Chapter 5

Enabling technologies supporting energy related services and products in networked smart homes

Gustavsson, R. - Krejic, M.

5.1 Executive Summary

Among the results of the KEES project we have learned that energy saving is considered as a very interesting opportunity for customers. Furthermore, we have clear indications from the project that the highest potentials for energy savings are in households and at small and medium enterprises. This situation is due to the fact that Karlshamns Energi AB has already installed measures for efficient energy usage at the bigger customers.

However, it is also obvious from our experiences that in order to have a clear business case we have to develop individual offers of services related to energy savings to the customers. Furthermore we have to develop clear value chains for all stakeholders involved. A way to create these business opportunities is to install and integrate a baseline of smart equipment at the premises of the customers.

Emergent technologies connecting people and smart equipment in networks' are thus key components in the creation of smart and energy efficient homes. An other key component is to properly design and implement information systems that support access to smart equipment in a way that is accepted, useful, and trusted by customers and service providers.

This chapter gives a short guideline to emergent technologies and their role. We also illustrate concepts with implemented demonstrators and field tests. We also mention some lesson learned from the field tests. Finally, we address some potential applications by outlining a roadmap to the future.

5.2 Introduction – The networked home

By now there are numerous ideas around *The networked home* or the *Smart home* [NEW], [MTD]. The background is of course the rapid evolution of Internet, or rather *web-based services* such as eBusiness. So far, the web-based services are mainly emanating from the original web-service of document publishing and distribution. The tremendous success and world-wide acceptance of those applications are due to the acceptance and use of the *standards* http for document transport and HTML (now rather XML) for content organization and layout. Further developments of these Internet standards are facilitated by the World Wide Web Consortium (W3C), [W3C]. The strength of standards for fostering new business and new value-added products, thus shown in the web-world, has resulted in similar efforts in new technical areas. We will in this context concentrate on efforts enabling *The networked and smart home.*

Firstly there are standardization efforts concerning extending the web-oriented approach in several directions. One kind of efforts is focusing on including transactions and on connecting companies with customers and other companies in product developments. These efforts can be summarized as technologies supporting *distributed component-oriented transaction based applications*. A key consortium is here Object Management Group (OMG) with over 800 industrial partners world wide. The main effort of OMG is development of the CORBA standards and work on business areas on top of that standard [OMG]. A second strand of efforts is on enabling wireless web access. The main consortium here is Wireless Application Protocol (WAP) Forum, which in cooperation with W3C, develops the WAP protocol (a thin version of http) and the WML, a subset of XML, content language, [WAP].

An other trend of today is efforts to make it possible to integrate smart equipment into the network as seam-less as possible. Present day difficulties to add or take away new equipment to a PC using bundles of cords and installing different drivers will be replaced by equipment communicating by radio or just plugged into the network, e.g., the electric grid. The Bluetooth consortium is, for instance, using radio as a medium for data communication, [Blu]. The JINI effort by SUN is addressing plug-and-play capabilities for smart equipment is adhering to standards such as Bluetooth, [JIN]. The OSG Initiative is focusing on integrating networks supporting different standards [OSG]. An important such standard for interconnecting smart equipment is Echelon's LonWorks, which is almost a de facto industry standard [Ech]. We will address these standards in more depth in Chapter 5.

In order to have flexible business processes we need to treat most of the smart equipment as semi-autonomous communicating entities. We need also the possibilities to bundle and integrate applications or parts thereof (i.e., engineering the business logic) to customize and support customer access. In short, we need to have software architectures supporting integration and use of active semi-autonomous software components, or *agents*. There are thus also several standardization bodies on agent technologies including OMG, see above, and FIPA [FIP].

Needless to say, there is of course several other consortia and developments of standards relevant in smart homes, for instance on the *power line as a communication media,* [Ene] and other broad band technologies.

The bottom line is, however: there is by now a tremendous technology push supported by major industries towards *The networked and smart home*. This fact does not, of course, imply that new services and businesses just happens, see section 5.6.2 on The Djupafors field test. The services and products must be related to customer needs and customer behavior as well as being sound business cases. The last condition might mean that the organizations and companies must change their usual way of doing business. This change might be as difficult as to understand customers needs. As a matter of fact these issues can often not be treated separately. The following picture gives an overview of the role of demonstrators in this context.

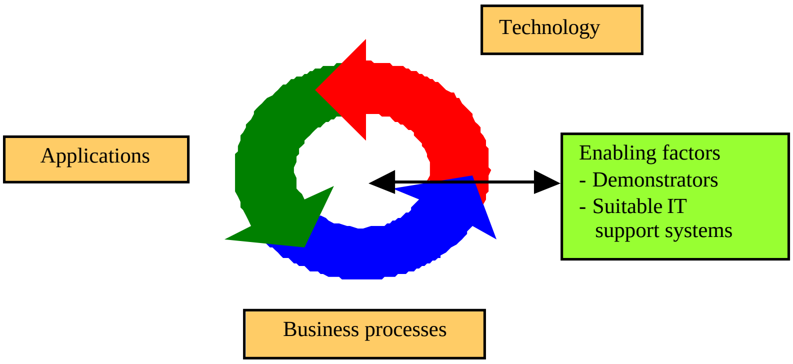

Figure 5:1. The role of demonstrators and software architectures in smart home applications

Given these opportunities to ‘connect people and smart equipment in networks’ it is clear that we have good reasons to believe that it is possible to create a complete new set of services and products. Of particular interest to us are energy-related applications.

We will in the following two chapters take a closer look, with some assessments, of some of the technologies mentioned above. We then report, in chapters 5.5 and 5.6, on work already done in the area of smart homes. In chapters 5.7 we give some plans for the near future as well as some possibilities in a longer perspective.

5.3 What is the problem? – Standards for what?

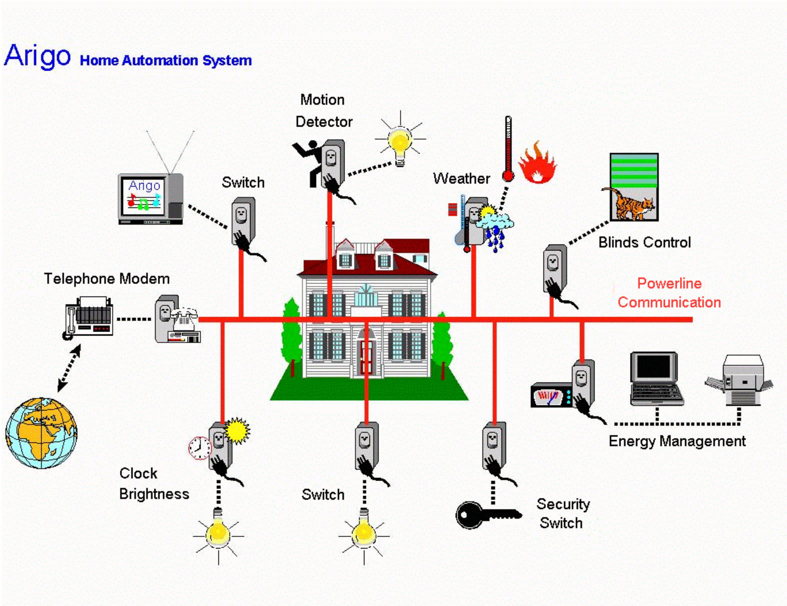

Figure 5:2. Arigo system components connected to the power line.

The following figure is quite standard for describing connected more or less smart equipment. In this case it describes components, sensors and actuators, of the Arigo system [Ene]. Sydkraft AB and IBM AB jointly developed the Arigo system in 1994. The system is LonWorks compatible and has been used in several of our demonstrators in Villa Wega. We will return to Arigo and these demonstrators later in chapters 5.4.5.

Figure 5:2 is a typical in the sense that it shows hardware components connected in some communication media, in this case the power line. The next figure, Figure 5:3, shows the ideas behind Ericsson's E-box [ILV]. This figure is focusing on the fact that we need a network management system, in this case the E-box, to coordinate the messages in the network. The figure also indicates new types of browser based access devices for the end user. The mobile telephone could, for instance, support the WAP protocol. New types of combinations of PC and telephones as well as different hand held devices accessing the web are soon on the market.

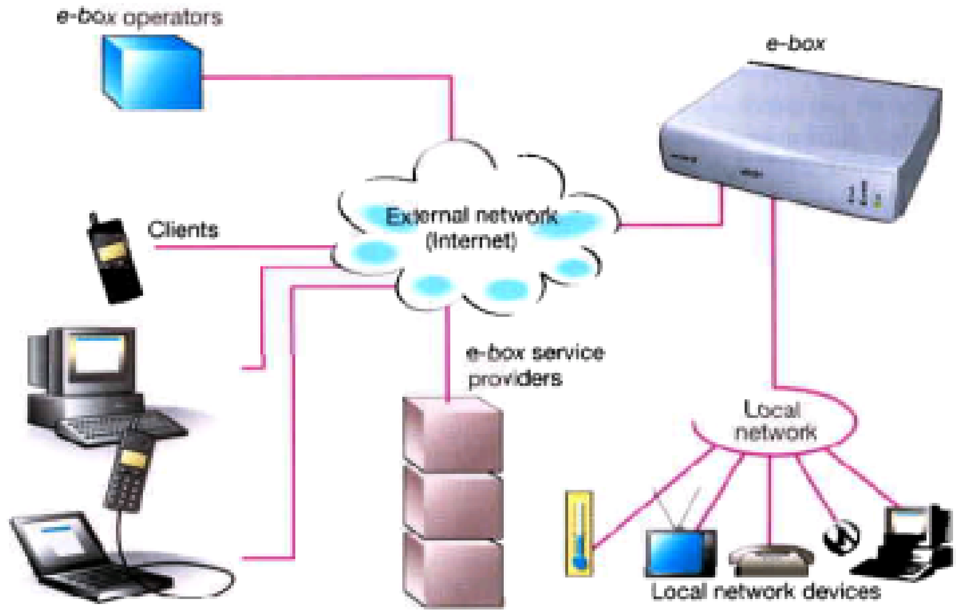

Figure 5:3. The intended role of Ericsson's E-box

Figures, like the two above, are quite common in system descriptions. These pictures show some physical components superficially connected in a communication media giving an overall picture. It is, however, very important to notice that they often play the same role as an architect's first drawings of a new residential area or business center. We all know that these drawings have to be interpreted and tested against the intended purpose and followed by an engineering effort to create and build the actual buildings. We also know that it all will be a failure if people can not use the building and infrastructures to support their living and business.

We will take the construction site metaphor a little further in order to highlight some issues and standards of interest to us. Crucial components for the inhabitants of buildings are the heating, lighting, cooling, and water and sewer systems. We do not install those after the houses have been built or make separate systems (applications) for each flat, use different standards of the plumbing and so on. However, this has been (and is) often the case when it comes to information system. Stand-alone applications, which are difficult to integrate, are more the rule than the exception. A crucial step towards the realization of the networked smart home (building) is therefore to adopt the same attitudes towards information systems as we have earlier adopted towards the other infrastructures mentioned above. As one example, everyone expects that proper electrical installations have been designed and installed during the construction phase of the building. Given that fact we can buy and plug in the electric appliances we need and like. When it comes to *information infrastructures* it is easy to understand the need for *physical* (or media) connectivity (that is local networks or LANs). However the smart equipment does not work unless we also provide means of *logical connectivity* (that is proper *protocols*) as well as easy ways to add and take away, *plug and play*, equipment. Most important is however that we provide proper means for easy access and creation of new services. That is, we must have a robust and flexible software architecture based on *distributed and active components.* These system requirements are not visible in the figures above. The following figures illustrate some of the relevant concepts.

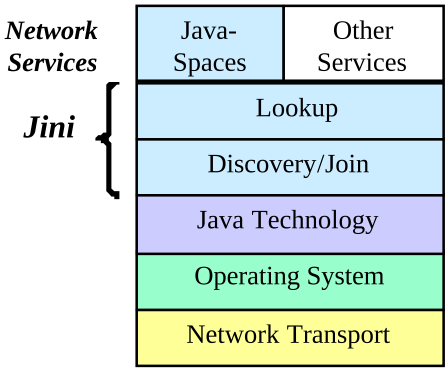

Figure 5:4. Jini infrastructures

Figure 5:4 illustrates the facts that Jini supports different hardware platforms in a transparent way (uses and extends the Java language). Furthermore the services Discovery/Join guarantees plug-and-play capabilities. The network and Jini services gives support for component based distributed computation [JIN]. More details about Jini is given in section 5.4.1.

The next figure, Figure 5:5, illustrates a traditional 3-tier model of information systems extended by agent based support. In order to simplify things, we start from the assumption that at the bottom of the software architecture we have the Jini platform.

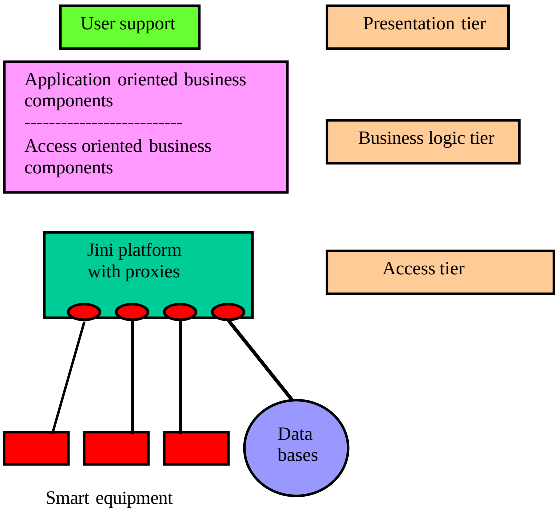

Figure 5:5. A three-tired model of information systems in smart homes

A good design of information systems has minimal coupling between the different tiers in order to ensure robustness and flexibility. Furthermore, by having a service oriented and component based architecture within the tiers it is possible to more easily create new value-added services and customized interfaces (by new combinations of components). The components of the Business logic tier are of course crucial in this respect. In the case of direct manipulation, by hand held devices, of smart equipment we can have an thin

Business logic tier (billing) and very thin presentation tier (display) and access tier (WAP). In the case of several smart equipment it would be preferable to have one hand held device to access equipment and also extend the business logic tier with services such as group addressing, monitoring and so on.

The R&D platform at our laboratory at IPD at HK/R is based on a Jini platform as above. Our main focus is to design and test out agent technologies to support the different tiers of Figure 5:5.

The bottom line of this section is: In order to enable the networked smart home it is necessary to design and implement a information infrastructure that supports the 3-tier model of Figure 5:5. Of course, all components need not be in place from the beginning! The trick is to the design and implementation in a cost efficient and acceptable way, Figure 5:1.

Again there is something to be learned from the construction of buildings. Not long ago it took some efforts to customize an ordinary flat for elderly and people with different types of handicaps. This adaptation was both costly and also sometimes created a “not-a-home” feeling. Sometimes this feeling was so strong that when a new inhabitant, with no handicaps, moved in, the flat has to be restored into its old shape and so on. Now there have been several adjustments into the building norms that flats and houses are designed and built suitable for a much broader range of people. In a sense, from an access point of view, a person can now get older or handicapped and still live in the old apartment with only a few adaptations.

Taking the metaphor to the networked smart house it would be desirable to adopt this way of design and implementation. The information system would allow a young family with children to access services supporting different phases of their lives up to old ages without major changes (upgrading and downloading of application software as well as adding and removing smart equipment is effortless in this scenario) of the basic infrastructure. This is, as a matter of fact, a very important aspect, not least in economical terms, of smart houses in home based health care.

5.4 A closer look at standards and emergent technologies for smart houses

The following two figures give an overview and a context of emerging standards of importance to the networked smart home.

Broad band technologies

- Mobil access
- At the end of 2001, the third generation of mobile phones will allow a bit transfer of 2 Mbit/s.
- Satellite
- There are technologies supporting a transfer rate of 7 Mbit/s.
- ADSL
- The technology supports a bit rate of 8 Mbit/s to the computer and 1 Mbit/s from the computer.
- Power line
- Field tests of transfer rates up to 10Mbit/s are under way in Sweden
- Ethernet LAN
- Ethernet technologies for Local Area Networks (LAN) allows up to 100 Mbit/s
- Cable TV
- Another technology for LANs. A bit rate, at least to the customer, of 10 Mbit/s.
- Radio
- A technology under development (e.g., bluetooth). Very high bit rates are expected.
- VDSL
- A follow up technology of ADSL expected to enter the market during the next decade. Gives a two-way bit rate of 25 Mbit/s via the phone socket.

Figure 5:6. An overview of broadband technologies and their current bit rates

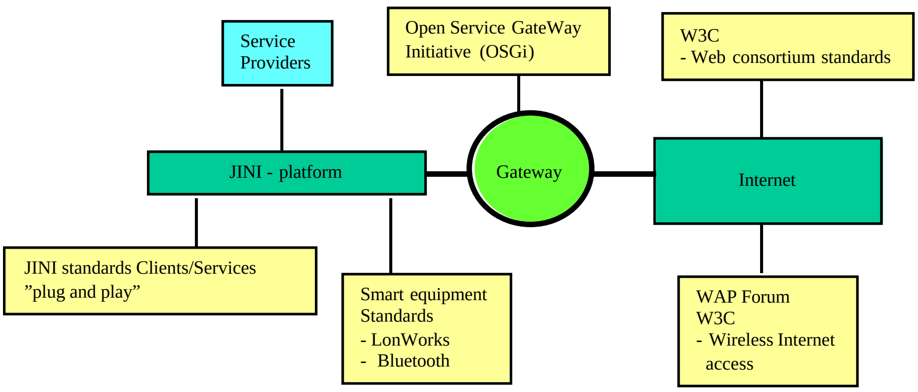

Figure 5:7. The most important standardization efforts and technologies supporting the networked smart house

We will in this chapter look more closely into some of the efforts indicated in Figure 5:7 and their implications on smart home applications.

LonWorks as the preferred technology for smart equipment and Ericsson's E-box as the preferred gateway to the homes. The E-box supports of course LonWorks. It is safe to say that in the future the E-box (or similar products) will comply with the OSGi standardization efforts, section 5.4.2 below.

5.4.1 Jini connection technology

Jini connection technology provides simple mechanisms which enable devices to plug together to form a flexible community – a community put together without any planning, installation, or human intervention. Each device provides services that other devices in the community may use. These devices provide their own interfaces, which ensures reliability and compatibility. Jini technology uses a lookup service with which devices and services register. When a device plugs in it goes through an add-in protocol, called discovery and join-in. The device first locates the lookup service (discovery) and then uploads an object that implements all of its services' interfaces (join). To use a service, a person or a program locates it using the lookup service. The service's object is copied from the lookup service to the requesting device where it will be used. The lookup service acts as an intermediary to connect a client looking for a service with that service. Once the connection is made, the lookup service is not involved in any of the resulting interactions between that client and that service.

It doesn't matter where a service is implemented -- compatibility is ensured because each service provides everything needed to interact with it. There is no central repository of drivers, or anything else for that matter.
The Java programming language is the key to making Jini technology work. Devices in a network employing Jini technology is tied together using Java Remote Method Invocation (RMI). By using the Java programming language, a Jini connection architecture is secure. The discovery and join protocols, as well as the lookup service, depend on the ability to move Java objects, including their code, between Java virtual machines.

Jini technology not only defines a set of protocols for discovery, join, and lookup, but also a leasing and transaction mechanism to provide resilience in a dynamic networked environment. The underlying technology and services architecture is powerful enough to build a fully distributed system on a network of workstations. And the Jini connection infrastructure is small enough that a community of devices enabled by Jini connection software can be built out of the simplest devices. For example, it is entirely feasible to build such a device community out of home entertainment devices or a few cellular telephones with no "computer" in sight.

5.4.2 The Open Services Gateway Initiative

Alcatel, Cable & Wireless, EDF, Enron, Ericsson, IBM, Liberate Technologies, Lucent, Motorola, Nortel Networks, Oracle, Philips, Sun, Sybase and Toshiba created the Open Services Gateway Initiative (OSGi) based on the following foundation:

- The networked home is the next frontier.
- The Internet and new technologies enable new services, value chains and business models.
- Standards are required for the market to take off.

- The consumers will require and end-to-end solution which requires Internet connectivity for the home equipment. This connectivity is provided by a gateway.

The OSGi is now a Non-Profit corporation organized in the USA. Sixteen additional companies- AMD, Certicom, COM21, Coactive Networks, Deutsche Telekom Berkom, Domosys, Echelon, EmWare, GTE, Invensys Controls, National Semiconductor, Nokia, Schneider Electric, Siemens, Sony, and Whirlpool- have announced their support for OSGi since the initial announcement. OSGi's mission is to create open specifications for the delivery of multiple services over wide-area networks to local networks and devices and to accelerate the demand for products and services based on these specifications worldwide through the sponsorship of market and user education programs.

Open Services Gateway defined

As residential telecom & datacom services combine and new technologies become available it is expected that homes and small offices will be equipped with service gateways that will function as the platform for many communication based services. The service gateway will enable, consolidate and manage voice, data, Internet and multimedia communications to and from the home and small office. The Services Gateway will also function as an application server for a range of other high value services such as energy measurement and control, safety and security services, health care monitoring services, device control and maintenance, electronic commerce services and more.

The Services Gateway may enable the connectivity and management of an entirely new category of devices e.g. Jini and HAVi, but will also be integrated in whole or part in existing product categories such as (digital and analog) set-top boxes, cable modems, routers, residential gateways, alarm systems, energy management systems, consumer electronics, PCs and more. The Services Gateway will accomplish this by adopting existing Java standards, such as JINI, and by integrating with other non-Java standards such as HAVi. The gateway will connect these device standards to the central office and management system as well as provide gateway to Service Providers to facilitate the deployment of services [OSG].

5.4.3 Wireless communication

Wireless communication, or radio communication, is one of the real promising technologies today. There are several different wireless communication solutions and one of the most promising wireless techniques is Bluetooth [Blu].

The technology is an open specification for wireless communication of data and voice. It is based on a low-cost short-range radio link, built into a 9 x 9 mm microchip, facilitating protected ad hoc connections for stationary and mobile communication environments. Bluetooth technology allows for the replacement of the many proprietary cables that connect one device to

another with one universal short-range radio link. For instance, Bluetooth radio technology built into both the cellular telephone and the laptop would replace the cumbersome cable used today to connect a laptop to a cellular telephone. Printers, PDA's, desktops, fax machines, keyboards, joysticks and virtually any other digital device can be part of the Bluetooth system. But beyond de-coupling devices by replacing the cables, Bluetooth radio technology provides a universal bridge to existing data networks, a peripheral interface, and a mechanism to form small private ad hoc groupings of connected devices away from fixed network infrastructures. Designed to operate in a noisy radio frequency environment, the Bluetooth radio uses a fast acknowledgement and frequency hopping scheme to make the link robust.
Bluetooth radio modules avoid interference from other signals by hopping to a new frequency after transmitting or receiving a packet.

Compared with other systems operating in the same frequency band, the Bluetooth radio typically hops faster and uses shorter packets. This makes the Bluetooth radio more robust than other systems. Short packages and fast hopping also limit the impact of domestic and professional microwave ovens. Use of Forward Error Correction (FEC) limits the impact of random noise on long-distance links. The encoding is optimized for an uncoordinated environment. Bluetooth radios operate in the unlicensed ISM band at 2.4 GHz. A frequency hop transceiver is applied to combat interference and fading. A shaped, binary FM modulation is applied to minimize transceiver complexity.

The gross data rate is 1Mb/s. A Time-Division Duplex scheme is used for full-duplex transmission. The Bluetooth base band protocol is a combination of circuit and packet switching. Slots can be reserved for synchronous packets. Each packet is transmitted in a different hop frequency. A packet nominally covers a single slot, but can be extended to cover up to five slots. Bluetooth can support an asynchronous data channel, up to three simultaneous synchronous voice channels, or a channel, which simultaneously supports asynchronous data and synchronous voice. Each voice channel supports 64 kb/s synchronous (voice) link. The asynchronous channel can support an asymmetric link of maximally 721 kb/s in either direction while permitting 57.6 kb/s in the return direction, or a 432.6 kb/s symmetric link.

5.4.4 Power line as a communication medium

The power line was designed for transporting current for various machines, equipment and appliances. It was not designed for communication purpose, but increasingly it is regarded as a very interesting communication channel as well. The big advantage is of course an already installed network reaching out to every socket and it has thus a very high penetration rate even in rural and rather isolated areas.

At present, there are several efforts world wide investigating the possibilities of the power line as a communication media [Ene]. At present bit rates up to 10 Mbit/sek is tested even in field tests. Of course, power line communication was also a major theme in the ISES project [Lin], [AHO]. At present these efforts are continued in the Swedish National Program on IT in Energy [Ene].

Echelon technologies

The company Echelon has developed a set of standards supporting distributed control [Ech]. LonWorks is developed by Echelon for power line communication. LonWorks is a field bus mainly developed for building automation purposes, but could be used for many other applications. The LonWorks technique has a range of approximately 300 meters, but in favorable cases a range up till 1.000 meter could be accomplished. The transfer rate is 5 Kb/s, which is a quite low speed but enough for the most applications.

Needed to be said is that LonWorks uses many other communication channels than power line, such as twisted pair, coaxial and radio.

Like the Bluetooth system, LonWorks could be used as an ad hoc transceiver but the technique could also be used with Echelons own microprocessors. They are specially designed for building automation applications. There are several products on the market using LonWorks technology.

One of the big problems with power line communication is the noise that is introduced into the power line by different kinds of equipment. But the development of the transceivers has come so far that this has become a quite small problem today.

Echelon is working together with, among other, SUN on Jini technologies and Cisco on Internet technologies. We have used Echelon technologies in all our demonstrators and field tests so far.

5.4.5 Products

We list a couple of commercial products that we have used in our different experiments together with a new interesting product, the E-box. The products are suitable for energy saving application and added-value services for applications identified in the KEES project.

Arigo

Arigo is a company from Germany that has focused on LonWorks-based products that uses the power line as communication channel. The products are focused on home automation applications and are controlled by kind a central controller or host-PC, see Figure 5:2 above. This means that the devices, or as they are called Arigos, are not smart in the sense of autonomous systems. The price for the Arigos is around 1 200 SEK for a switch-Arigo. A switch-Arigo can only switch a load on and off. There are other Arigos for measuring temperature, brightness, energy and so on.

The advantage with the Arigos is that the units are cost effective. The disadvantage is that they are built for central control. This means that each Arigo has a static program and there are no possibilities to reprogram them, which limits the flexibility.

Adasis

Adasis is a modular LonWorks based product family that has been designed for building automation purposes. The general idea is to have a transceiver module and then attach the desirable add-on modules to it (see the picture below). Today there are modules for presence, thermostat (including temperature), energy-pulse measuring and a control-module (for controlling a load).

The advantage with the Adasis system is the modularity and the possibility to customize the internal program in the modules.

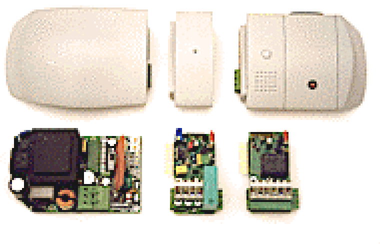

Figure 5:8. Architecture of the Adasis system

Adasis has been implemented tested in the SoftExpo and Hjorthöjden field tests, chapters 5.6.3 and 5.6.4 below.

Ericsson´s E-box

Ericsson has recently, 1999, launched a product, or server for the “connected home”, Figure 5:3 above and [ILV]. The E-box will be evaluated in a demonstrator project, *The Energy barometer*, at HK/R and Kungsbäck IT Center (KIT) in Gävle [WHN].

5.5 Villa Wega demonstrators

The Villa Wega demonstrators have been instrumental in our research and development of smart communicating equipment. We have built demonstrators on load management, smart homes, smart resource allocations, Internet access to smart equipment, active documents et cetera. The results have been reported in numerous articles such as: [FrY], [YAK], [BDG], [Gu2], and [Dav].

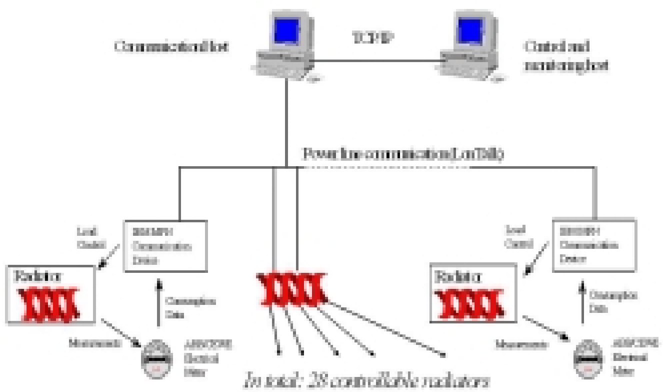

Figure 5:9. Villa Wega installations supporting load management

The Athena project is the most sophisticated demonstrator of intelligent energy management so far in Villa Wega. Athena is a demonstration system that shows the possibilities of dynamic load management in an actual building and a simulated environment. The purpose is to show the economical benefits and the possibilities of new ways of controlling/scheduling energy consumption, while providing high comfort and minimal interference at the customer side. As default, the energy consumption of the building will be optimized with respect to spot-market prices, but the user of the system will be able to override the default when profitable, e.g. when it is possible to sell electricity in other ways through bilateral contacts or when the demand needs to be reduced due to various constraints. The demo will utilize the Internet to enable users to interact with the villa independently of location. The Athena project is described at the EnerSearch web-site [Ene]. There is also a CD available which include a simulation environment.

The role of Villa Wega has now been taken over by the SoC research laboratory at the department IPD at HK/R. The focus of the laboratory is to build an infrastructure, Figure 5:5, allowing building and testing new types of services based on communicating smart equipment [Gu3].

5.6 The Påtorp, Djupafors, SoftExpo, and Hjorthöjden field tests

The demonstrators in Villa Wega have been further tested and evaluated in several field tests in the community of Ronneby. A first test was in the Påtorp are where smart equipment was installed already in 1996. Simultaneously a field test was starting at the paper and pulp industry Djupafors.

These to field tests showed us two things. Firstly, it was feasible to install smart equipment communicating on the electric grid. Secondly, smart equipment and very good test results are far from enough in order to create new business processes. This is even more true if the value chain is not understood or if some re-orientation of old business models are necessary.

SoftExpo and Hjorthöjden are two follow up field test (1998-99) with goals to further explore and show possibilities with communication smart equipment.

The bottom line is that the chain of demonstrators developed in Villa Wega and followed up by the mentioned field tests have been a very fruitful way of building up competence as well as a preparation of a next wave of useful and value-adding applications, Chapter 6.

5.6.1 The Påtorp field test

As early as 1996 smart meters were installed in 70 households in the Påtorp area in Ronneby. One purpose was to have a first field test of the then new IDAM system supporting remote metering. An other purpose was to test the electric grid with respect to communication channel quality. A third purpose was to investigate new business opportunities based on two-way communication with customers.

The first goal has been successful and Ronneby Energi AB (REAB) is now using the equipment for remote reading. The second point has been investigated successfully also and has resulted in several reports and a licentiate degree [Lin]. In order to develop new business opportunities several prototypes were developed. Among those a web-based Inreactive Bill service [DRY]. However, it turned out that it was far to early for the stakeholders to come up with a viable business model with clear values for each partner [Gu1].

The Påtorp field test is planned to continue in the planned BRIDGE project, see below in chapter 8.

5.6.2 The Djupafors field test

Djupafors is a paper and pulp industry in Ronneby owned by the Canadian company Cascades. The production line as such is rather old but the production segment is high quality paper and cardboard. The continuos working is about 8.000 hours per year with a production in the order of 50.000 tons. Djupafors has a power level of between 9 and 10 MW. The yearly energy bill amounts to 23 MSEK.

In October 1996 we reached an agreement with Djupafors to install and test energy saving measures, that is IDAM equipment communicating on the power grid. The purpose was two-fold: we wanted to have experience of installing and testing the equipment in a real world environment and Djupafors wanted to test different possibilities of energy saving such as *intelligent load balancing*.

Djupafors identified, as the test case, 8 different loads (equipment and lighting) and a need of a signal to the operator of the grinding machine when the power level approaches given levels. Given the power level information, the operator can maintain a more energy efficient disposition of operation.

Experiences

The project on *Intelligent distributed load balancing* was completed in November 1997. The communication over the power grid was very good, which was quite surprising given that we used already installed power lines in sometimes “hostile” environments. The distance between endpoint nodes was 250 meters. The results of the *energy savings* on the loads was about *30% in SEK*, due to load balancing, lower levels of power usage and better lighting schemas [And]. Despite the very promising results of the field tests there has been no follow up project. The main reason for this is that neither the utility company involved nor Djupafors was prepared to change existing business models to take full advantage of the possibilities. One obvious possibility is to exchange selling kWh to selling smooth production. Unpredicted stops in production are very costly and can sometimes be avoided by installing smart distributed maintenance systems on top of a load balancing system.

The success of the Djupafors project has led to two new field tests, SoftExpo and Hjorthöjden, see below. Furthermore, at least two new spin-off companies have been formed and a new product, Adasis, has been developed. The product Adasis is reported in the section on [New products] and illustrated in the next chapter on SoftExpo field test.

5.6.3 SoftExpo field test

The SoftExpo field test was co-ordinated by NovaPower AB with partners: Ronneby Energi AB (REAB) for installations of energy metering systems, Ronvab for installations of water meters, ABB Contracting together with Soft Center Fastighetsbolag AB for general installation work, Bexstroem, provider of smart equipment (temperature, energy, water, and movement detectors), SysMik / Weidmuller, router providers [Bäc].

Overview

SoftExpo is an information system tailored at monitoring and steering of a set of consumption, comfort and security parameters within the buildings of SoftCenter in Ronneby. The purpose of the project was to install state-of-the-art smart equipment and evaluate possibilities of building smart houses. Existing power lines was used for communication in order to avoid costly installations of new cables.

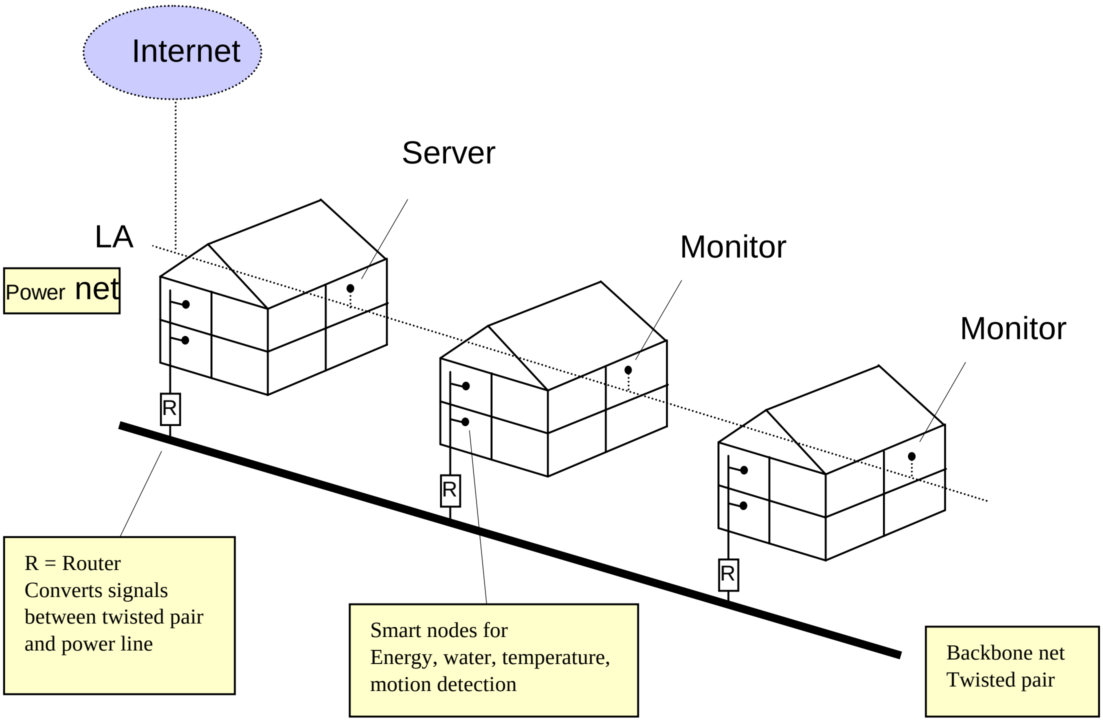

Figure 5:10. Architecture of SoftExpo

The installation has the following main components:

Meters and sensors

Meters are units that register for instance energy consumption, temperature and water consumption. All meters have a signal interface supporting automatic reading. The meters are not indicated in the figure above, but are mostly placed near the nodes, see below.

Nodes

The nodes are connected to the meters and sensors. Software supporting monitoring and control is implemented in the nodes. The nodes communicate between themselves as well as with a server in order to create services. In the SoftExpo field test the nodes are built from components of the Adasis node family, chapter 5.4.5.

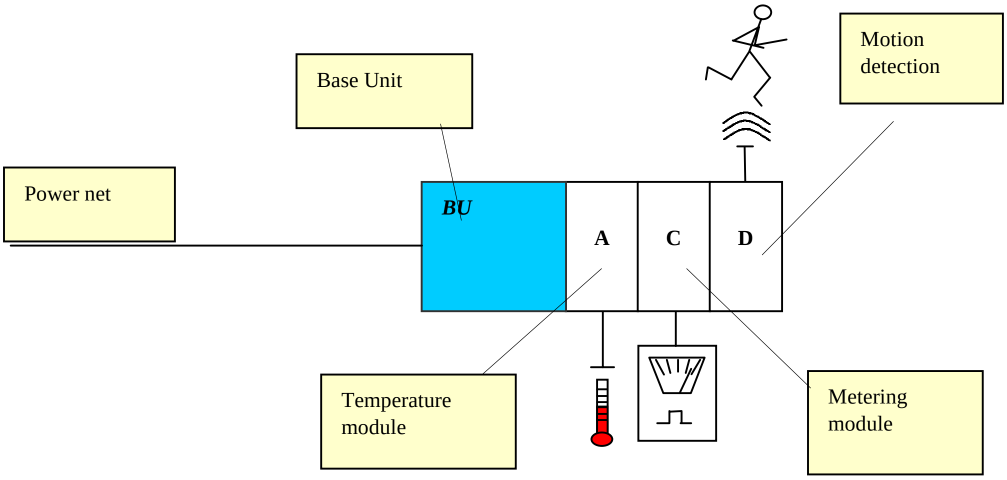

Figure 5:*11. Architecture of the Adasis node family*

Server

The server is a PC build on LonWorks operating system LNS and using the communication protocol LonTalk. The server has a capacity of 32.000 different nodes in different buildings. The server is equipped with Windows NT and the data base Windows Access.

The following measuring points are installed in six different buildings:

- Active energy consumption
- Reactive energy consumption
- Water consumption
- Indoor and outdoor temperature
- Motion detection in selected areas

SoftExpo services

The server collects data from the nodes and bundles it to different services to the user. Services include load balancing of the energy consumption, early detection of disturbances in operations or power failures, early detection of water leakage and so on. Additional features include:

- Possibilities of quick and accurate evaluations of energy saving measures.
- Individual metering down to specific equipment such as elevators and pumps.

- Comparisons of parameters such as energy consumption and outdoor temperature.
- Possibilities to introduce customer specific services for companies at SoftCenter.

Monitors

One purpose of the SoftExpo project is to show and illustrate possibilities of smart equipment in creation of smart buildings. To that end, there are monitors installed in every reception area allowing visitors to follow metering and monitoring of temperature as well as energy and water consumption.

Web-server and Internet access

A web-server has been installed to provide Internet access to the project. The project has an own homepage on the Internet where visitors can learn more about the project as well as follow some consumption patterns. The following screen dump shows aggregated energy consumption (Aktiv elförbrukning).

Figure 5:12. A screen dump from SoftExpo homepage showing aggregated energy consumption

5.6.4 Hjorthöjden field test

Hjorthöjden is a multi family housing area in Ronneby. The local government in Ronneby, AB Ronnebyhus, owns the apartment buildings. A consortium of AB Ronnebyhus, REAB, and NovaPower AB and supported by DESS is during 1999 installing smart equipment (individual metering systems of energy and water consumption in each flat to begin with). The installments and choice of equipment are based on experiences from earlier mentioned field tests. All communication between the distributed smart equipment is on the electric grid. The installments will be tested at the end of 1999.

5.7 A plan for next generation of demonstrators and field tests

A common denominator of our investigations and field tests is summarized in Figure 1 above, i.e., a need to have a comprehensive view on technology, applications and business models.

5.7.1 Possibilities of new applications and services

There is a set of ideas concerning applications [MTD], [NEW]. We have identified the following possibilities of special value to elderly and handicapped people [Boe].

Help with operating complicated devices

- Video programming over power line

People often have trouble programming their VCR. VCRs may be extended by a device that allows them to be programmed from a distance over the power line. Instead of programming the VCR themselves, people may have the utility do that for them. They call the utility by phone (e.g. over the power line), and tell what program they want to be taped. Then the utility programs the VCR over the power line.

- TV, radio, and VCR channel tuning over power line

People often have trouble programming the channel frequencies in their TVs, VCRs and radios.
TVs and VCRs may be extended by hardware allowing them to be initialized (i.e. channel settings) over the power line from a distance. Each time new channels are offered by the cable company or each times channel frequencies are changed, settings may be adapted automatically over the power line by the utility from a distance.

- Intelligent (alarm) clocks

The utility may send signals over the power line to adjust clocks from a distance. Alarm clocks equipped with special hardware pick up these signals and automatically show the correct time always. People won't have to remember daylight saving time for instance. Digital clocks don't have to be set to the right time by hand anymore when they have been without power. As soon they're plugged into a socket, they automatically show the correct time.

Safety (fire, burglary)

- Fire and smoke detection

System gives warning when fire or smoke is detected. Utility may be warned automatically by e.g. communication over the power line.

- Detection system for open windows / doors (see below)

- Access by fingerprint reader

People may forget to lock the front door or loose the keys. Instead of using keys the front door is opened by fingerprint recognition. Only the inhabitant can enter the house.

- Camera and intercom at front door

Older people are often afraid to open the door. Have a camera and intercom installed at the front door so they can see who's at the door.

Health care

- Accident detection

System detects when person needs help. Person may push a button or shout for help (speech recognition) Or system may ask person to push a button or give a sign when it knows the person is in the house and no movement is detected for more than half an hour. If no sign is given the system will get assistance.

- Intelligent refrigerator / freezer / cupboard

Fridge / freezer / cupboard reads bar codes of products that are inside fridge. It gives a warning when products have exceed their expiration date. This prevents people from eating / drinking bad food.

- Filth detection system

Intelligent toilets, showers, bathroom, kitchen: gives warning when too many bacteria are detected.

- Intelligent toilet

Toilet monitors people's health by chemical sampling of you know what…

Energy saving

- Comfort management system

System tries to keep a certain comfort level in the house (temperature, humidity, air quality (also: health), lighting, etc.) at the lowest possible price. System buys energy on the energy market itself (homebot, see ECN Dego project proposal).

- Detection system for open windows / doors

Old people are forgetful and may forget to shut and lock windows or doors when they leave the house or go to bed. This not only is dangerous (safety:

burglary prevention) but also energy wasting. System may give a warning when front door is being locked while other doors and windows are still open. Or it may shut windows automatically. A panel can show the status of the house: which doors and windows are still open / unlocked.

- Detection system for appliances not being shut off.

Old people are forgetful and may forget to shut off energy using devices like lamps, irons, cooking plates, heaters etc. This is not only dangerous (safety: fire protection) but also energy wasting. The system gives a warning when appliances are left on at times at which normally these appliances would have been shut off. E.g. when people leave the house or go to bed. The system might give a warning when the front door is being locked and the lamp in the cellar is still on. It also may shut off the appliances itself automatically. A panel near the front door could give an overview of what appliances are still on (see also PLT Demo proposal, VU Amsterdam).

- Intelligent refrigerator / freezer

Fridge / freezer gives warning when door is not shut for a long time, or when temperature drops below a predefined level (also: health, prevents products from going bad).

5.7.2 Methodological issues

A crucial issue in identifying, designing and implementing new services of the kind we have outlined earlier and in section 6.1 concern issues such as *values* and *acceptance and trust*. Promising results on value identification and assessment has been put forward in a recent report on a methodology, *e^3-VALUE* [GAV].

5.7.3 The next step

It is desirable to identify an umbrella project, the name BRIDGE has been suggested. The BRIDGE project would have duration of 3 years and including several shorter subprojects with a common goal. A suggested overall goal is *Constructing the bridge from enabling technology to new energy business.*

Possible subprojects include

- An energy system demonstrator at Kreativum in Karlshamn.
- A next generation of services, including the Energy barometer, at the Påtorp field test site.

5.8 References

[AHO] Akkermans, H., Healy, D., and Ottosson, H. The Transmission of Data over the Electricity Power Lines. In Ottosson, H., Akkermans, H, and Ygge, F. (eds.) *The ISES Project Information/Society/ Energy/Systems*, EnerSearch AB, 1998 (available from www.enersearch.se).

[And] Andersson, R. Projektet Djupafors. NovaPower internal report, 1997, NovaCast, Ronneby.

[BDG] Boman, M., Davidsson, P., Skarmeas, N., Clark, K., and Gustavsson, R. Energy Saving and Added Customer Value in Intelligent Buildings. In *Proceedings of the Third International Conference on the Practical Application of Intelligent Agents and Multi-Agent Technology* (PAAM'98), pages 505-517, 1998.

[Boe] Boertjes, E. *Some ideas for applications aimed at comforting elderly people*. Internal Report, VUA and HK/R, 1999.

[Bäc] Bäckström, M. Teknisk beskrivning SoftExpo. NovaPower, 1999, Ronneby.

[Dav] Davidsson, P. Intelligent Buildings: Energy Saving and Value added Services. In Ottosson, H., Akkermans, H, and Ygge, F. (eds.) *The ISES Project Information/Society/ Energy/Systems*, EnerSearch AB, 1998 (available from www.enersearch.se).

[DRY] van Dijk, E., Raven, R., and Ygge, F. SmartHome User Interface: Controlling your Home through the Internet. In *Proceedings of DA/DSM Europe 1996, Distribution Automation & Demand Side Management, Volume III*, pp. 675-686, PennWell, 1996.

[FrY] Ygge, F. *Market Oriented Programming and its Application to Power Load Management*. Ph.D. Thesis. ISBN 91-628-3055-4, CODEN LUNFD6/(NFCS-1012)/1-224/(1998). Lund University, 1998.

[GAV] Gordijn, J., Akkermans, H., and van Vliet, H. *Value Based Requirements Creation for Electronic Commerce Applications*. Report VUA and HK/R, 1999.

[Gu1] Gustavsson, R. Knowledge Management through IT support in Distributed Organisations. In Ottosson, H., Akkermans, H, and Ygge, F. (eds.) *The ISES Project Information/Society/Energy/Systems*, EnerSearch AB, 1998 (available from www.enersearch.se).

[Gu2] Gustavsson, R. Agents with Power. Invited paper, in *Communications of the ACM*, March 1999, Vol. 42 No.3, pp. 41-47.

[Gu3] Gustavsson, R. Smart Equipment Creating New Electronic Business Opportunities. *Proceedings of The 12th International Conference on Industrial and Engineering Applications of Artificial*

Intelligence and Expert Systems, IEA/AIE'99, Springer Verlag, 1999.

[ILV] Idermark, T., Lilliestråle, M., and Vasell, J. Ericsson's e-box system – An electronic services enabler. *Ericsson Review*, No. 1, 1999, vol 76.

[Lin] Lindell, G. Power Line Communication. In Ottosson, H., Akkermans, H, and Ygge, F. (eds.) *The ISES Project Information/Society/Energy/Systems*, EnerSearch AB, 1998 (available from www.enersearch.se).

[MTD] Böhlin, B. Smarta hus – bra för miljön. Miljöteknik-delegationen, 1999.

[NEW] The smart home. Newsweek, May 31, 1999.

[WHN] Westergren, K-E., Högberg, H., and Norlén, U. Monitoring energy consumption in single-family houses. In *Energy and Buildings*, No. 29, pp. 247-257, 1998.

[YAK] Ygge, F., Akkermans, H., Andersson, A., Krejic, M., and Boertjes, E. The HomeBOTS System and Field test: A Multi-Commodity Market for Predictive Power Load Management. In *Proceedings of the Fourth International Conference and Exhibition on The Practical Application of Intelligent Agents and Multi-Agents (PAAM99)*, April 19 - 21, London, 1999.

URL addresses

[Blu] The Bluetooth consortium
URL: www.bluetooth.com

[Ech] The Echelon Cooperation homepage
URL: www.echelon.org

[Ene] EnerSearch home page
URL: www.enersearch.se

[FIP] Foundation for Intelligent Physical Agents
URL. www.echelon.org

[JIN] The Community Resource for Jini technology
URL: www.jini.org

[OMG] The Object Management Group
URL: www.omg.org

[OSG] The Open Services Gateway Initiative
URL: www.osgi.org

[WAP] Wireless Application Protocol (WAP) Forum
URL: www.wapforum.org

[W3C] The World Wide Web Consortium
URL: www.w3c.org