protocols to exchange important information such as dynamic price signals, reliability signal, emergency signals, market participation information (e.g. bids) and load predictability and generation information. Thus facilitate many of the envisioned enterprise level services such as emergency response, energy management and trading.

3.3.6. OpenADR

Open Automated Demand Response Communication Standard (OpenADR or Open Auto-DR), began in 2002 following the California electricity crisis, and is an open standards-based communications data model designed to facilitate the sending and receiving of DR signals. It provides a suite of functions and capabilities used for automated exchange of DR information between utilities or network operators and their participants.

The standard defines an interface and functions of a Demand Response Automation Server (DRAS) used to facilitate the automation of customer response. The DRAS is an infrastructure component in Automated Demand Response Programs that facilitates the communications among entities. This is valid for entities (e.g. utilities, grid operators) that produce and distribute electricity and managing entities (e.g. facilities and aggregators) of electricity consumption.

The purpose of the DRAS is to automate the various communications channels necessary for Automated Demand Response programs and dynamic pricing. Such communications include varied price and reliability related messages and information that are sent from utilities / grid operators to the various parties that manage the consumption of electricity in order to curtail the consumption of electricity during peak periods.

The idea behind using such standard origins from large corporations with wide spread geographical operations across multiple electrical jurisdictions and thus must deal with multiple utilities. Likewise, utilities / grid operators must perform systems integration and test each of participants in the DR program. Thus, there is an obvious relation with SmartHouse/SmartGrid project.

Figure 16 shows the architecture of the components and systems used together with the DRAS interface to manage automated DR events. The Figure shows the architecture used to automate the submissions of bids by participants in a DR program.

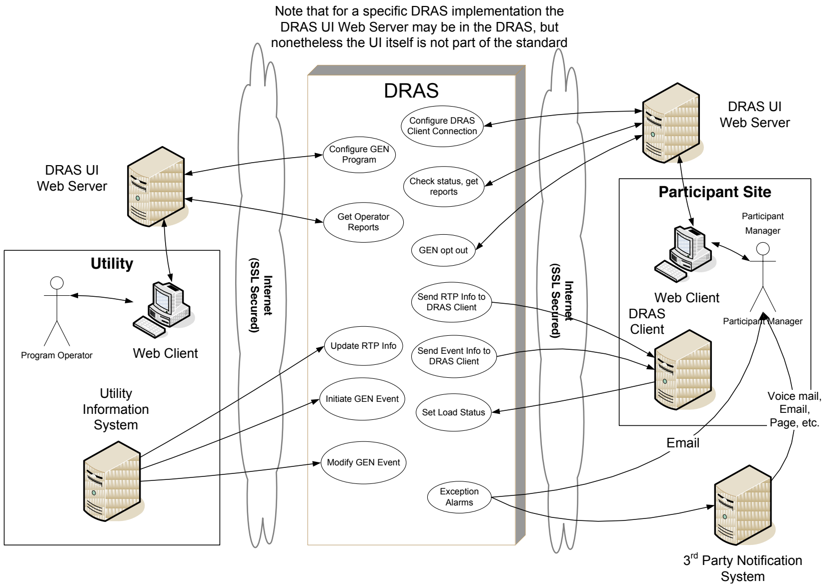

Figure 16: OpenADR general automated events architecture

The intention of the data model is to interact with building and industrial control systems that are pre-programmed to take action based on a DR signal, enabling a demand response event to be fully automated, with no manual intervention. First OpenADR compliant platform is designed by Tendril known as Tendril Residential Energy Ecosystem (TREE).

3.3.7. German Standardization Roadmap E-Energy

Within the framework of the nationally co-funded research scheme E-Energy[33] which comprises six model regions in which different approaches of future smart grid concepts and demand side management are tested in the field, a standardization roadmap has been created [DKE 2010]. The aim of this roadmap is to draft a strategic but also technically orientated roadmap which represents the standardization requirements for the German vision of the smart grid, taking especial account of the E-Energy research projects. It provides an overview of standards in that context, and of current activities, necessary fields of action, international cooperation and strategic recommendations.

The roadmap is intended as a targeted strategic plan of German activities in the context of European and global developments. It focuses on standardization aspects in the fields of power system management, electricity storage, distributed generation, safety and security, automation technology, smart meters and home automation. It describes the core standards of a future electrical power supply system, states their importance and areas of application, and presents the resulting opportunities, challenges and effects. The standardization roadmap will be regularly revised and developed on the basis of new findings.

3.3.8. Open Meter Communication (MUC)

Open Metering Communication (MUC: Multi-Utility-Communication)[34] is a group of manufacturers who provide products for the smart metering domain in Germany. The aim of the group is to develop an open architecture and to define the functions and interfaces of the single components, based on existing open standards. The most important focus in this project concerns the whole measurement process (including data capture, data transmission and data processing) of Electricity consumption. The system should also be able to perform Gas, Water or Heath consumption measurement.

[33] http://www.e-energy.de/

[34] http://www.m-u-c.org/aims.htm, http://www.vde.de/de/fnn/arbeitsgebiete/messwesen/documents/FNN_LH-MUC_1-0_2009-08-05.pdf

The MUC platform is developed regarding to the application, the system components and the interfaces. A MUC – Controller is inserted between the meter and the rest of the system. This interface enables this system to be compatible with all the different meters. The platform is independent from the meter type and the meter manufacturer. Thank to this architecture, the measurement tool is decoupled from the rest of the information system. An important interoperability level is also guaranteed.

All the participants of the measurement process are studied (from the end customer to all network actors like supplier, TOS, DOS, or others). A communication system between there has been designed. It is based on the SML (Smart Message Language). Thank to this language, the developed system is compatible with the largest number of communication technologies that currently exist.

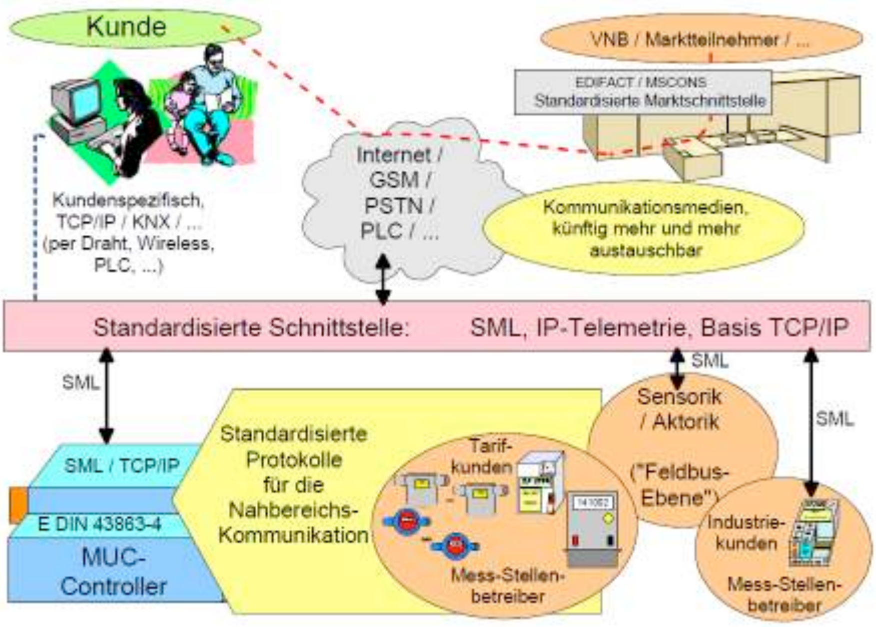

Figure 17: MUC Scope

The MUC Project wants to create the information system that will be the basis for the future customer and companies services. One of the aims of this project is to be able to provide as well for the end consumer as for the supplier the measurement to every type of communicative system (from a PC to every imaginable appliance). This whole project is in strong relationship with other standardisation work and standardisation authorities. He namely use an important number of existing normalisation standards from different authorities like DIN (German Standardisation Institute), ISO, IEC and EN.

3.3.9. DLMS User Association

Demand side management needs universal definitions and communication standards. DLMS/COSEM is the common language enabling the partners to understand each other.

Device Language Message specification (DLMS) is a generalised concept for abstract modelling of communication entities. COmpanion Specification for Energy Metering (COSEM) sets the rules, based on existing standards, for data exchange with energy meters.

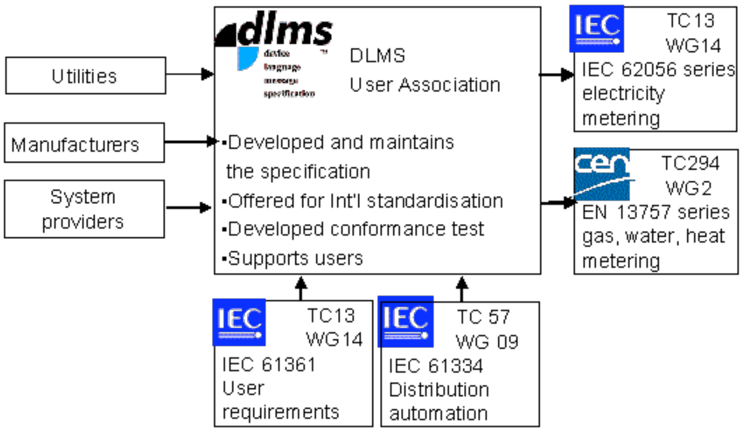

Figure 18: DLMS/COSEM scope[35]

DLMS/COSEM is composed of:

- An object model of the meter, which provides a universal interface for accessing metering information.
- An identification system of all meter data.
- A messaging method for communicating with the model and encoding data.
- A transportation method for carrying the information between the meters and the data collection system.

3.3.10. Web2Energy

Web2Energy is a research project in the 7th framework program of the EU with the call "ENERGY.2009.7.3.5 – Novel ICT solutions for smart electricity distribution networks". The project is directed to implement and approve all three pillars of "Smart Distribution":

1. Smart Metering – the consumer participates in the energy market

2. Smart Energy Management – clustering of small power producers

3. Smart Distribution Automation – higher reliability of supply

Smart Grids require the linking of its clients. Consequently, an advanced information and communication infrastructure shall be established using advanced, established and prospective international standards. The data models and services of the advanced standard series IEC 61850 for substation communication are used. Web2Energy supports in this way the ongoing work in the IEC bodies for extension, adaptation and improvement of the standards series regarding their application for smart grids solutions. The standard series will be extended for the application of various physical channels as well. In the data bases of all smart grids clients common information models (CIM) in accordance with IEC 61968 will be applied. With that data files can be exchanged without problems between the different users, between the network operator and the trader for example. The Web2Energy project will tackle these tasks head-on, by developing, building, field-demonstrating, and operationally deploying an open ICT communication system.

3.4. Security in Smart House Communication

Opening up a closed infrastructure as that of energy networks and taking into account the associated business background cannot be done without well-tested security and trust models in place. Furthermore, if in the longer term the smart meter evolves to a gateway for household devices, the implications are far reaching, since it is expected that any device will have its own IP address and it will be possible not only to turn it on/off, but also to constantly monitor its behaviour. It is clear that several aspects have to be taken care of in order to provide a secure basis for all the implicated actors. In such a heterogeneous infrastructure

[35] Source: DLMS

as the envisioned future energy one, the author of services to be deployed in the smart meters, the entity that deploys a service, the owner of the smart meter, and the owner of the data may be different entities governed by different interest. A comprehensive threat model needs to be defined. Some aspects of this analysis are discussed in more detail in the following subsections.

3.4.1. Precision of the Metering Data

First of all, the precision of the metering need to be as high as possible. This precision includes the quantity of kWh consumed as well as the time of the measurement. Both pieces of information are needed both by the end costumer and by the electricity supplier or other actors like the DSO and the TSO. They will represent a great part of the transmitted data. Both acquisition and transmission will contribute to the quality and the precision of the metering data.

For the end consumer, the metering precision is necessary for two principal reasons. The first concerns the billing. If the measurements are not precise, the bill based on those data would not be correct. Second, metering inexactness will also give to the consumer a false idea of his electricity and energy behaviour. This is particularly true in the case of measured data under the real consumption. Besides, errors of measurements in households or in network installations (e.g. transformers or concentrators) will have a consequence on the consumption forecasts and on the generation-consumption equilibrium that is needed for avoiding network problems and instability.

It can be assumed that new smart meters offer sufficient security against electricity burglary. They are all protected against installation modifications that can conduct to such situation. So they will contribute to create a more efficient measuring infrastructure.

3.4.2. Transmission of the Data

All the data collected in the different households and industry need to be transfer to the different actors in a fully secured transmission way. Projects like SELMA (see also Section 2.1.5) have already tackled parts of this threat, as it has developed a security architecture that authenticates the measurement data, provides access security and certified software. However, since the smart meter is able to host execution environments, and external entities can deploy services on it, the security model needs to be further elaborated.

The four points for a good, safe and quality network transmission need to be observed. The authentication on both sides shall have very strong requirements. Both hardware and software authentication technologies have to been considered when creating this part of the algorithm. The confidentiality of all data must be warrant with technologies like SSL or other encryption process. In addition, care needs to be taken of data integrity and none repudiation. Issues like masquerading, denial of service, unauthorized access need to be successfully tackled. The security of the SmartHouse/SmartGrid system must be at the same level as internet banking. The data which are transferred and processed have in both domains the same criticality.

3.4.3. Security and Quality of the Equipment

Technologies used to tackle issues raised above are expected to be state-of-the-art and not specifically tailored (at least not at their basic level) for the SmartHouse/SmartGrid context. Besides, many of the concepts under consideration in the project such as DPWS, OPC-UA etc. deal partially with the security issues and provide the basic building blocks. With these different technologies, the different equipments which would be developed should be durable. For example the central meter and the gateway should have an operating period comparable with the today apparatus (20 years or more). On the software side, a remotely update an easily restart capability can help to develop such equipment.

SmartHouse/SmartGrid concepts involve new communication flows both within the house and towards the grid and the enterprise. Different telecommunication technologies are used in the smart devices to allow the data exchange. One prominent option for this is PLC (see also Sections 3.1.4 and 3.1.5). One problem with this technology is that the wires haven't been designed for such a use. Some studies fear that this high frequency signal in none screened line will produce too much radiation. With PLC, the unscreened current lines have the same behaviour as an antenna.

Other technologies like Wi-Fi or GSM are also used within smart meters. A lot a study on the danger of such radio frequency emission on the human body have been published, but no clear conclusion have could be made, no precise radiation exposition limit has been fixed. For avoiding as much as possible the risks of the SmartHouse/SmartGrid components, and in application of the precaution principle, the emissions need to be reduced as much as possible, as well in intensity as in duration.

3.4.4. Security of Supply and Accessibility

With SmartHouse/SmartGrid systems, new hardware and software will be introduced into the network to perform remote control and to manage the entire infrastructure. All the side effects of these new installations need to be studied. All processes that will manage the smarter electricity grid in the next years have to provide the same or a higher availability of electricity for all customers (from the smallest household to the largest industrial site) as today. The communication system, which will be at the heart of the networks, should be dimensioned and developed to achieve this goal. There must be the same exigency for the inner network of households. Nobody should have problem for using an electrical appliance (remotely managed or not) because of inner system communication problems.

The SmartHouse/SmartGrid system needs to be accessible to the largest part of the households. Neither the price nor the complexity of use of the system should prevent energy consumers to be able to use the new technologies and contribute to the energy efficiency gains thus created. The communication interfaces with the customer should be ergonomic, so that persons of all ages are able to manage their electricity consumption and to set up some scheduling rules for specific electrical appliances.

3.5. Privacy in Smart House Communication

Since now via the smart meter private information goes beyond simple energy consumption profiling, as their correlation can reveal indication of money flow (amounts of energy produced/bought/sold), personal habits (monitoring of energy consumption per device, possibly at very fine-grained time intervals) and other private context data, it has to be assured that there is no misuse or unwanted exploitation of this information. On the other hand, the end-user will be able to enjoy a variety of sophisticated services and with the right tools be in full control of the personal info s/he shares with other parties, something that is not at high degree possible in practice today (but is implied by the legal framework and the contracts between the parties). Furthermore, the interactions at global level will have to be investigated, and security and trust must be tackled at technology and business model level [Karnouskos et al. 2007].

If all the home appliances are connected to a gateway and have their own IP address, retrieval of the customers' habits can become even easier. This information need to be protected for avoiding creating new business by selling those private data to other economical sector like the insurance one or for the marketing, advertising companies. EPIC (Electronic Privacy Information Center) has created a list of potential privacy consequences of smart grid systems:[36]

- Identity theft
- Determine personal behaviour patterns
- Determine specific appliances used
- Perform real-time surveillance
- Reveal activities through residual data

[36] http://epic.org/privacy/smartgrid/smartgrid.html, accessed on 15.07.2010

- Targeted home invasions (latch key children, elderly, etc.)
- Provide accidental invasions
- Activity censorship
- Decisions and actions based upon inaccurate data
- Profiling
- Unwanted publicity and embarrassment
- Tracking behaviour of renters / leasers
- Behaviour tracking (possible combination with personal behaviour patterns)
- Public aggregated searches revealing individual behaviour

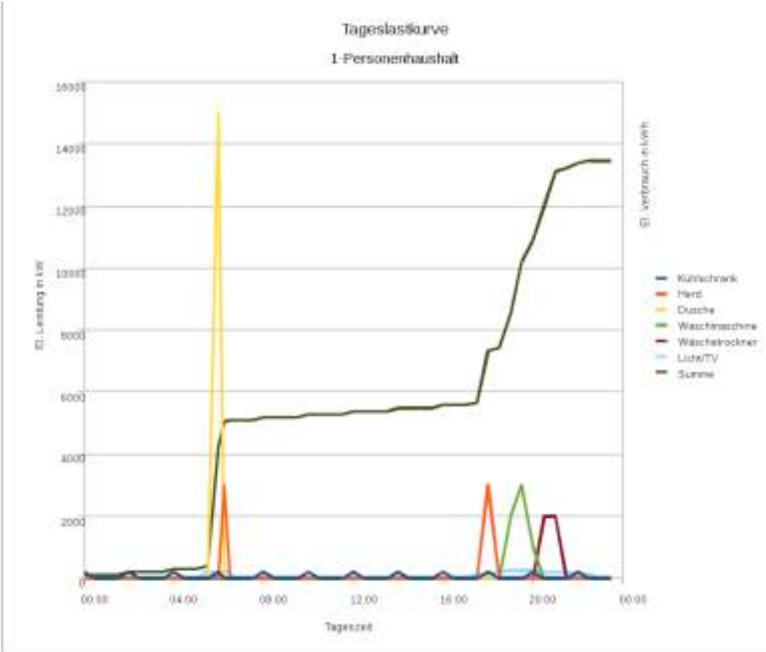

Figure 19: Example energy usage pattern of a household

Protecting the privacy of all the future user of SmartHouse/SmartGrid will be one of the major points for a fast deployment. For the adoption of new technologies, the privacy problem is one of the most important breaks for a massive adoption. The system which will be installed in residential environments requires privacy measures so that the technologies can be accepted by the occupants. This is due to the very private nature of the home and the invasive nature of SmartHouse/SmartGrid technology.

One solution to avoid the temptation of some actor to survey private behaviour with available data is aggregation. The TSO, DSO or the electricity supplier each has different data needs and it is not necessary to send them all the details. For example, the DSO does not need the precise consumption auf each household connected to the same LV transformer – an aggregation of all them per LV transformer would be sufficient for his purposes. Data aggregations provide a better privacy protection of all user of the SmartHouse/SmartGrid system without compromising process performance.

Besides distributing data on a "need-to-know" basis, customers need to be clearly informed about all usages that are made with the collected data. This information should be presented in an easily comprehensive way for all the citizens, so that full transparency on who owns what data is guaranteed.

4. Architectures for Decentralization of Energy Management and Control

The vision of SmartHouse/SmartGrid is to develop concepts and processes for a more intelligent and efficient operation of the electricity system, deploying smart concepts on a large scale. The envisioned order of magnitude of the system size is one million of participating houses, which can each comprise several controllable appliances or distributed power generation units. All system components taken together will produce an enormous amount of data. This data is only of use if it is processed in an intelligent and meaningful way, delivering valuable information to the customer and to operating parties. Models of how data is transmitted and processed thus have to be highly scalable.

Most investigations related to industrial communication focus on a data transport centric protocol specification and communication behaviour. Centralized PLC architectures with over-sampling or proxy technology are the frequently used applications. SmartHouse/SmartGrid will also investigate decentralized control architectures. The impact of the communication channel to the distributed automatic control algorithms become an important topic.

The relatively new research and application field, called Network Controlled Systems, is dealing with

- communication channels models,
- signal quantification during the emission/reception of data packets,
- compression/decompression of the information forwarded by the network,
- queue length management on the router site in order to guarantee the stability or performances of the system considered when the network is congested,
- stabilization of the systems in the presence of delay,
- bandwidth limitation (dependent on the occupancy level of the network) and resources allocation.

There might be need for a multi-field approach integrating

- the control theory of dynamic systems in the presence of delays or data losses,
- the information theory when the data is encoded or compressed and
- the need for taking into account models or estimations of the network behaviour in the control architecture.

In the following, architectural options for SmartHouse/SmartGrid systems are reviewed in the view of the requirement of high scalability. A focus is placed on Multi-Agent Systems (MAS, Section 4.1), Device to Business Integration (Section 4.2) and Service-Oriented Architectures (SOA, Section 4.3), as the SmartHouse/SmartGrid project partners already gained experience with these concepts, and insights from previous work will be considered within this current project.

4.1. Multi-Agent Systems

In the past, multi-agent systems have found application in several settings, without reaching widespread adoption, however. At present, their usage is mostly limited to simulations. Nevertheless, the agent technology introduces functionalities that support efficiently the distributed system needs, such as modularity, decentralisation, and dynamic and complex structures characteristics.

The concepts of service-oriented architectures typically provide dynamic discovery and invocation of processes in a loosely coupled manner, facilitating the reorganisation of distributed systems. Therefore, a strong conceptual and complementary synergy between the SOA and the agent-based approaches is seen.

Applying SOA to agent-based control systems, it is expected to contribute to the creation of an open, flexible and agile environment, by extending the scope of the collaborative architecture approach through the application of a unique communications infrastructure. Moreover, one of the reasons why agent-based systems have failed or became more or less technological islands in the past is that they were implemented with communication technologies that obstructed reconfiguration, counteracting the desired autonomy principle.

4.1.1. Agent Definition

There are several definitions in the literature for what an agent is [e.g. Russell/ Norvig 1995, Maes 1995, Foner 1997, Hayes-Roth 1995, Wooldridge/Weiss 1999, Franklin/Graesser 1996, McArthur et al. 2007a,b]. The definitions described in the references have differences, however there are some common concepts: agent, environment, autonomy. According to Wooldridge, an agent is merely "a software (or hardware) entity that is situated in some environment and is able to autonomously react to changes in that environment." The agent can be a physical entity that acts in the environment or a virtual one, i.e. with no physical existence. In our case the physical entity is the agent that acts directly in the power grid and a virtual one is a piece of software that makes bids to the energy market or stores data in a database. Note that a virtual agent can have a physical counterpart that implements control decisions in the power grid

Therefore the environment is simply everything external to the agent. In order to be situated in an environment, at least part of the environment must be observable to, or alterable by, the agent. The environment may be physical (e.g., the power system), and therefore observable through sensors, or it may be the computing environment (e.g., data sources, computing resources, and other agents), observable through system calls, program invocation, and messaging. An agent may alter the environment by taking some action: either physically (such as closing a normally-open point to reconfigure a network), or otherwise (e.g., storing diagnostic information in a database for others to access).

4.1.2. Multi Agent Systems Definition

A multi-agent system is simply a system comprising two or more agents or intelligent agents. It is important to recognize that there is no overall system goal, simply the local goals of each separate agent. However, an agent can represent the system and join a MAS, striving for a system goal, such as a broker agent in a trading system. The system designer's intentions for the system can only be realized by including multiple intelligent agents, with local goals corresponding to subparts of that intention.

Depending on the definition of agency adhered to, agents in a multi-agent system may or may not have the ability to communicate directly with each other. However, under Wooldridge's definitions, intelligent agents must have social ability and therefore must be capable of communication with each other. In SmartHouse/SmartGrid contexts, communication should be supported.

4.1.3. Multi-Agent System Architectures - FIPA

An example of a set of standards for an open architecture is that defined by the Foundation for Intelligent Physical Agents (FIPA)[37]. The FIPA Agent Management Reference Model covers the "framework within which FIPA agents exist," defining standards for creation, registration, location, communication, migration and retirement of agents. Under the FIPA model, an agent resides on a particular agent platform which provides some sort of message transport system to allow the agents to communicate. One requirement of an open agent architecture is that the platform places no restrictions on the creation and messaging of agents, while a second is that some mechanism must be available for locating particular agents or agents offering particular services within the platform. FIPA offers standards for the use of certain message transport protocols such as HTTP and IIOP.

Each agent platform includes two utility agents: the agent management service agent, which is compulsory, and the directory facilitator agent, which is optional. The agent management service acts as white pages, maintaining a directory of agents registered with the MAS platform. The directory facilitator acts as yellow

[37] http://www.fipa.org/

pages, maintaining a directory of agents and the services they can offer to other agents. An agent can use the directory facilitator to search for other agents that can provide services to aid it in fulfilling its own particular goals.

Many early multi-agent systems had closed architectures where the specific interactions were effectively "hard wired" at design time. The FIPA Agent Management Reference model, on the other hand, provides an open architecture, i.e., an architecture to which agents can easily be added and removed. In many power engineering applications, this extensibility is one of the key benefits of the use of agents.

4.1.4. Agents in Power Systems

In the Smart Grid, the electricity infrastructure will be interlinked with an ICT infrastructure in order to control flexible power flows for secure and reliable power delivery. Typically, the Smart Grid will contain secure two-way communication between actors, components and nodes in the electricity grid. Sensors and actuators will provide information and use this information to implement intelligent control decisions at arbitrary places in the grid. This leads to a so-called distributed control as an enhancement to current top-down SCADA control systems.

Figure 20: Definition and characteristics of intelligent agents

In distributed control, data and information flows can be kept as locally confined as possible, establishing autonomy of processes at the local level. This autonomous behaviour typically is one of the strengths of multi-agent systems. Previous EU projects have identified agent-based technology as an essential building block for enablement of the Smart Grid [EU 2005]. Also outside Europe, agents are subject of research in smart power systems. A thorough overview of the potential value of multi-agent systems in power applications, including a comprehensive review of applications is given in McArthur [2007]. Most of the below mentioned initiatives are aimed at actually applying the multi-agent concepts in practice, dragging them out of their theoretical ivory tower.

Crisp/PowerMatcher: Results from the European project CRISP [Kamphuis 2004; Kok 2005; Akkermans 2004] show how agents, using algorithms based on micro-economic theory, and that are implemented using mainstream ICT, can be applied to coordinate large numbers of distributed generators and consumers. This approach has been worked out in the PowerMatcher concept[38], and has been tested since in a number of experimental field tests [Warmer 2006 and 2007; The Fenix Northern Demonstration[39]].

Crisp/Cell concept: Also in the CRISP project multi-agent control has been introduced to manage so-called grid cells containing electrical components including conductors, distributed generation and loads in one or

[38] http://www.powermatcher.net/

[39] http://www.fenix-project.org/

several distribution network feeders. One of the tasks that has been assigned to the Smart Grid Automation Device (or SGAD) agents is fault management and grid reconfiguration, thereby creating a flexible distribution network, in which reconfiguration can be automated based on real-time grid status and power needs [Schaeffer 2006].

BEMI/DINAR: Developed within the German project DINAR the Bidirectional Energy Management Interface (BEMI) is a simple agent situated at the grid connection point of each customer. It represents an intelligent metering cabinet including a load profile meter, a grid surveillance unit, a core computer and a man-machine interface. BEMI optimizes the operation of local devices based on a price signal provided day ahead and on local requirements defined by the user and the local devices [Nestle 2007]. It may also negotiate intraday price adaptations with a central agent, the Pool-BEMI [Ringelstein 2008].

Microgrids: Agents have been identified as operating entities, representing local consuming or producing devices, within microgrids, cooperating and competing for power, keeping in mind other tasks such as producing heat for local environment, controlling local voltage, or providing backup for critical loads.

CSIRO: Australia's national science agency CSIRO has performed a number of field trials in which agents are used to improve energy efficiency. Within constraints for loss of comfort and cost, agents are used to measure and control the local environment by communicating and collaborating with other agents [Platt 2007][40]. They also worked together with a US-based software developer, Infotility, using their *GridAgents* software framework in building an infrastructure in which a gas micro-turbine, photovoltaic arrays, and a wind generator, along with two cool rooms and a zone of a building climate system, are controlled in order to coordinate supply and demand in a microgrid by reacting intelligently to market price signals.

Simulation of SOA device infrastructure: In the future Internet of Things, intelligent embedded devices are expected to not only offer their functionality as a web service, but also to be able to discover and cooperate with other devices and services in a peer-to-peer way. Examples of such devices are the smart meters, as well as household appliances etc. The simulation of such an infrastructure composed of heterogeneous web-service enabled ("SOA ready") devices with the help of a multi-agent system has been proposed [Karnouskos/Tariq 2008].

4.2. Device to Business Integration

One goal of SmartHouse/SmartGrid is to enable the integration of device-level services with enterprise systems. This goal will require the definition of new integration concepts taking into account the emerging requirements of business applications and the explosion of available information from the device level. Of particular interest is the availability of real-time event information, which will be used to specify new enterprise integration approaches for applications such as business activity monitoring, overall equipment effectiveness optimisation, maintenance optimisation, and others.

The next generation of metering and data exchange technologies is known as advanced meter infrastructure technologies. With abilities to support bi-directional flows of information, AMI enables far more responsive sales and service departments and allows customers to make more informed energy-consumption decisions in response to different price signals. All processes and systems involved – both within and beyond company boundaries – can be linked through composite application technologies that consume enterprise services exposed by a process-centric data exchange infrastructure. This, in turn, enables two-way communication between metering systems and enterprise applications so that utilities can build innovative sales and customer service processes.

[40] http://www.csiro.au/science/SmartAgents.html

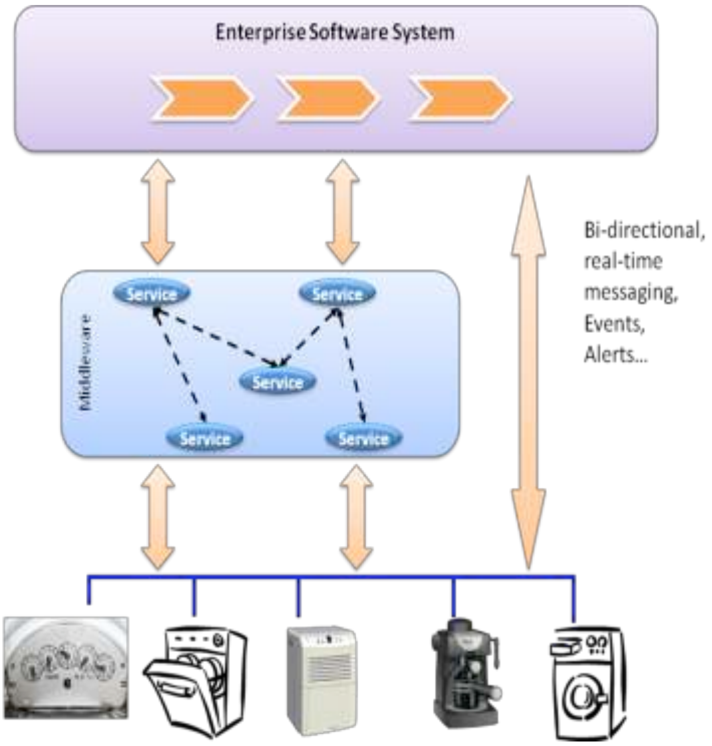

Figure 21: Device to business integration

Figure 22 is portraying a particular communication relationship between the meter infrastructure and the back-end system. The first step in the process involves the collection and consolidation of relevant consumption and meter-reading data from the customers' meters. The meter infrastructure must then transfer this data to a raw database for storage, but not before executing consistency checks and replacement-value procedures for data quality purposes. The information and billing systems can perform these activities – as it might be required when the back-end system of the utility is receiving implausible values from the AMI system, which would prevent a further processing of the data in energy settlement and billing.

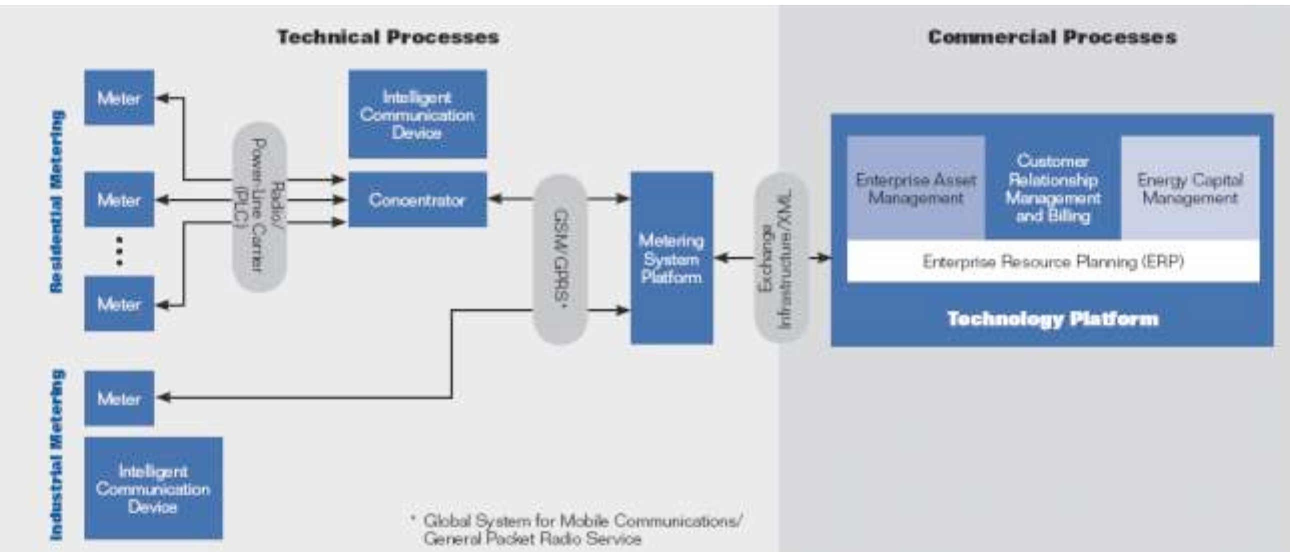

Figure 22: Enterprise to meter integration

4.3. Service-Oriented Architectures

SOA is the basic technology intended to be applied across all layers of the SmartHouse/SmartGrid project. It is comprehensively described covering

- web services,
- relevant standards,
- a framework (based on OASIS), and
- orchestration and choreography

	State-of-the-Art		**Grand Challenges**
Service Foundations	Enterprise Service Bus	• Open standards-based message backbone • Implementation, deployment, management • Set of infrastructure capabilities implemented by middleware technology • Implementation backbone for SOA (applications as services)	• Dynamically (re)configurable run-time architectures • Dynamic connectivity capabilities • Topic and content-based routing capabilities • End-to-end security solutions • Infrastructure support for application integration • Infrastructure support for data integration • Infrastructure support for process integration • Service discovery
Service Composition	Orchestration	• Service interaction at message level • Perspective and control of single endpoint • Executable business process	• Composability analysis operators for replaceability, compatibility, and typing/syntactic, behavioural and semantic conformance • Autonomic composition of services • QoS-aware service composition • Business-driven automated composition
Service Management	• Web Services Distributed Management (WSDM) • Management Using Web Services (MUWS) • Management of Web Services (MOWS)		• Self-configuring services • Self-healing services • Self-optimizing services • Self-protecting services
Service Design and Development (Service Engineering)	• Port existing components using wrappers • Component-based development, object-oriented analysis and design • Do not address key elements: services, composition, components realizing services • Only address part of the requirements		• Design principles for engineering service applications • Associating a services design methodology with standard software development and business process modelling techniques • Flexible gap analysis techniques • Service governance

Table 2: Overview of state-of-the-art and grant challenges in services research[41]

[41] Papazoglou et al. 2006

The service-oriented architecture as driven by the main IT companies need specialization for automation-related architectures. Several approaches are known, such as Universal Plug and Play (UPnP), Devices Profile for Web Services (DPWS), OPC/OPC-UA etc. These technologies are today mostly related to specific application fields.

According to the Web Services Architecture Working Group[42], a service-oriented architecture is a form of distributed systems architecture that is typically characterized by the following properties:[43]

- Logical view: The service is an abstracted, logical view of actual programs, databases, business processes, etc., defined in terms of what it does, typically carrying out a business-level operation.
- Message orientation: The service is formally defined in terms of the messages exchanged between provider agents and requester agents, and not the properties of the agents themselves.
- Description orientation: A service is described by machine-processable metadata.
- Granularity: Services tend to use a small number of operations with relatively large and complex messages.
- Network orientation: Services tend to be oriented towards the use over a network, though this is not an absolute requirement.
- Platform neutral: Messages are sent in a platform-neutral, standardized format delivered through the interfaces.

There are several challenges in services research (depicted in Table 2), and SmartHouse/SmartGrid will touch up on some of them. Furthermore, for the SmartHouse/SmartGrid project several web service related standards will most probably be applicable, and therefore will be considered for further evaluation. These are summarized in Table 3.

Reference	Document Title and URL
XML	Extensible Markup Language (XML) 1.0 (Fourth Edition) http://www.w3.org/TR/2006/REC-xml-20060816/
XMLSchema	XML Schema Part 1: Structures (Second Edition) http://www.w3.org/TR/xmlschema-1/ XML Schema Part 2: Datatypes (Second Edition) http://www.w3.org/TR/xmlschema-2/
SOAP	Simple Object Access Protocol (SOAP) 1.1 (W3C Note) http://www.w3.org/TR/2000/NOTE-SOAP-20000508/
WSDL 1.1	Web Services Description Language (WSDL) 1.1 http://www.w3.org/TR/wsdl
WSDL20	Web Services Description Language (WSDL) Version 2.0 Part 1: Core Language (Candidate Recommendation) http://www.w3.org/TR/2006/CR-wsdl20-20060327 Web Services Description Language (WSDL) Version 2.0 Part 2: Adjuncts (Candidate Recommendation) http://www.w3.org/TR/2006/CR-wsdl20-adjuncts-20060327
UDDI	UDDI Version http://uddi.org/pubs/uddi_v3.htm

Table 3: Standards related to web services

[42] http://www.w3.org/2002/ws/arch/
[43] W3C Working Group Note 11, February 2004

Reference	Document Title and URL
WS_Addr	Web Services Addressing 1.0 – Core http://www.w3.org/TR/2006/REC-ws-addr-core-20060509/ Web Services Addressing 1.0 - SOAP Binding http://www.w3.org/TR/2006/REC-ws-addr-soap-20060509/
WS_Transfer	Web Services Transfer (W3C Member Submission) http://www.w3.org/Submission/WS-Transfer/
WS_Eventing	Web Services Eventing (W3C Member Submission) http://www.w3.org/Submission/WS-Eventing/
WS_Reliability	WS-Reliability 1.1 http://docs.oasis-open.org/wsrm/ws-reliability/v1.1/wsrm-ws_reliability-1.1-spec-os.pdf
WS_Man	Web Services for Management (Draft) http://www.dmtf.org/standards/published_documents/DSP0226.pdf
WS_DM	Web Services Distributed Management: Management Using Web Services (MUWS 1.1) Part 1 http://www.oasis-open.org/apps/org/workgroup/wsdm/download.php/20576/wsdm-muws1-1.1-spec-os-01.pdf Web Services Distributed Management: Management Using Web Services (MUWS 1.1) Part 2 http://www.oasis-open.org/apps/org/workgroup/wsdm/download.php/20575/wsdm-muws2-1.1-spec-os-01.pdf Web Services Distributed Management: Management of Web Services (WSDM-MOWS) 1.1 http://www.oasis-open.org/apps/org/workgroup/wsdm/download.php/20574/wsdm-mows-1.1-spec-os-01.pdf
SOA_RM	OASIS Reference Model for Service Oriented Architecture V 1.0 http://www.oasis-open.org/committees/download.php/19679/soa-rm-cs.pdf
SCA	Service Component Architecture (several draft specifications) http://www.osoa.org/display/Main/Service+Component+Architecture+Specifications
WS_BPEL	Web Services Business Process Execution Language V 2.0 (Draft) http://www.oasis-open.org/committees/download.php/18714/wsbpel-specification-draft-May17.htm
WS_CDL	Web Services Choreography Description Language V 1.0 (Draft) http://www.w3.org/TR/ws-cdl-10/
OSGi	Open Service Gateway Initiative http://www.osgi.org/Specifications/HomePage

Table 3 (continued): Standards related to web services

4.3.1. SOA in SmartHouse/SmartGrid Scenarios

The concept of service-oriented architectures is well suited for integrating a large number of flexible and intelligent devices to one scalable overall system. Services could be delivered directly by smart meters, or by other devices that process information; a house energy management system for example could both use and offer web services. The idea behind a service-oriented approach within the SmartHouse/SmartGrid concept is that data is processed at the place where it is needed, and all devices can subscribe to those services that they actually need. For example, a billing process does not need to have to-the-minute information of energy consumption, nor does it need to know exactly which devices consumed how much electricity. It only needs aggregate data, coupled with the applicable tariff at the time of consumption, which could be provided by an according service. A consumer who wants to compare his consumption pattern with that of similar households would be interested in the distribution of consumption among different appliances, but maybe wouldn't care for the availability of electricity from renewable sources at the times of his consumption. So he could subscribe to a service which offers him exactly this information, without transmitting further data that is not necessary for this information.

In such a scenario, services can be seen as tradable goods, and the service providers can generate income from offering the service to other parties. An energy supplier might be interested in offering value-added services to his customers. He could either offer them free of charge in order to be more attractive than his competitors, or he can sell services, charging a fee for those customers who use them. So the energy supplier is most likely to create new services and implement them. At the same time, the supplier uses many web services for his billing processes, and these services may be offered by third parties such as a metering company.

4.3.2. SOA for In-House Services

Within the premises of the customer, a variety of services should be provided by a flexible structure of behind-the-meter hardware and software. In this case, the local agent itself will be enhanced or even be composed of a set of local services. A different architecture will be required to make such services possible. New services come as a piece of software and need to be installed on existing hardware. It is favourable to allow for hardware independent programming of such services and for an administration framework for the software implementing these services. It is also possible that such services are provided by newly installed electrical devices that are connected via a home automation system that usually does not support TCP/IP directly.

OSGi is a framework that allows for administration and interaction of such services based on Java and is designed also to suit requirements of embedded devices if they offer a Java virtual machine. Nokia announced in 2008 to create a new Nokia Home Control Center, which might become a platform that specifically allows for the handling of in-house related services. They propose a solution based on an open Linux based platform enabling a technology-neutral smart home which can be controlled via a mobile phone. The control centre by Nokia supports Z-Wave and will incorporate further proprietary technologies, so that third parties can develop solutions and services on top of the platform; it acts as a dictionary that translates different technological languages so that they can be presented in a unified user interface.

4.3.3. Web Services and Multi-Agent Systems

Web services provide the technology to support the machine to machine interaction that is needed to build distributed systems. The agent community has recognized the potential of web services to extend this technology in order to support autonomous control as offered by multi-agent systems. As a result, FIPA has installed a working group dealing with the interaction between FIPA compliant agents with W3C compliant web services. The main issue is the discovery and invocation of each other's instances. The working group has published a preliminary paper in which a set of requirements are drawn to enable interoperability between FIPA compliant agents and web services [Greenwood 2007]. The requirements include:

- Discovery: finding the location, communication method and services offered by agents and web services. This requires translations between WSDL web service descriptions and FIPA agent service descriptions.
- Messaging and invocation: the addressing scheme and message formats of agents and web services should be mapped onto each other. This requires translations between the FIPA Agent Communication Language and SOAP messages as are common in web services.
- Interaction protocols: An agent interaction protocol describes a communication pattern as an allowed sequence of messages between agents and the constraints on the content of those messages. Similar interaction models between agents and web services should be developed.

The main purpose of the integration of agents and web services is the provision for agents to access any web service they want to use, and to offer the agent services to any interested parties that are not necessarily agents. Thus, the simple request-response model which often underlies the web service applications can be enhanced by applications that require complex interactions between autonomous entities, the latter typically represented by agents.

In the SmartHouse/SmartGrid environment, the ECN PowerMatcher concept for agent-based coordination of supply and demand is one of the techniques that will be applied. It will need cooperation with other concepts, such as the MAS model developed by ICCS and the BEMI model by ISET. The business cases following from these concepts may be able to use common components or services, e.g. for monitoring and control of devices and smart metering, instead of implementing each their own private components.

5. Necessary Progress Beyond the State-of-the-Art

After having reviewed the various technology trends relevant for SmartHouse/SmartGrid concepts, the gap between the state-of-the-art and the requirements formulated within the deliverable D1.1 can be pointed out. In the following, the research questions that have to be answered to fill the gap and to implement the envisioned SmartHouse/SmartGrid system are formulated.

5.1. Clarify the Economic Value of SmartHouse/SmartGrid Concepts

From the viewpoint of a utility, the avoidance of peak load and the more equally distributed load over time contains an important potential for cost savings. Today, production capacity is mainly dimensioned for the peak demand and therefore associated with a high financial risk and with low capacity utilization for peak power plants. With a bi-directional communication between utilities and the end-user, peak loads can be avoided by offering more flexible tariffs and enabling the customers to run their electrical devices more intelligently during off-peak periods. The economic value of these concepts has to be analyzed and realistically numbered in order to deliver a solid basis for decisions of investments into Smart House or Smart Grid concepts. The research questions to be answered comprise an estimation of the amount of investment and operational costs that can be saved by SmartHouse/SmartGrid concepts; on the other hand, it has to be analyzed how financial incentives for end-users must be designed so that they deploy their devices according to the requirements of the generation and grid side, leaving enough profits for the utilities.

While the benefits that can be gained through smart metering or an advanced metering infrastructure alone, e.g. reducing power theft or increasing the efficiency of business processes such as meter inspections or disconnection and reconnection of devices, have been studied in several analyses [e.g. Darby 2006, U.S. DOE 2006, Houseman 2007], the additional benefit arising from bi-directional communication has not yet been quantified. The impact has to be quantified in terms of monetary benefit, considering its allocation among the various stakeholders.

Besides the technical feasibility of enabling Smart Houses to contribute to delivering ancillary services to the grid, the economic benefit of this possibility is an equally important determinant to the success of SmartHouse/SmartGrid concepts.

The analysis of the economic value and the validity of the business cases described in Deliverable D1.1 will be done in the framework of work package 4 of this project and will be reported in Deliverable D4.2.

5.2. Gather More Realistic Information on Customer Behaviour

It is advisable that any technological solution assisting or commanding end users is not just developed with *design logic* as a starting point, but also with *user logic* in mind [Jelsma 2001]. Design logic is the logic underlying the design of the technological solution. Often, reasoning is mainly driven by the function of the design and is clouded by “professional” views. User logic is the logic that guides the user in its use of a product of design. User logic can vary between different users due to age, gender, lifestyle, etc. and due to different sensitivity to incentives, such as economics, ecology, comfort requirements, reliability. A design process may deliberately or not support or counteract the logic of the technology user. Therefore, in a good design process user influence, either by direct participation or consultation of users, or by representation, is indispensable. In this way, a number of the potential barriers may be thrown down. The European project Changing Behaviour[44] specifically aims at bridging the gap between technological energy changes and practical use.

The SmartHouse/SmartGrid project aims at the residential and small office/home office (SOHO) environment as well as commercial buildings and industrial customers at the LV and MV network. There is a clear distinction between residential / SOHO customers and commercial users. In the following, the focus

[44] http://www.energychange.info/

will be on the first group. In a residential house, the following types of devices give potential for energy efficiency as targeted by SmartHouse/SmartGrid:

- Storage type devices, either by battery (UPS, electric vehicles) or by electricity controlled heat buffering (tap water heating, space heating, cooling and freezing). In order not to loose functionality, the state-of-charge must be maintained within a certain range.
- Shiftable operation devices that can be shifted over time but have a fixed total demand or supply, such as washing and drying processes, or ventilation.
- Reduced operation devices that can change their power usage or supply for some time, such as dimmable lighting or emergency generators.
- A special case are the must run devices, that require operation driven by user needs, such as audio and video appliances or computers. The latter will even be stricter in an office environment than in a residential home.

Market-based control for each of these device types may need a different adaptation level from customers, as can be seen in Table 4.

	Shiftable operation device	**Storage type device**	**Reduced operation device**	**Must run device**
Awareness of management potential	High: peak / off-peak tariffs	Low: unaware of flexibility	Medium	High
Economics	Direct visibility of cost/benefit	Low visibility of cost/benefit	Direct cost driven energy reduction	No interference allowed
Control strategies	Smart user interface required; Automation possible	Automated control required	Smart user interface required; Automation possible	User in control
Barriers	Acceptance	Believe Acceptance Reliability	Acceptance Benefit	Reliability

Table 4: Adaptation of market-based control for different device types

Customer awareness is most visible for shiftable devices, as many customers are already familiar with the ratio of on-peak and off-peak prices. As a result, washing machine operation can be manually shifted towards the night. If more time-varying price schemes are used, the operation of the devices becomes less clear, requiring some kind of automated reaction to price changes. Shifting operation leads to peak reduction and therefore indirect energy efficiency due to more efficient central generation or more efficient use of available renewable sources. Note that instead of economic incentives, also ecological incentives can be used as control signal, motivating direct use of renewable production [Herrmann 2008].

Using the flexibility of storage type devices also leads to peak reduction and therefore to indirect energy efficiency. The potential of this flexibility is far less visible for customers. In their vision, the device is directly coupled to a task (space heating or tap water heating, or charging an electric vehicle). Therefore, control should be taken out of the hands of the customer as much as possible, providing him only with a user interface to define the task of the device. The invisibility of such a controlled process may lead to disbelieve and lack of acceptance. In a field test in the Netherlands, a number of micro-CHPs have been controlled based on varying prices. Parts of the barriers were addressed by measures such as: use of the thermostat as an accepted user interface; and making no concessions to user comfort. The reliability issue was addressed by providing a back-up conventional control in case of failing of market-based control [Warmer 2007].

Reduced operation devices can be directly coupled with peak load reduction. Just like shiftable operation devices, they will require an automated reaction to price changes. However, this may lead to a barrier in acceptance, since not everyone will be pleased when lights are suddenly dimmed or switched off. And emergency generators will only allow operation if the benefits outweigh the marginal cost and environmental issues are not at stake, such as noise.

For the special group of must run devices, reliability of power supply is the main issue. In normal circumstances this poses no problems, but in critical circumstances, in which either supply or capacity shortage exists, these devices will need a high priority for operation compared with other devices. The Smart House can assist in delivering the extra reliability, especially if electrical storage is available.

A number of general issues may need attention, because they also might raise barriers for the introduction of market-based control:

- User feedback of energy consumption has shown its potential in direct energy savings up to 5-15 % in several European case studies. However, the feedback should be clear and unequivocal, and more direct feedback leads to better results.
- Since customers are used to fixed cost per kWh, variable price schemes may have low acceptance, and may only be accepted if the real benefit can be made explicit. One way to overcome this is not to work with variable prices, but with discount schemes for participation in certain programs.
- Market-based control may not directly lead to energy savings at the household level. However, the total energy efficiency in the whole system can become higher, because peak reduction due to demand response allows shutting off less efficient peak generation plants. Market-based control can also enhance the integration of renewable energy sources. This must be made visible to the customer, so that s/he can better understand the efficiency increase and the concrete savings that resulted from his or her reaction to the price signals.
- The acceptance of external control may be low. This may be overcome by new initiatives, such as a shift in focus from energy to energy services, e.g. thermal comfort services instead of gas use / heat delivery.
- Sharing information on kWh use may lead to privacy violation, giving insight on user behaviour: In the Netherlands, privacy is used as an argument against smart metering by consumer organisations, since detailed meter information can give ample knowledge about the life style of the customer.
- New market structures for local trading require new regulation. According to current regulation small users are precluded from participation in the wholesale market. Commercial aggregators may position themselves as intermediates to the market.

These issues will have to be clarified by field trials confronting real customers with real-world smart houses in smart grids and appropriate data collection and evaluation.

Within the scope of SmartHouse/SmartGrid, all the LV and MV customers should be considered. There are different requirements among these consumers which are defined by their needs. The majority would seek economic benefits from the concepts introduced in the project. However a small number of customers considers the quality of power supply as the most critical part and is willing to pay more accordingly. One important parameter is the costs that the SmartHouse/SmartGrid technologies will induce on customers. Assuming that the financial impact will be considerable, it is probable that the target groups should be restricted to the following:

- Large consumptions (MV industrial customers)
- Financially comfortable (high-income) customers
- Young (age-wise) consumers, who are willing to adapt to new technologies
- New housing settlements, probably in tourist areas, in well-developed islands etc.

- Big shopping areas (malls etc.)

An area where the SmartHouse/SmartGrid technologies can have an immediate and much easier acceptance is in government-controlled buildings, especially in areas with high concentration of government activities. In these cases, "convincing" the customers will be much easier, while there are considerable loads that can be monitored and controlled, e.g.:

- Lighting of offices: there are days of the year, or even hours within a day, where outside lighting is adequate. In these cases, smart remote holistic control can be of assistance.
- Air conditioning of buildings: setting of temperatures in central systems can be adjusted taking into account outside temperatures and grid requirements.

At the beginning, the customer that will interact as active market participant will not be an average customer, but rather an economically and technically/ecologically engaged minority. However, the idea is to also reach and include the average customer. The intensity at which such a customer will participate in the market will finally depend – beside any economic benefit – on the complexity of the system and the ease of use/operation. Therefore the customer-system interface should be given attention allowing an interaction of different depth level, including a fully automated mode, allowing a step-by-step learning process and displaying rather fast and easy any benefit.

Among the three field trials, mainly trial B investigates the customer behaviour and acceptance of the deployed technology. A socio-economic complementary study will be carried out in a related project; besides, some insights and lessons learned about the installation and use of the Bi-Directional Energy Management Interface (see Deliverables D2.2 and D3.1 for a detailed description of this technology) will be gathered in the framework of the SmartHouse/SmartGrid project and will be reported in Deliverables D3.3 and D3.4.

5.3. Design a SmartHouse/SmartGrid System that is Practically Applicable on a Large-Scale

It has been outlined how Smart Houses can become decisive elements of Smart Grids in the future. Several challenges have to be solved for this goal, though. A lot of standards are available for different elements already. However, these standards are mostly not interoperable yet, or they lack a commonly accepted semantics definition that can express the specific information required for Smart Houses and Smart Grids. This concerns web services as well as local service frameworks such as OSGi. Also, existing software that has been designed for enabling Smart Grid applications which have been described as business cases in deliverable D1.1 of this project, like the PowerMatcher and the BEMI technology have to be further developed in order to be fully compatible to suitable standards in the areas described before (in-house communication, wide area communication and SOA). This is necessary in order to allow for automated interoperability of the entire system from control stations at grid operators and energy traders as well as electronic market places to the electrical units controlled, such as co-generation systems, cooling and heating systems, electric vehicles, washing machines, but also transformer taps, measurement units and automated relays in the grid.

The development must also aim at reaching tough cost goals of the hardware used in the distribution grid in order to allow for mass application, but also high levels of customer friendliness, robustness towards user behaviour, plug&play installation and efficiency of communication. Transmission of price signals might be required within a few seconds, and existing communication infrastructure should be used for reasons of lower costs.

The current status of discussions within the SmartHouse/SmartGrid project foresees to only consider electricity and the power grid. However, it might be worth to also take into account heat and/or natural gas as two further important energy flows. The motivation for this more holistic approach is that besides the only electricity-supplying utilities, there are also many companies offering multi-commodity services. In Germany for example, there is a traditional structure of municipal utilities that supply not only one "media" such as electricity or water, but also others such as gas and water.

Electricity is a bit different as it cannot be stored and the purchasing of electricity on the market just-in-time is an additional challenge causing costs and bearing economic risks. Therefore, a better balanced or at least better predictable load curve avoiding expensive peak demand is in the aim of the supplier (here decentralised electricity triggered CHP with heat storage are of advantage). Gas and water could better be stored, and the daily load curve and related purchasing prices are of less relevance. However, for the grid, its capacity design and stress respectively maintenance needs, electricity, gas and water show similarities. A grid used in a balanced way can be reduced in sense of peak reserves, and is less stressed causing less repair costs. Finally, for the metering, a multi commodity is looking for similar devices and procedures, both regarding the metering, the customer surface, and in particular the signal processing and signal/information transfer. Therefore, whatever is developed for the electricity market should be enabled to allow other media to be metered and treated with one interface and one or a similar protocol.

From the utility (MVV) point of view, the kinds of products for energy delivery and ancillary services that should be considered within the SmartHouse/SmartGrid project are the following:

- Dynamic tariffs (variable by time, load) by energy supplier and grid operator
- Energy management services for private customers as well as business customers
- Further energy related services (e.g. security checks via smart metering)
- Use of energy data (smart meters, sensors) on the demand side for the intelligent online coordination of "smart house devices"
- Control of power consumption reducing load peaks and offering new energy services, on the side of the network carrier for the optimum control of the flow of electricity, and on the side of decentralized generation for new trading services

Taking into account the structure and the difficulties of the Greek power system, the ancillary services in order of importance are:

- Spinning reserve
- Cold reserve
- Voltage support
- Black start

It is under consideration, which of the above ancillary services can be considered by the SmartHouse/SmartGrid project. The reason is that the quantities are not always compatible, between the country's electric system and the micro-grid of a SmartHouse/SmartGrid. A more "convenient" environment can be found in the isolated systems of the Greek islands.

5.4. Be Aware of Possible Restrictions and Opposition: Threat Analysis

The most sensitive issue with the operation of SmartHouse/SmartGrid is related to confidentiality and privacy policy. There must be restrictions to third parties in accessing personal data of the customers. However, these restrictions may limit certain business options, thus creating opposition. For example, a load forecast service may require accurate knowledge to the behaviour of the consumers. However nowadays citizens are very sensitive in sharing private data and may set restrictions.

Another issue that may create opposition is related to the objective function and the goals of the operation of SmartHouse/SmartGrid. The selection between market participation, provision of ancillary services or support of local needs is not easy taking into account the needs of each party. For example, the end-users may prefer an environmental friendly behaviour despite possible financial losses.

The evaluation of the economical benefits and results of SmartHouse/SmartGrid concept is the only procedure that will indicate the entities that will or will not have positive benefits. The key question is whether the benefits of SmartHouse/SmartGrid concept are sufficient to depreciate the investment for the equipment. In the case in which Smart Grid technology is introduced based on additional legal requirements, additional investment cost may occur that does not lead to the same amount of cost reduction in grid operation in the short term. It is obvious that – directly or indirectly – the additional cost would be shifted to the customers. Therefore, if the concept of SmartHouse/SmartGrid fails to provide sufficient benefits, the end users would have to pay more.

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OGEMA Technology in Brief

How OGEMA works and what it can do for you

The Open Gateway Energy Management Alliance (OGEMA) provides an open software platform for energy management which links the customer's loads and generators to the control stations of the power supply system and includes a customer display for user-interaction. The main technology goal of OGEMA is to allow software applications from various sources to be executed on an embedded computer (the "gateway"). The gateway connects to building automation systems and to communication systems outside the customers' premises in order to enable energy management and energy efficiency. This paper describes the most important concepts and features of OGEMA developed in order to fulfil this goal.

OGEMA uses well-known widely-accepted software standards for its execution environment that are available as open source and as commercial products

To be able to execute software applications from various sources on a single embedded computer a common execution environment has to be defined to which all these applications are deployed. OGEMA uses Java and OSGi as widely accepted software standards that provide a cross-platform execution environment. OSGi enables different applications to be executed in parallel. Like OGEMA also these technologies are available as public standards with open source implementations available for download on the internet, but also several commercial products are on the market.

References:
http://www.sun.com/java/
http://jamvm.sourceforge.net/ and http://www.gnu.org/software/classpath/ (open source java implementation)
http://www.osgi.org/Main/HomePage
http://www.eclipse.org/ (open source development platform)

OGEMA allows connecting to an arbitrary number of different home automation systems in parallel

Each communication system and protocol can be connected to an OGEMA gateway by installing the appropriate software driver. Also the required hardware interfaces have to be installed at the gateway, of course.

OGEMA links the "Smart Grid" and the customer sphere by providing data models for both domains and connecting to different communication technologies relevant for these areas

OGEMA offers data models for "smart grid data" such as variable energy prices, metering data and control signals. But it includes also data models for control and supervision of devices inside the customer's premises. OGEMA connects to home and building automation systems as well as to Wide Area Networks (WAN).

OGEMA allows applications to be developed independently from the communication connection of devices and communication drivers can be developed independently from the application that uses the driver

This feature is why we call OGEMA an "operating system for energy management at the customer side". Both applications and drivers connect to data models that are defined by the OGEMA specification. These data models act as a Hardware Abstraction Layer allowing both applications and drivers to be developed against this common interface definition (see figure 1).

New device types can be added to the framework dynamically by providing appropriate Java classes (see next Section).

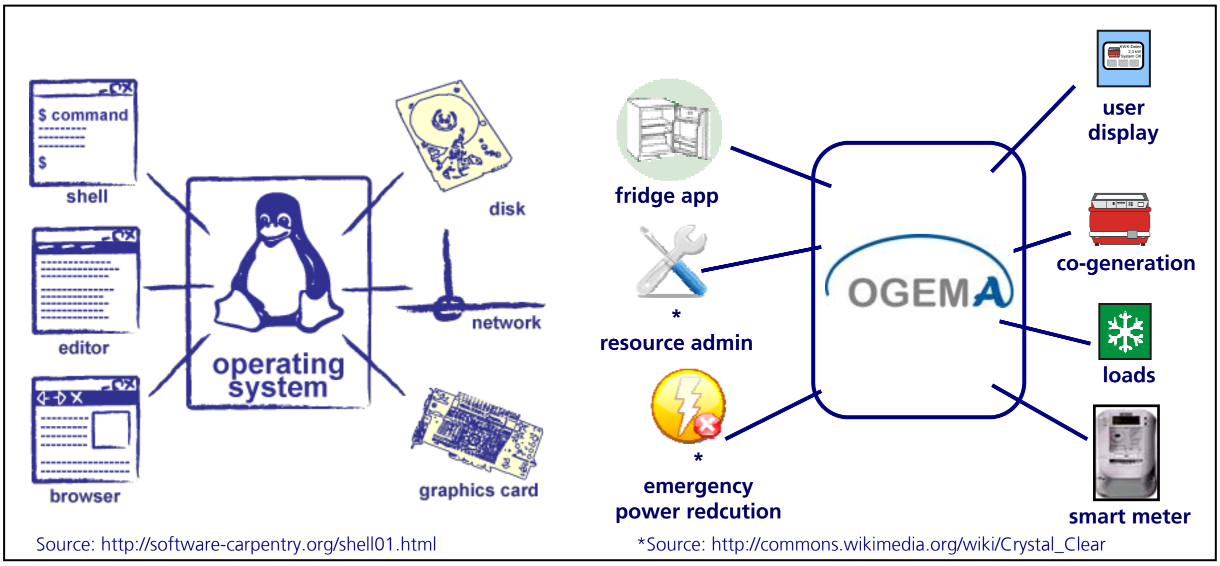

Figure 1: OGEMA links applications on the gateway computer to devices inside the house like an operating system on a PC links applications to the hardware resources of the PC.

Representation of devices and common services by data models

The OGEMA framework provides a fixed number of services needed to register/unregister device types, representations of the devices installed, applications and communication drivers. Also services for the Plug&Play-functionality, for application runtime control, for logging and for getting information on components registered are included into this API. Finally methods for reading and writing device data are part of this API. The framework does NOT provide any methods specific to any device type, though. This has the advantage that new device types can be installed just by adding new data structures to the framework, which can be read and written by the standard framework API. No extension of the framework itself is necessary to add device types. Any additional code required for using / managing a device must be provided as part of an OGEMA application or a communication driver.

Open interface for software applications and hardware/communication drivers

The entire API of the OGEMA framework including interfaces for software applications and communication drivers is made public on the OGEMA web site. Also sample source code for applications and communication drivers is provided as projects for the Eclipse development environment, which is also available as Open Source software. So starting the development of your own applications and software drivers for OGEMA is made as simple and free of cost for you as possible.

Applications and drivers can be any type of open or closed source. The license used by OGEMA allows you to offer commercial applications and drivers without restrictions. If you want to put the OGEMA logo on your product certification is required, though. The cost of the certification will have to be covered by the party requesting the certification, of course.

Plug&Play#1: Interface for hardware/communication drivers allows for various levels of auto-detection and installation of new devices depending on communication system capabilities

Two main steps have to be performed in order to make use of any device newly connected to the gateway: Firstly the device has to be discovered via the communication system by which it is connected to the gateway with its capabilities. Secondly the device discovered has to be assigned to one or several applications making use of the devices capabilities.

The OGEMA interface for communication drivers allows for various communication concepts and levels of auto-detection of devices. Ideally a device is discovered completely automatically. This is not always possible, though. Many communication systems for home automation have data models for various sensors and actors, but not for entire devices like freezers, washing machines etc. So either the user has to tell the system to what kind of device the sensors and actors found belong to (because the user should know, what type of devices has been connected to the gateway) or it is also possible to use applications automatically trying to find out e.g. from sensor values which type of device probably has been connected. OGEMA also allows “semi-autodetection” provided by vendor-specific applications that detect devices from specific manufacturers by proprietary information.

Some communication systems do not have any auto-discovery functionality at all. In this case the installation of devices has to be performed manually. OGEMA also supports such kind of communication drivers and allows for simple configuration via the OGEMA web interface if the driver provides a suitable configuration web page.

Plug&Play#2: The management agent brings together applications and devices available

The OGEMA framework API allows applications to register the types of devices they are able to connect to. As soon as a suitable device is available (either by auto-discovery or by manual installation, see Plug&Play#1) the application is notified and connected to the device. Sensors can be read by several applications in parallel. In contrast each actor and device parameter can only be controlled/written by a single application at a time in order to avoid interfering control actions on a device. In case more than one application registers for write access for the same device connection is granted based on a priority system. So emergency applications can gain control on relevant devices quickly in case they are activated - independently from the applications that perform the control in normal operation.

Plug&Play#3: OGEMA device models use flexible components allowing for communication drivers and applications to address only relevant parts of devices

As described in Plug&Play#1 many communication systems only provide the information which sensors and actors are connected, but not entire device information. In this case such a communication driver can register a suitable sensor or actor data model in order to provide as much information by auto-detection as possible. These component models can than be mapped to the device model they belong to via the OGEMA framework API.

Most applications are not limited to a specific device type but can be used for a number of similar device types. For example an application shifting operation of a device based on a variable electricity price by using a thermal storage can be applied to a fridge, a freezer and (in some cases) even to a heat pump with thermal storage. In the OGEMA framework such applications would not register demand for each such device type separately, but for the OGEMA component “thermal storage”, which is part of the relevant device models. Even if a new device with thermal storage is installed in the system that was not known at the time of the development of the application, it can be controlled by the application via the known data model components.

“Firewall” between public grid and customer grid: access control, data privacy

OGEMA communication drivers are used to connect to devices inside the house as well as for connections going out of the customers’ premises, e.g. connecting to the dispatching and grid control stations of the energy supply system. The interaction of these communication systems (meaning also the interaction between the grid control station and the devices) is determined by the configuration of the gateway computer and by the applications installed. The gateway computer may be limited to a protocol converter with a user web interface or it may perform most of the energy management algorithms. But in both cases the gateway acts as a firewall between the public and the private communication systems allowing only the interaction between the systems as defined by the gateway configuration.

Additionally user confidence and data privacy shall be supported by the possibility to display data usage explanation and data privacy statements for each data connection delivering data outside the customer’s premises and to display these statements in the web interface.

Resource control based on user-specific access rights and permissions

The OGEMA gateway shall allow executing software from various sources. In order to allow for a maximum protection of the system against usage not intended by the user only applications signed by a trusted authority should be installed. Evaluation of applications is simplified by a declaration of Java-permissions needed by the application. Experienced users can even asses applications that are not signed based on the required permission declaration.

The different parties deploying software shall each have an OGEMA user account on the gateway granting specific device access permissions. So the administrator of the gateway can control which devices can be accessed by applications installed by each user.

Applications bring their own web page(s)

The user interface is a decisive element of most applications in the area of energy management and energy efficiency. Also for the gateway functionality user information and interaction is important so that the user is able to see how his private space is connected to a smart grid system.

OGEMA uses standard web technology to implement the user interface. So the user can access the interface by any web-enabled device with an internet browser. Applications bring their own web pages using HTML, Servlets and JSP (Java Server Pages) for dynamic page content. The reference applications also contain samples for building such web pages and for their connection to the application data. The application web page is integrated into a general framework navigation via a separate frame. This allows for a flexible extension of the user interface via standard software/programming technologies.

Applications register their web pages and a desktop icon in their OSGi manifest file. Icon and access to the application pages are integrated into the user web interface navigation by the framework automatically.

OGEMA supports development, deployment and service by logging functionalities

The specification extends the standard OSGi logging functionality and the reference implementation offers persistent storage and filtered view of log messages. The specification also contains interfaces for storing and accessing data logging series and for the configuration of the data logging for any sensor or other data value in the resource models.

OGEMA is designed to run also on embedded devices

It shall be possible to implement the OGEMA specification on an embedded platform with less than 64 MB RAM and power consumption considerably below 5 W. Work to demonstrate this goal is ongoing. OGEMA can also be executed on any larger architecture for which Java is available including PCs running windows or Linux. In order to limit energy consumption for the energy management system this is not recommended for productive systems in private households and small businesses, though.

For further questions please contact:

Dr. David Nestle
Head of Decentralized Energy Management
Tel: +49 (0)561-7294-234
info@ogema-alliance.org
http://www.ogema-alliance.org

Fraunhofer Institut für Windenergie und Energiesystemtechnik IWES
Königstor 59
D-34119 Kassel / Germany
Fax: +49(0)561-7294-200
http://www.iwes.fraunhofer.de/