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COGAIN

Communication by Gaze Interaction

Network of Excellence
Information Society Technologies

D2.4 A Survey of Existing 'de-facto' Standards and Systems of Environmental Control

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Executive Summary

The lack of standards for using gaze tracking as a control method for manipulation and control of a personal environment is a significant block for implementing gaze enabled environmental control systems. This deliverable is the first step towards defining standards for data formats and application-programming interfaces for gaze based environmental control. The deliverable addresses this issue by examining what existing standards, and standards bodies working in the area, are available, by explaining what is meant by environmental control, and by showing how people with disabilities may control their personal environments, giving examples of this control. The deliverable then examines both the currently available interfaces, and the wide range of currently available protocols for environmental control in order to establish if any interfaces and protocols exist that may be suitable for gaze control. Finally, the deliverable proposes the next steps toward producing a COGAIN commonly held standard for gaze based environmental control, which will lead to the realisation of standard software elements and recommendations, methods and protocols for gaze environmental control.

Diverse existing environmental control standards

The deliverable survey revealed a very wide and diverse number of interfaces, network systems and protocols that may be used in any given environmental control situation. There did not appear to be one overriding popular system that could be adopted as a COGAIN interface or protocol that could fulfil all of the requirements for a gaze based system that would be successful with a high uptake. **Due to this diversity, it is logical for COGAIN to step back from attempting to adopt a single network system and protocol to support with gaze control. Instead COGAIN should aim to support as many of the differing systems (and hence their users) as possible.**

A single COGAIN environmental control standard

In order to interface with the existing diverse Smart Home networks, the easiest method would be to connect to them via their application programming interfaces (API’s). Those systems that present an API will allow communication and control of the systems by external standardised software, developed by COGAIN. This would then interface any supported Home System with any gaze driven system via a single standard COGAIN interface. In addition, the COGAIN single standard interface would allow the connection of dedicated gaze driven interfaces to be easily interfaced with any environmental control system, enabling gaze control of Smart Homes for COGAIN users. **Hence COGAIN should develop a single Smart Home standard driver that will connect to existing system API’s and allow control of these diverse networks and protocols by gaze based systems.** This will be the subject of the next deliverable, D2.5 – Draft Standards for Environmental Control.

1 Introduction

1.1 This Deliverable

The lack of standards for using gaze tracking as a control method for manipulation and control of a personal environment is a significant block for implementing gaze enabled environmental control systems. This deliverable is the first step towards defining standards for data formats and application-programming interfaces for gaze based environmental control by examining what existing standards, and standards bodies working in the area, are available.

The deliverable starts by explaining what is meant by environmental control, and how people with disabilities may control their personal environments, giving examples of this control. It then goes on to survey what existing standards bodies are currently available that can be utilised to further the progress of a gaze based standard. The deliverable then examines both the currently available interfaces, and the wide range of currently available protocols for environmental control in order to establish if any interfaces and protocols exist that may be suitable for gaze control. Finally, the deliverable proposes the next steps toward producing a COGAIN commonly-held standard for gaze based environmental control, which will lead to the realisation of standard software elements and recommendations, methods and protocols for gaze environmental control. This will allow third party applications and systems to use these control standards to further the uptake of gaze as a viable medium for environmental control, enabling many users who would otherwise not be able to actively and independently control their environments.

1.2 What is Environmental Control?

Environmental control is the control, operation, and monitoring of an environment via intermediary technology such as a computer. Typically this means control of a domestic home. Within the scope of COGAIN and this deliverable, this environmental control concerns the control of the personal environment of a person (with or without a disability). This defines environmental control as the control of a home or domestic setting and those objects that are within that setting. Thus, we may say that environmental control systems enable anyone to operate a wide range of domestic appliances and other vital functions in the home by remote control.

In recent years the problem of self-sufficiency for older people and people with a disability has attracted increasing attention and resources. The search for new solutions that can guarantee greater autonomy and a better quality of life has begun to exploit easily available state-of-the-art technology. Personal environmental control can be considered to be a comprehensive and effective aid, adaptable to the functional possibilities of the user and to their desired actions.

We may say that the main aim of a smart home environment is to:

- **Reduce the day to day home operation workload of the occupant**

1.3 Terminology

There are several terms that are currently used to describe domestic environmental control. Often a domestic environment that is controlled remotely is referred to as a 'Smart Home', 'SmartHouse', 'Intelligent Home' or a 'Domotic Home'; where 'Domotics' is the application of computer and robot technologies to domestic appliances. This is a portmanteau word formed from domus (Latin, meaning home) and informatics. All of these terms may be used interchangeably. Within this deliverable environmental control within the home as a form of assistive technology to aid users with disabilities will use the term '*Smart Home*' (unless a system referred to has a different name) as it encompasses all of these terms in a clear and understandable way, and allows for levels of automation and possible artificial intelligence over and above simple direct environmental control of objects within the home.

Often the term 'remotely controlled' gives the impression that the home is controlled from some other place outside of the home (perhaps from the workplace for example). This can be the case, but within the terms of COGAIN 'remotely controlled' means an object or function of the home that is controlled without the need to handle or touch that object. In these terms, the object may be right in front of a user, with that user controlling the object remotely via a computer screen rather than actually handling, lift and manipulating the object – physical actions that user the user may not be able to accomplish.

1.4 Disability and Environmental Control

When a user has a physical disability, that user may not be able to manipulate physically objects in their environment at all. Thus an environmental control system moves from being a useful labour saving device to a personal necessity for independent living, by enhancing and extending the abilities of a disabled user and allowing independence to be maintained. The environmental control system may be the sole and only way such a person can control their environment.

Hence, extending the definition of the previous section, when that occupant has a physical disability, the aim of smart home systems is extended (from 2.1), it will:

- **Reduce the day to day home operation workload of the occupant**
- **AND enable the occupant of the home to live autonomously as much as is possible**

Such personal autonomy over their environment has the benefit of reducing the reliance on the continuous help of a carer and/or family member, and increasing the self-esteem of the user as they can control the World around them.

1.5 Typical Applications

Typical applications may be those items within the home that may be easily controlled, and which the user would often wish to control. Examples include:

- Lighting (switches, dimmers);
- Windows and blinds;
- Door Lock;
- Intercom (microphone and button at the door as well as bell and loudspeaker in the apartment);
- Heating, Ventilating, and Air-Conditioning (HVAC);

- Home appliances (also called white goods – domestic equipment such as refrigerators, cookers, washing machines and central heating boilers);
- Brown goods (name for Audio Visual Appliances and devices);
- Home security devices (e. g. burglar alarm, fire alarm);
- Telecommunication;
- Information access.

Applications may be illustrated by examining a contemporary and popular commercial system designed for users with a disability (Figure 1).

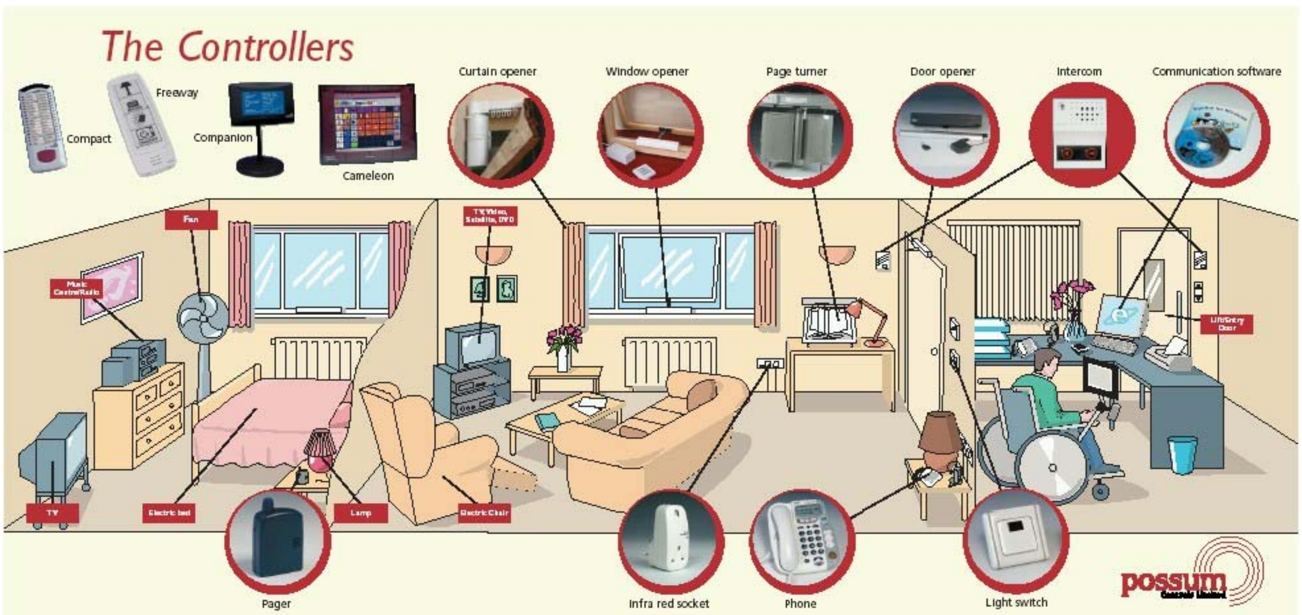

Figure 1. A typical environmental control system for a disabled user[1]

However, such a system is limited as it requires the user to actively and deliberately control each device. This may become tiresome and cause fatigue over time. Many functions could be automated to save the user the efforts of controlling the system themselves. Thus, an improvement to direct control is to add a level of ‘intelligence’ to the system.

1.6 Intelligence, Integration and Central Control

Electronic devices that contain processors or are computers that can communicate with other systems are increasingly popular among ordinary homes. In order to address security and control, communications, leisure and comfort, environmental integration and accessibility, it is desirable to have a central control system to integrate and manage all the devices throughout a domestic home. Therefore, it is essential that this

[1] Courtesy of Possum Controls Ltd

environment control system can interact and work together with all the electronic devices within the home to benefit the users in the home.

Most modern homes have appliances that allow some degree of remote control. Environmental control aims to integrate and extend this control throughout the home. A home with an environmental control system installed might have many computers, perhaps built into the walls, to allow the homeowner to control applications in any part of their home from any other, or it may have a single simple computer operating an essential function such as emergency call and security.

In addition to integration, intelligent systems are being developed. The great potential of these systems lies in their ability to apply computer programming to act in what could be called "intelligent" ways. This involves the programming of logic that takes into account variables such as temperature, time, power status etc., e.g.: TURN ON kitchen lights IF light levels are low AND person is home ELSE TURN OFF kitchen lights IF on, or, e.g.:

- Work with your utility company to take advantage of off peak electricity rates and provide choices for comfort, safety, and energy conservation.
- Ensure that the right light is on in the right place, keeping lights on where you may be, and switch off lights in empty rooms, or ensuring that the right lighting intensity and mood are achieved.
- Providing intelligent garden sprinklers and other plumbing; the lawn is watered only when it is needed, and you can enjoy a quiet stroll through your garden without risking a drenching.
- To do such things as adjust lights and music to the personal preferences of each member of the household, as they come into or leave a particular room.
- Control curtains, window blinds, and sun shades automatically, all day, without human interaction.
- Monitor health and activity and automatically call emergency services if illness or inactivity is found.
- Only allow designated known people into the home.

2 COGAIN Related Standardisation Organisations

Standardisation takes on a particularly important role to help prevent the duplication of effort and ensure interoperability between the resulting technical solutions. Standardisation can create trust and confidence in the products and increase market relevance and is an essential requirement for the open exchange of information; without it, the network will simply not work. Standardisation activities are usually overseen by standards organisations, classified by their role, position and the extent of their influence on the local, national, regional and global standardisation arena. Clearly, knowledge of the activities of relevant standardisation organisations is essential to COGAIN in order to work with these organisations to form new gaze based standards for environmental control. This section shows the results of a survey of all the main European and International standards organisations that could be relevant to COGAIN, and who COGAIN could work with to form new gaze based standards.

This section details the results of this survey, showing the main organisations, and the roles and committees they hold, and ends with identification of the most relevant organisations that COGAIN should involve when developing gaze based environmental control standards.

2.1 Main European Standardisation Organisations

There are three relevant main European standardisation organisations:

- The European Committee for Standardisation (**CEN**, in French Comité Européen de Normalisation) [http://www.cenorm.be]
- The European Committee for Electro-technical Standardisation (**CENELEC**, in French Comité Européen de Normalisation en Electro-technique) [http://www.cenelec.org]
- European Telecommunications Standardisation Institute (**ETSI**) [http://www.etsi.org]

CEN, CENELEC and ETSI are all European Standards Organisations “ESOs”. Standardisation work in CEN or CENELEC Technical Committees is generally carried out through national delegations with interested parties contacting their national CEN or CENELEC member organisation. Activities within ETSI Technical Committees and Projects and CEN/ISSS Workshops are open to all interested parties, subject to relevant membership or subscription requirements. The European Committee for Standardization (CEN) covers standardisation in areas other than the electro-technical and telecommunications fields. In the fast-moving domain of information and communications technologies (ICT), CEN has created the Information Society Standardisation System (CEN/ISSS). In addition to the traditional CEN Technical Committees, this makes use of open workshops which are held whenever there is an identified need and which are open to all interested parties. Their deliverables are published by CEN as CEN Workshop Agreements (CWAs). Detailed information about the work of CEN/ISSS is available at http://www.cenorm.be/isss.

2.1.1 Broad aims of European Standards[2]

CENELEC issued the Workshop agreement "SmartHouse Code of Practice" (CWA50487) that gives the broad aims of Europe for Smart Homes. The issues specific to the user that the smart home designer needs to be aware of and which are considered in CWA50487 are listed below:

1. Technical issues

- Reliability and quality of service
- Energy consumption
- Access*
- Interoperability
- Social issues *

2. Compatibility with essential services

- Health care
- Security*
- Privacy*
- Safety
- Infotainment*

3. User issues

- Cost benefits
- Design for all*
- User interfaces*
- Easy to understand and use
- Personalisation*
- Comfort and convenience*

*COGAIN specific issues.

Clearly many of these issues are relevant to the aims of COGAIN to enable greater home independence via gaze based environmental control. In particular, COGAIN can address Access, Social issues, Security, Privacy, Infotainment, Design for All, User Interfaces, personalisation and Comfort. These issues are all highlighted in the lists with asterisks (*).

[2] Section reference: CEN/CENELEC Guide 6. Guidelines for standards developers to address the needs of older persons and persons with disabilities. Web link: http://portal.etsi.org/hf/cen-cenelec_guide6.asp

2.1.2 COGAIN related CEN Technical Committees

We can now examine what areas of the the European Committee for Standardisation are available to COGAIN. These are broken down into the relevant technical committees:

- CEN/TC 293 –Technical Aids (Assistive Devices) for Disabled Persons, providing for all types of disability
- CEN/TC 251 – Health Informatics, which has a very extensive and long-standing programme of standardisation in many areas

Forty European Pre-Standards (ENVs) have been produced, a number of which have been converted into global standards or are in the process of becoming full European standards. Discussions are to take place on future standards requirements in this area. CEN standards are available from the national standards bodies in countries in the European Union

2.1.3 COGAIN related CENELEC Technical Committees[3]

The European Committee for Electrotechnical Standardization (CENELEC) is the recognized European Standards Organisation in the field of electrotechnical standardisation. Its members have been working together in the interests of European harmonisation since the late 1950s, creating both voluntary and Harmonised Standards that have helped to shape the European Internal Market. CENELEC works with 35,000 technical experts from 22 European countries. Its work directly increases market potential, encourages technological development and guarantees the safety and health of consumers. Technical committees that may be relevant to COGAIN include:

- TC 205 – Home and Building Electronic Systems (HBES) – this is the main European contributor to Intelligent Homes standardisation, and is coordinating activity in this area on behalf of the ICTSB. Its mission is to identify standardisation needs, taking into account users' requirements in the areas of networks inside the home, residential gateways and services. Subcommittee 205A is responsible for Power Line Communication offers huge potential to support Internet access.
- TC 79 is responsible for Alarm Systems. It also concerns Intelligent Homes standardisation.
- CENELEC Technical Board Working Group (BTWG) 101-5 in response to EC Mandates is preparing guidance documents for use by all CENELEC Technical Committees dealing with Information Technology (IT) on the safety and usability of IT-based electrical products for people with special needs (including children, the elderly and those with disabilities). This should ensure that Design for All and Assistive Technologies requirements are taken into account in all of CENELEC's standardisation work. CENELEC standards may be purchased from the relevant National Committee in own country.

2.1.4 COGAIN related ETSI Technical Committees and Projects[4]

The European Telecommunications Standardisation Institute (ETSI) is the recognised European Standardization Organisation for telecommunications and the related fields of broadcasting and information technology. It produces a wide range of standards and other technical documentation as Europe's contribution to worldwide standardisation. A non-profit making organisation based in Sophia Antipolis, France, ETSI unites nearly 900 members from over 50 countries inside and outside Europe, and represents manufacturers,

[3] Section reference: www.e-europestandards.org/ESOs.htm
[4] Section reference: www.etsi.org/etsi_radar/literature/documents/ETSI_DECT.pdf

network operators, administrations, service providers, research bodies and users. Technical committees that may be relevant to COGAIN include:

- ETSI Project Power Line Telecommunications (EP PLT), which is working to provide high-speed local loop solutions with IP access at around 10 Mbit/s.
- ETSI Technical Committee Human Factors (TC HF). TC HF is responsible for considering the ease of use and accessibility of telecommunication equipment and services for all users, including disadvantaged groups such as the elderly and disabled. A number of guides have been produced, with recommendations which will particularly affect the next generation of mobile telecommunications and could also lead to alternatives to the use of long telephone numbers by the introduction of more meaningful methods.

With the launch of the eEurope Initiative, TC HF's experience and reputation in the field of human factors was quickly recognized and the Committee has emerged as a key player in the development of standards to assure e-Accessibility[5]. The EC has provided funding to put together thirteen teams of experts, known as Specialist Task Forces (STFs), to work under TC HF. Some of these completed their work in June 2002, producing a number of key documents:

- STF 180 – produced an ETSI Guide (EG 202 067) on Universal Communications Identification (UCI), which could give every individual a communications identifier to be used throughout life, irrespective of changes in communications systems.
- STF 181 – reviewed the needs of older and disabled users for assistive technology devices and prepared an important ETSI Technical Report (TR 102 068) offering guidance as to how these devices can be connected to ICT systems. The report looks at input and output devices and wired and wireless transmission technologies at the interface where an assistive device can be connected. It makes recommendations for suitable protocols at the connection interface and proposes ways to encourage their implementation.
- STF 183 – in relation to the needs of people with disabilities and the elderly, looked at alternatives to visual icons, symbols and pictograms and drafted an ETSI Guide (EG 202 048) on their use in multimodal interfaces.
- STF 184 – published Design for All Guidelines for ICT products and services, an ETSI Guide (EG 202 116) aimed at the working design engineer rather than the human factors expert, setting out the characteristics of users and their disabilities and describing the human centred design process.
- STF 201 – examining access to ICT by children under 12 – the first time an STF has been established to look into the access problems of young people.
- STF 202 – working on the use of the characters of different European languages on telephone keypads.
- STF 204 – working on multimodal interaction, communication and navigation at the user interface of ICT systems and terminals.

Individual ETSI deliverables are available free of charge from the Publications download area of the ETSI web site. A full set of ETSI deliverables is obtainable by subscription to the ETSI Documentation Service offered on the web site[6].

ETSI has published a Special Report, SR 001 996, which is an annotated bibliography of documents dealing with Human Factors and disability, which provides a catalogue of human factors standards produced by

[5] E-Access bulletin. Web link: http://www.e-accessibility.com/archive.html.
[6] www.etsi.org

various standardisation organisations, with short comments for the reader on their content and applicability. The report is available to all as a document on the ETSI web site, but new work is now commencing, aimed at turning it into a web-based version.

2.1.5 Recognition and Enforcement in Europe

These European Standardisation Organisations are formally recognised by the European Union under Directive 98/34/EC, which guarantees the status of European Standards (ENs). Under agreement, when an EN is published, all conflicting national standards should be withdrawn; conformance with ENs is often a means for manufacturers to show they are complying with relevant legislation, such as the 'New Approach' Directives. These principles have been of considerable benefit to the creation of the European Single Market.

2.2 Common Efforts of ESO and EC in ICT standardisation[7]

Information and Communication Technologies (ICTs) are becoming an essential part of the life of the European citizen – in the economic sphere, in education, in our social lives – and they offer tremendous potential for growth, employment and inclusion. The changes they are bringing, perhaps the most significant since the Industrial Revolution, are far-reaching and global and they are not just about technology. They will affect everyone, everywhere. Bringing people closer together, creating wealth, sharing knowledge, they could enrich everyone's lives. Managing this transformation represents a central economic and social challenge for the European Union.

There is concern about whether the new products and services which are available are fully accessible, especially to elderly people and people with disabilities. At the same time, ICTs offer enormous potential to help these same groups to maintain and improve their quality of life, their integration and independence. To push forward standards, the ICT Standards Board (ICTSB) [http://www.ictsb.org] was formed as an initiative from the three recognized European standards organisations (CEN, CENELEC, and ETSI) with the participation of specification providers as partners to co-ordinate specification activities in the field of ICT.

2.2.1 ICT Standards Board[8]

The ICTSB listens to requirements for standards and specifications that are based on concrete market needs and expressed by any competent source. The Board then considers what standards or specifications need to be created, and how the task will be carried out. In addition to the traditional European Standard deliverables, the dynamic Workshop (CWA: CENELEC Workshop Agreement) has been included in its portfolio, offering an open platform to foster the development of pre-standards for short lifetime products where time-to-market is critical.

ICTSB is dealing with:

- Design for All and Assistive Technologies [http://www.ictsb.org/DATSCG_home.htm];
- Intelligent Transport Systems [http://www.ictsb.org/ITSSG_home.htm];
- SmartHouse Standards [http://www.ictsb.org/SHSSG_home.htm];
- Network & Information Security [http://www.ictsb.org/NISSG_home.htm].

[7] Section reference: http://www.e-europestandards.org/
[8] Section reference: http://www.ictsb.org/

It has completed its co-ordination work on Electronic Signature and has contributed to the discussion on ICT standardisation. The ICTSB is also involved in the political initiatives such as eEurope.

For COGAIN the most important initiatives are: Design for All and Assistive Technologies, and the SmartHouse Standards.

The number of elderly or disabled people within the European Union is growing; by the year 2020, it is estimated that 25% of the population will be over 60, with the largest increase in the 75+ age band, where disability is most prevalent. As user interfaces become more complex due to technological development and improved functionality, design becomes increasingly important. 'Design for All' is an approach to design activity intended to ensure that products are usable by all people, to the greatest extent possible, without the need for specialized adaptation.

Where a Design for All solution is not reasonably achievable, perhaps because a person's abilities are very severely impaired, one possible solution is the provision of a so-called 'assistive device'. Assistive Technologies involve the use of a technical interface to permit the use of an assistive device to prevent, compensate, relieve or neutralize a handicap. Together, the device and its technical interface enable a user, who is not otherwise able, to access a mainstream device. By adopting the Design for All approach and ensuring that Assistive Technologies are considered as part of the design process, it is possible to widen access to the Information Society to groups which might otherwise be excluded from its benefits.

In response to EC Mandate 283 on design for all in standardisation, CEN and CENELEC have worked together on design for all. The CEN/ISSS Workshop on Design for All and Assistive Technologies in ICTs was launched in September 2001. The contribution of the user/consumer/disabled community is regarded with such importance that, to increase their participation, travel costs for attending meetings are reimbursed to selected participants. Workshop will have completed its first phase of work, which includes publication of the 'sector guidelines' for ICTs, building on CEN/CENELEC Guide 6 (technically identical to ISO/IEC Guide 71), and offering detailed information for ICT standardisation experts working within CEN. The Workshop is also working on a report on the need for future standardisation activities in the area of assistive technologies and ICT, based on a review of existing or completed Research and Technological Development projects funded by EU programmes. The requirements for standardisation will be examined in consultation with representatives of the disability communities and the assistive technologies manufacturing industry. Guide 6 is a set of guidelines to address the needs of older persons and people with disabilities when developing standards.

2.2.2 The SmartHouse Standardisation Initiative[9]

The overall objective of the SmartHouse project is to grow and sustain convergence and interoperability of systems, services and devices for the SmartHouse that will provide the European Citizen with access to increased functionality, accessibility, reliability and security that a SmartHouse, with common and open architectures, will deliver in an expanding broadband infrastructure throughout Europe.

Since 2001, the European Committee for Electrotechnical Standardization (CENELEC) and the European Commission DG ENTR have been working together to develop understanding of requirements for the SmartHouse and have recently completed work on a Code of Practice for SmartHouse operation.

The SmartHouse Standardisation Initiative aims to support initiatives ensuring that Service Providers, Government, Health, Learning and local community Services can interact with all the citizens of the EU. They will then be confident that their systems are communicating into homes with networks, systems and

[9] Section reference : http://www.cenelec.org/

equipment that are constructed, installed and set up to known standards, are interoperable and interactive and will deliver predictable information and receive intelligible responses from any home in the EU.

It is the contention of the SmartHouse Standardisation Initiative that while currently the majority of connected (to the Internet with or without broadband) citizens are reasonably well informed and can manage the multiple inconsistencies and incompatibilities of current services and broadband delivery; when the objectives of eEurope i2010 and beyond are achieved, every citizen will have access to a range of Broadband services and applications. Of these, many will be uninformed, many will be in demographic groups that find the use of new systems non-intuitive, many will be disadvantaged by disability, poor health, poor education and by old age.

One of the objectives of SmartHouse is to make the new technology of the connected home accessible to all.

SmartHouse Phase I consisted of work to understand the SmartHouse and the standards involved in it. Much work was carried out to catalogue and organise all the standards, stakeholders and systems involved in any SmartHouse. The main deliverable was a comprehensive report which led to the establishment of Phase II.

The specific objective of this second phase of the SmartHouse Phase II mission was to deliver a *Code of Practice* that informs all actors, systems, networks, protocols, applications and services involved in the SmartHouse of all (or as many as possible) the methods, issues (commercial and technical) and the trade-offs when they are involved or operating in the SmartHouse or its environment. It had a more specific aim of discussing the issues, recommending and referencing appropriate standards. This work was completed in November 2005 by the delivery of the SmartHouse Code of Practice in the form of the first CENELEC home-grown Workshop Agreement: CWA 50487.

The ICTSB maintains a dialogue with the Commission and links standardisation with research activities for mutual benefits: State of the Art in standardisation and increased market relevance of standardized solutions based on research projects. Five ICTSB partners (CEN, CENELEC, ETSI, The Open Group and W3C) have combined to launch a support action under FP6 to optimise the interface between standards and research. details of this project – the Cooperation Platform for Research and Standards (COPRAS) – are found at http://www.copras.org. The COPRAS project evaluated the requirements for standardisation of the IST projects, and offered collaboration for the management of their contribution to the standardisation system.

2.3 International Standardisation Organisations

International organisations that may be relevant to COGAIN include:

- International Organization for Standardization(ISO) [http://www.iso.org];
- International Electro-technical Commission (IEC) [http://www.iec.ch];
- International Telecommunications Union (ITU) Standardization Section [http://www.itu.int/ITU-T];
- United Nations Economic Commission for Europe (UN-ECE) [http://www.unece.org].

ISO functions as a voluntary network of the national standards bodies. OSI (Open Systems Interconnection) reference model as specified in ISO/IEC 7498.

2.3.1 The main Internet Standardisation Organisations

There may be possibilities that COGAIN will also influence internet standards either directly or indirectly by enabling gaze based interaction. Organisations involved in internet standardisation include:

- Internet Engineering Task Force (IETF), www.ietf.org
- Unicode, www.unicode.org
- World Wide Web Consortium (W3C), www.w3.org
- Organization for the Advancement of Structured Information Standards OASIS, www.oasis-open.org
- Object Management Group (OMG), www.omg.org
- Open Mobile Alliance (OMA), www.openmobilealliance.org
- The Open Group (TOG), www.opengroup.org
- Web3D Consortium (Web3D), www.web3d.org
- Institute of Electrical and Electronics Engineers (IEEE), www.ieee.org

Among these guidelines are the ones produced by the WAI. Established as part of W3C's commitment to realize the full potential of the web, the WAI guidelines aim to increase accessibility of the web for people with disabilities. A resolution of the European Parliament has recommended them for use by public web sites, EU Institutions and Member States.

2.4 Conclusions

CEN, CENELEC, ETSI are the main European Standardisation Organisations. All issue standards related to COGAIN. CEN Technical Committee TC293 is working on Technical Aids for Disabled Persons. CENELEC Technical Committee TC205 is working on Home and Building Electronic Systems. ETSI has Technical Committee on Human Factors.

CEN, CENELEC, and ETSI established the ICT Standards Board. ICTSB has established the workshop "Design for All and Assistive Technologies", which created Guide 6. This is a set of guidelines to address the needs of older persons and people with disabilities when developing standards. The ICTSB Smart House initiative succeeded in agreeing a *"SmartHouse Code of Practice"*.

The most relevant organisations are the ICTSB based
Design for All and Assistive Technologies **[http://www.ictsb.org/DATSCG_home.htm] and**
SmartHouse Standards **[http://www.ictsb.org/SHSSG_home.htm].**

3 Interfaces and Protocols

The survey of de-facto standards in environmental control was conducted with respect to how we might incorporate gaze based control into these existing systems. This section first shows the elements of an environmental control system and then examines how gaze might be connected to such systems. It then examines what de-facto standard interfaces these system have, and what communication protocols they may have. Finally, the section briefly discusses if any systems might be suitable for gaze based control.

3.1 Elements of Environmental Control

For the purposes of this deliverable, environmental control systems may be thought of as comprising of five elements:

- **The communication capabilities of the user** – the physical capabilities of the user to convey their needs to the environmental control system (such as the ability to click a switch, or point with their eyes).
- **The user interface to the system** – to allow the user to control the environment via the interface by showing the state of the environment, and receiving user control input to that environment (such as a computer screen showing a graphical representation of the environmental state).
- **The central domotic system** – that processes user commands and environmental states and adds integration and intelligence to the system, receiving input from the user and the environment and sending out environmental control signals (the central computer based 'hub' of the system).
- **The communications system** – that flows to and from the central domotic system to the environmental actuators and sensors in the domestic environment (the wires or wireless transmission system that links the distributed actuators and sensors in the environment).
- **The domestic environment** – the real-world devices and functions controlled by the system (such as doors, heating systems, curtains, alarms).

A Smart Home for disabled people may include assistive devices (electro-mechanical/robotic systems for movement assistance), devices for health monitoring and special user interfaces. In the case of COGAIN it is a gaze based interface.

Examining which of these elements concern this deliverable, the communication abilities of the user are shown elsewhere (in Deliverable D3.1) and are open-ended and cannot be subject to standardisation, and nor can the wide range of domestic environmental objects a user may wish to control be standardised.

However, of concern to this deliverable are the three elements of the system itself – the user interfaces, the central domotic systems, and the communication system that flows to and from the central domotic system to the environment. For each of these elements we need to know how eye gaze may control these interfaces and systems, and how eye gaze control may be interfaced into any existing de-facto standard systems.

The relationships between the five elements of the system are shown (Figure 2).

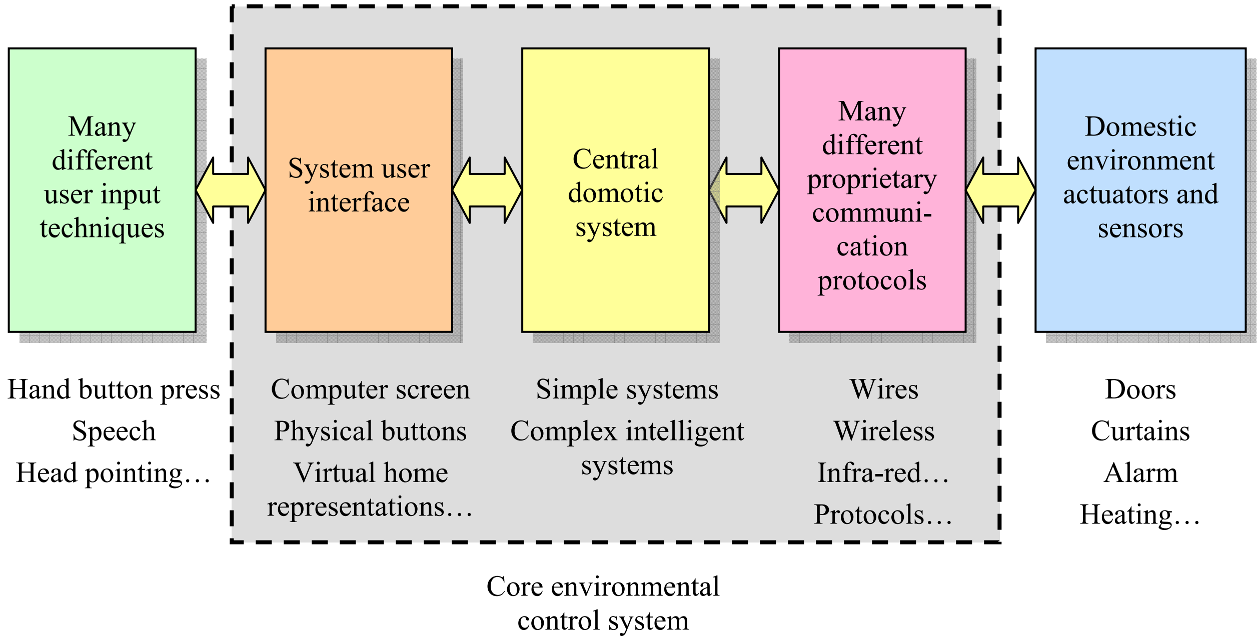

Figure 2. Overview of the elements of an environmental control system

3.2 Gaze Control

Interoperability is one of main issues in standardisation. Home Automation (Domestic) Systems are mostly closed solutions, which now are rapidly advancing in complexity. Hence, the Smart Home is a complex system, which consists of a large and wide ranging set of many Services, Applications, Equipment, Networks and Systems. They act together in delivering the "intelligent" or "connected" home in order to address security and control, communications, leisure and comfort, environmental integration and accessibility. These components are represented by many actors that interact and work together to provide interoperable systems that benefit the home-based user in the Smart Home. Because of this wide-ranging variability of the elements in the Smart Home, there is a very high level of potential complexity in identifying the optimal solution for integrating gaze based control into any particular Smart Home. We know that to enable gaze control of existing systems, gaze control must integrate with those existing systems without the need for modification of those systems due to the closed nature of these systems and the increasing inner complexity of the systems. There are three possible methods of integrating eye gaze control into such systems:

- The first (option 1) is to simply use gaze as a means of controlling the existing system and interface without modification.
- The second (option 2) is to bypass the existing interface and replace the system interface with a gaze-friendly custom interface into the central domotic system.
- The third (option 3) is to bypass the core system and integrate gaze control into the communication protocols with the environment.

These three approaches are illustrated (Figures 3, 4 and 5).

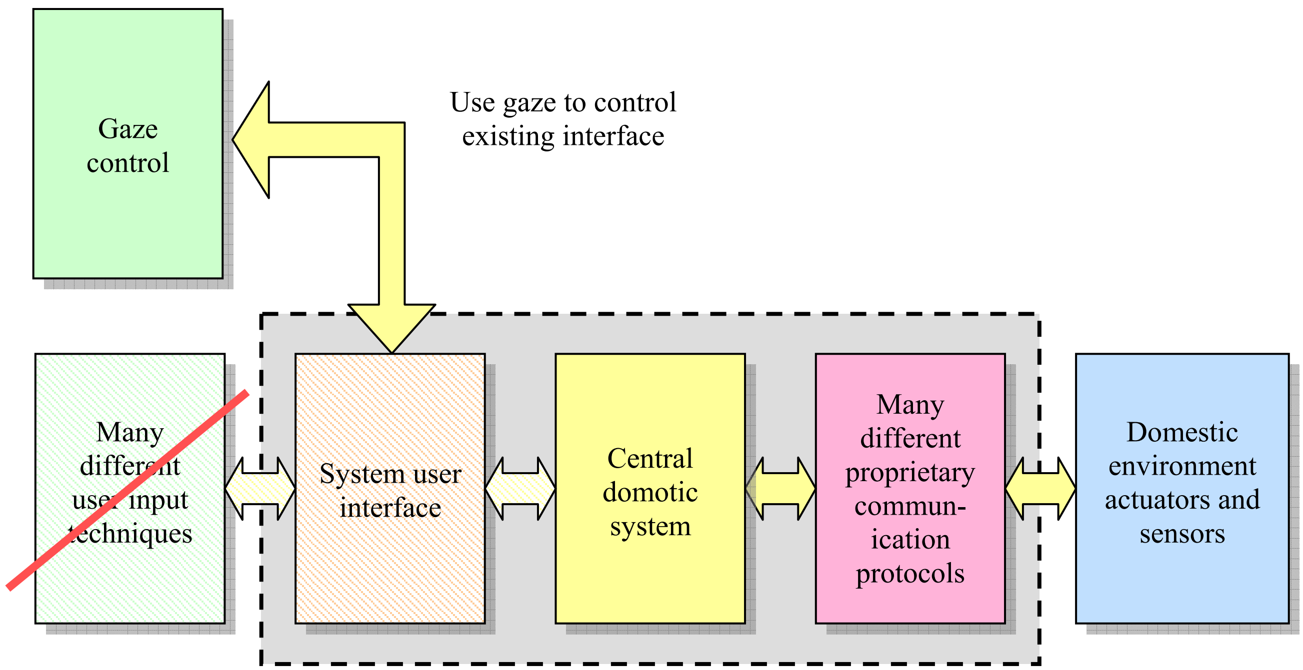

Figure 3. Option 1 – Integrating gaze on an existing interface

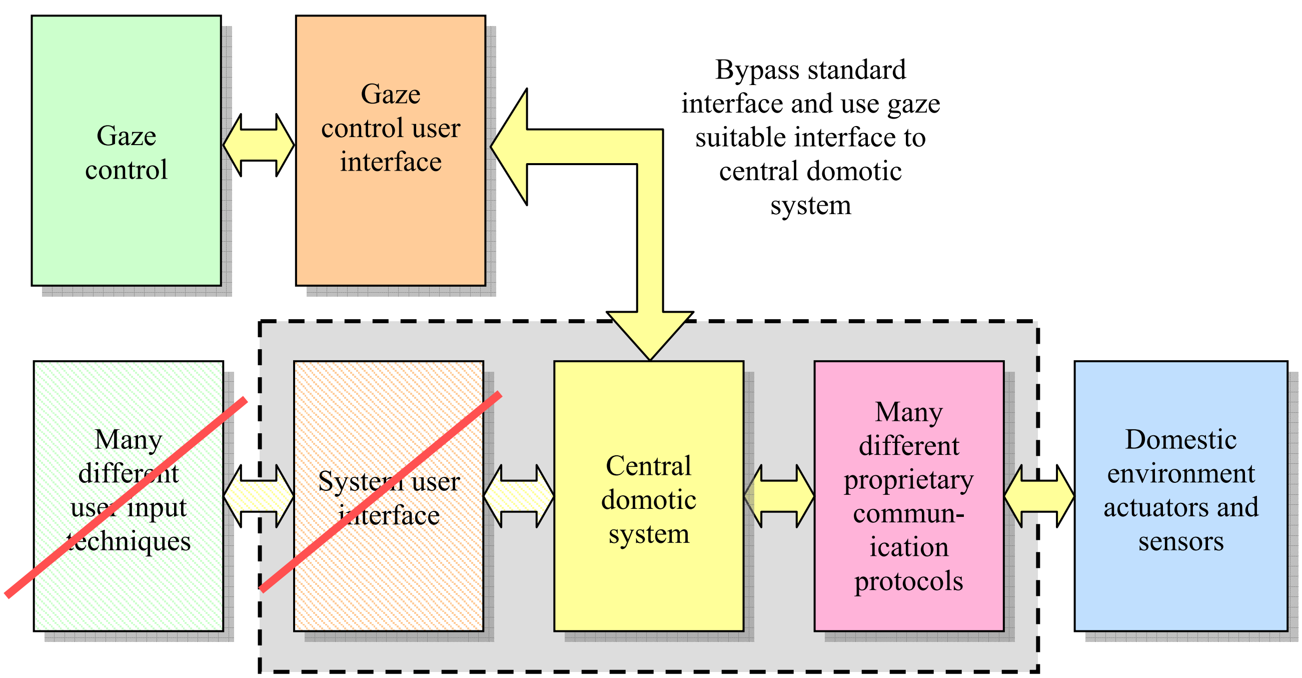

Figure 4. Option 2 – Integrating a custom gaze interface on an existing central domotic system

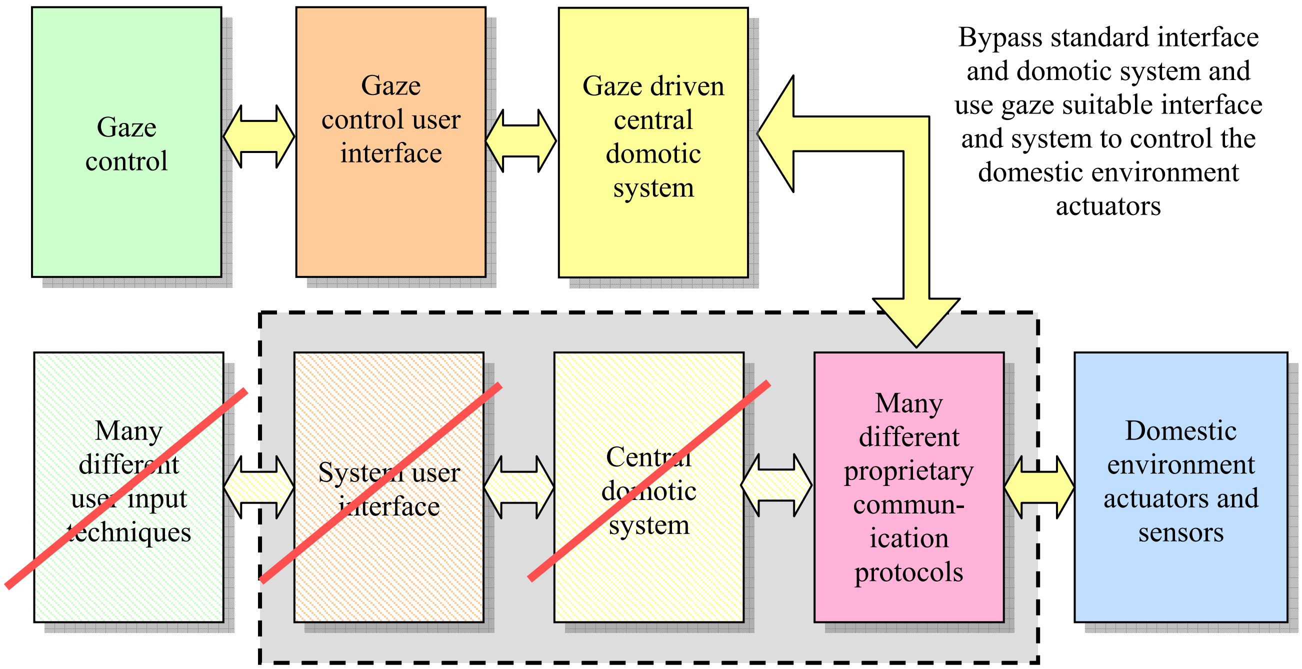

Figure 5. Option 3 – Integrating a custom gaze interface and controller on an existing communication protocol

In order to know how gaze control may be integrated in any of these three methods we need to know what type of interfaces are currently de-facto standards in use so we may determine if we can directly control these interfaces via gaze (option 1) or that we can replace these with gaze-friendly interfaces (option 2). We also need to know what communication protocols are currently de-facto standards so we can bypass the core domotic system and control the environment actuators directly (option 3).

To determine which of these options are available, a survey of de-facto standards of interfaces and communication protocols was required.

3.3 De-facto Standard Interfaces

Interfaces may be divided into the physical methods used to interact with the interface. Four methods in commercial usage were found:

- Computer based graphical user interfaces that require cursor-based pointing (such as a mouse or head pointer for example)
- Speech based interfaces that require distinct speech commands (such as saying ‘door’)
- Physical button or touch screen interfaces that require a physical contact with the interface (such as pressing the touch screen with a finger)
- Scanning based interfaces that could be controlled by a single remote switch (such as a hand-held click switch)

3.3.1 Graphical User Interfaces

These are interfaces that are displayed on a computer screen, and consist of graphical elements representing the various home control functions of the system. Examples of these systems are shown in Figures 6 to 8[10].

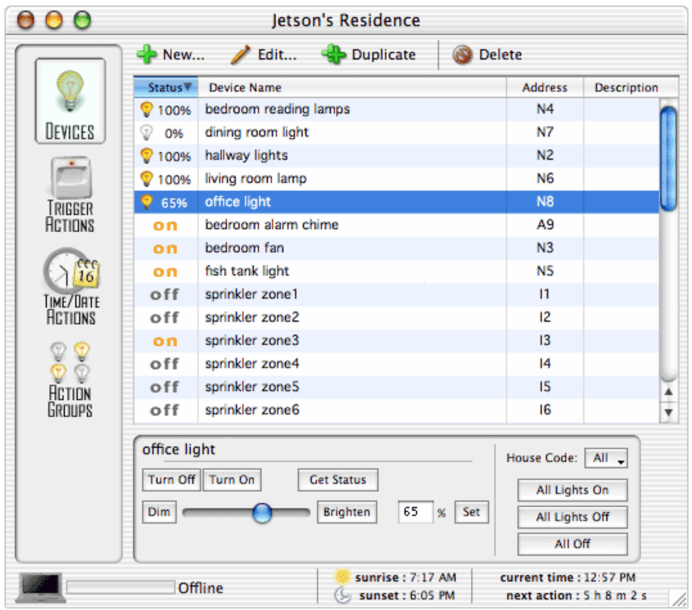

Figure 6. Indigo home control software 1430

[10] www.smarthome.com

Figure 7. PowerLinc V2 home control software

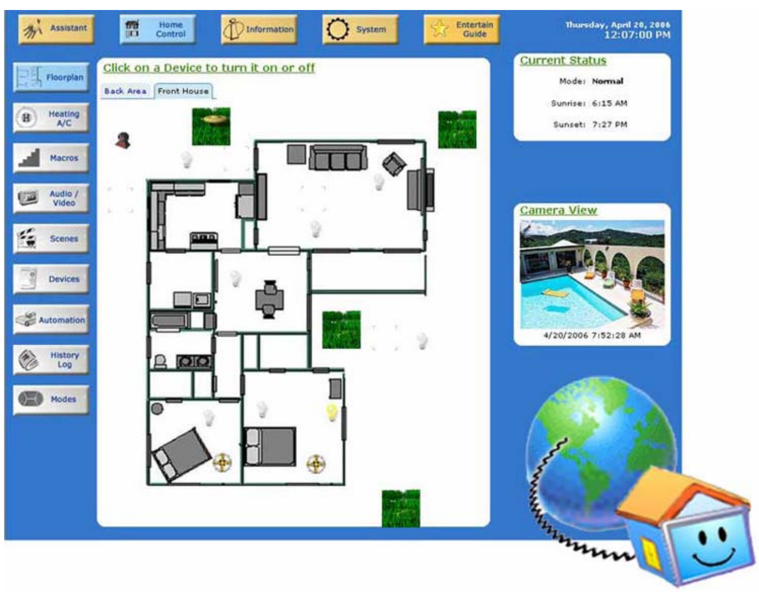

Figure 8. Central Home Automation Director

All of the graphical computer based systems had essentially the same properties of on-screen buttons and menu items to control functions, together with some form of pictorial feedback on the state of the system. These interfaces provide the greatest levels of control and functionality, and also the greatest levels of information about the state of the home system. However, they require complex and precise manipulation to control the often small interface icons.

3.3.2 Speech Based Interfaces

These are speech interfaces that consist of either a graphical display or a simple input device with no display that require clear speech to operate the various home control functions of the system. Examples of these systems are shown in Figures 9 to 10[11].

Figure 9. HALdmc Digital Music Center

Figure 10. HAL voice controller

These interfaces offer less information on the state of the home than graphical user interfaces, but can give a wide range of input commands depending upon voice distinction and distance from the microphones.

[11] www.smarthome.com

3.3.3 Physical Button Interfaces

These are physical interfaces that consist of tablets with either touch screen or physical buttons that require actual physical contact and force to operate the various home control functions of the system. Examples of these systems are shown in Figures 11 to 13[12].

Figure 11. 110417 OMNI TOUCH SCREEN

Figure 12. 12830T Elk 7-Inch TFT Touchscreen

[12] www.smarthome.com

Figure 13. 110722 HAI OMNI CONSOLE

These interfaces offer less information on the state of the home than graphical user interfaces, with often simplified and reduced interfaces. Manipulation of the home controls involves often multiple button presses and layers of sub-menus.

3.3.4 Scanning Based Interfaces

These are physical interfaces that consist of display screens or simple array of illuminated buttons or indicators that are sequentially automatically scanned (illuminated in sequence). These systems require only a minimum of a single on/off contact switch input (from any external switch or device) to operate the various home control functions of the system. Examples of these systems are shown in Figures 14 to 16[13].

Figure 14. Vivo! CONTROLLER

[13] www.possum.co.uk

Figure 15. HC2000B Freeway

Figure 16. HC1200 Compact

These interfaces are the most simple, offering very limited information on the state of the home, but require the simples form of control and can be operated via a single (remote) switch input. These interfaces, unlike graphical and touch screen/button interfaces, are specifically designed for users with physical disabilities and can accept a wide range of switch inputs from assistive technology devices.

3.4 Gaze Based Interfaces

These are graphical interfaces that consist of on-screen buttons or areas that may be activated by gaze control. Several gaze tracking system manufacturers provide some basic forms of gaze control of environmental control system, though none are compatible with each other.

3.4.1 LC Technologies

LC Technologies do provide a basic gaze controlled 'Lights and Appliances' program, which includes their own computer-controlled switching equipment. This system provides basic control of lights and appliances anywhere in the home. To use the system the user turns appliances on and off by looking at a bank of switches displayed on the screen, with commands sent to home sockets and light switches via the home mains electricity wiring via an X10 protocol.

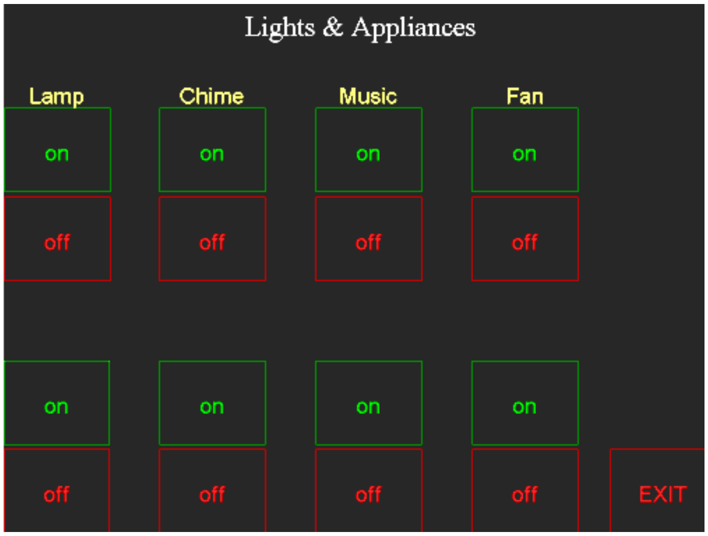

Figure 17. LC Technologies Lights and Appliances program[14]

The LC Technologies system goes some way toward environmental control, but is still quite limited in its functionality, as can be seen from Figure 17.

3.4.2 ERICA

The ERICA system[15] offers essentially the same basic functionality as the LC Technologies system, by presenting the user with a grid of buttons relating to environmental objects, with a main-borne X10 communication system. In addition the user may control an infrared transmitter that can be programmed with TV and other commands to control IR domestic environments.

[14] http://www.eyegaze.com/2Products/Disability/Disabilitymain.htm
[15] http://www.eyeresponse.com/Disabilities/Environmental_Control.aspx

3.5 De-Facto Standard Protocols

One of the main barriers to the development of environment control systems is the lack of a standard protocol, the "language" by which the various elements of control communicate among themselves. The protocol has been a subject of discussion among the principal market manufacturers since the origins of environment control systems, as the capability of one system to interact with other products depends on the format used. Common use of a standard protocol would be ideal, however, the current market has seen a large variety of protocols co-existing as well as many proprietary systems.

3.5.1 Protocols and Layers

The entities of home automation system need to exchange information with other entities both within that home and outside it. Traditionally entities that interact with each other were directly linked, e.g. light switch to the light, the TV-set with its antenna. Connecting an entity to a network allows it to communicate with multiple partners and provides extra flexibility, allows repositioning and accommodates changing requirements.

Perhaps the best way of describing where protocols lay in environmental control systems is to use the layer model standard ISO/IEC 7498-1. This defines seven layers of network, which are called OSI (Open System Interconnection) layers. The layers are divided to transport protocols and application protocols (Table 1).

When addressing Smart Homes, two additional layers were added by CENELEC (see section 2) – this was agreed as the "SmartHouse Code of Practice" in the form of the first CENELEC home-grown Workshop Agreement: CWA 50487)[16]. These new layers are Media and Pathways and Spaces. Both layers are incorporated into the transport infrastructure (Table 1).

Table 1. *The Modified OSI model [from CWA50487]*

<table>
<tr><th>Layer</th><th>Layer name</th><th>Protocols</th><th>Standard</th></tr>
<tr><td>7</td><td>Application layer</td><td rowspan="3">Application protocols</td><td rowspan="7">ISO/IEC 7498-1</td></tr>
<tr><td>6</td><td>Presentation layer</td></tr>
<tr><td>5</td><td>Session layer</td></tr>
<tr><td>4</td><td>Transport layer</td><td rowspan="4">Transport protocols</td></tr>
<tr><td>3</td><td>Network layer</td></tr>
<tr><td>2</td><td>Link layer</td></tr>
<tr><td>1</td><td>Physical layer</td></tr>
<tr><td>0</td><td>Media</td><td rowspan="2">Transport infrastructure</td><td rowspan="2">CWA50847</td></tr>
<tr><td>-1</td><td>Pathways and spaces</td></tr>
</table>

Note that information exchanged between entities of home automation network is split in three groups or superclusters, primarily characterised by their needs for bandwidth/bit rate [CWA50487]. The dividing line between these clusters is not very sharp, rather they overlap. Additionally, there are potential applications and

[16] http://www.cenelec.org/Cenelec/CENELEC+in+action/Horizontal+areas/ICT/SMARTHOUSE+-+PHASE+II.htm

services. The group of applications with the lowest transmission requirements is called CCCB (Commands, Controls and Communications in Buildings). It includes the electrical installation, HVAC, security devices, appliances (white goods). Examples of these devices are switches and dimmers, thermostats, radiator valves, window opening contacts, motion/smoke/glassbreak detectors, fridge, oven and washing machine, control panels, Intercom. The highest bandwidth is required for systems delivering Audio and Visual information (A/V) e.g. moving images like TV. Since music and sound radio very often are required at the same place as TV they are combined in the group called BCT (broadcast communications technologies). However, A/V data streams may not require perfect data integrity and may well accommodate and correct small failures in data delivery.

We may use the modified ISO model (Table 1) to show where the protocols we are surveying reside in the environmental control structure. Here these protocols lie in the lower layers (-1 to 1) that describe physical media (wires and wireless links) known as the transport infrastructures.

3.5.2 Transport infrastructures

Transport infrastructures are the physical ways in which command and control are relayed around the Smart Home. These communication medias can be divided to two groups:

1. **No new wires** – the use of existing wires in the home
2. **New wire** – the installation of new wires in the home

The first group (no new wires) consists of communication media using:

- Power lines
- Wireless
- Infrared

Second group (new wires) consists of communication media using:

- Coaxial cables
- Twisted pair cables
- Optical cables

3.5.2.1 Power Line Communications (PLC)

This solution allows to reuse the common power lines available in a home via signal modulation on the power lines. With this transmission technology it is necessary to handle some problems related to noise, attenuations, interferences and variation of impedance. Broadband over Power Lines (BPL) is the use of PLC technology to provide broadband Internet access through ordinary power lines. PLC modems transmit in medium and high frequency (1.6 to 30 MHz electric carrier). The asymmetric speed in the modem is generally from 256 kbit/s to 2.7 Mbit/s. OPERA[17] (Open PLC European Research Alliance) is a R&D Project with funding from the European Commission. It aims to improve the existing systems, develop PLC service, including BPL, and standardise systems.

The advantage of PLC is that power lines are already cabled to all power outlets. Actually home device control is often power control from power lines. PLC includes Broadband over Power Lines (BPL) with data rates sometimes above 1 Mbit/s and Narrowband over Power Lines with much lower data rates. In Europe,

[17] http://en.wikipedia.org/wiki/Power_line_communication

signal transmission via energy supply system currently is controlled by CENELEC standard EN50065. The frequency allocation is limited as follows:

- Range of 3 to 95 kHz: energy suppliers and their licenses
- Range of 95 to 148.5 kHz: available for general applications
- Over 148.5 kHz; forbidden range

Range of 95 kHz to 148.5 kHz is further divided into three bands:

- Band 1: 95 kHz to 125 kHz, without access protocol
- Band 2: 125 kHz to 140 kHz, with access protocol
- Band 3: 140 kHz to 148.5 kHz, without access protocol

3.5.2.2 Wireless Communications

Nowadays, communication through radio frequency has become very efficient for vocal and data transmissions, thanks also to the increased bandwidth and improved compression algorithms. In many cases this can be adopted as a cheap solution for homes and small offices. Wireless Communications is communication by radio frequency which has the advantage that there is no need for extra cables installation, except power line cables feeding any power requirements to systems. However, wireless communications also have some disadvantages:

- limited penetration of some building materials and damp;
- open medium that needs protection for many applications;
- information security risk, both easy to intercept and the traffic indicates presence or absence of user in the home;
- EMC and physiological effects need to be considered.

The over 40 member nations of the European Conference of Postal and Telecommunications Administrations (CEPT) have established a fairly high degree of standardisation throughout Europe on the operation of low power radio equipment. Most disagreements are in the nature of allowed modes and transmit duty cycles that may be accounted for in software control, allowing the same hardware and technical standards to be used throughout Europe. The ETSI develops technical standards for CEPT countries. Requirements are spread in bellow listed documents:

- ERC 70-03 (Relating to the Use of Short Range Devices (SRDs), April 2002)
- CEPT CISPR 16-1: 1999 (Specifications for radio disturbance and immunity measuring apparatus and methods: Part 1: Radio disturbance and immunity measuring apparatus)
- ETSI EN 300 328-1, 2 (Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Wideband Transmission Systems; Part 1 and Part2)
- ETSI EN 300 220-1 (Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Short Range Devices (SRDs); Part 1)

The industrial, scientific and medical (ISM) radio bands were originally reserved internationally for non-commercial use of RF electromagnetic fields for industrial, scientific and medical purposes. Examples of bands:

- 868-870 MHz band;
- 1.8 GHz band

- 2.4 GHz band;
- 5.8 GHz band.

Wireless Personal Area Networks (WPAN) operates in ISM band. Examples are Bluetooth and IEEE 802.15.4 standard.

3.5.2.3 Cables

Cables are secure, safe, and reliable. They are easy to install during building and refurbishing phase. As data rate requirements increase the advantages out weight the disadvantages of installation in a lived in home.

Disadvantages:

- unless ducts readily available laborious and disruptive to install in an inhabited home
- with unshielded cables EMC effects have to be considered specifically

During the building or refurbishing phase of a home the installation of a cabling system causes so little trouble and cost that such a system should always be installed. The upcoming European cabling standard for homes EN 50173-4, now under inquiry, will specify (and its international equivalent ISOI/IEC 15018, published 2004) already specifies an up to date cabling system for all applications that may be used in a home and that allow to pre-cable a building even if the application that will use the cabling will not be chosen for many years. This fixed cabling system should be well structured and documented and connect all the points where application specific equipment including senders and receivers of infrared and wireless may be connected at any later time. A guide on the planning and installation of pathways and spaces for cables is presented in CWA50487.

Cable based systems typically use a bus-base. Here systems with this transmission technology have each device connected to a shared line, or bus. Each bus is responsible for data transport and often also power supply. Usually the bus is an Unshielded Twisted Pair (UTP) which connects all the home appliances in parallel. Coaxial cables, twisted pair cables or optical cables may be used.

3.5.3 De-facto standard communication protocols

Since 1976, when the first automation standard (X10) was approved, many other systems standards have appeared. We hope that system descriptions presented below will help assistive technologies specialists and users to choose an appropriate system. Also, the material will inform the decisions of COGAIN to determine which protocols to support and integrate with gaze based control.

It is difficult to find common criteria for system evaluation because the systems are very different. When early systems appeared they were simple remote control systems where it was possible from one or more control panels to control remote devices, sending messages to them to actuate and so on. Practical usage of the devices revealed control system disadvantages and developers of next-generation systems attempted to overcome the disadvantages of previous systems. Some system stacks and protocols became very sophisticated, but this lead to increased resources and increased system costs. Other developers tried to create simple but more reliable systems.

The communications media of systems are very different. Firstly, systems defined their own protocols for physical layer communications, and later systems appeared which used worldwide popular physical and data link layers protocols. Also, systems were created that used protocols which based on the TCP/IP protocol, which was intended for Internet communication. Hence, there are is a diverse and differing collection of systems in use.

In order to assess the de-facto standards that may existing between systems and within systems, it is very important to know the fundamental control structures of the systems, these can be defined as:

- how devices (actuators, sensors etc) in the system are addressed;
- what is the format of these messages;
- what are the commands and their parameters;
- are there any hardware interfaces to a computer;
- what software applications and libraries are available for system control.

To understand the answers to these questions we need more knowledge about the underlying system. For example:

- the protocol stack;
- the available communication media(s);
- the available topologies.

Also, we must consider what factors are important for consumer issues. Considering only the most important commercial standards, the following sections discuss in detail what de-facto standards are currently found in use:

3.5.3.1 EIB[18]

This standard was developed by EIBA (European Installation Bus Association) which was a pool of European companies that operating on the production of electrical components and materials with the purpose of simplifying and automating electrical implants in buildings. The maximum length of the network cannot exceed 1000 meters for each segment, 700 meters among devices and 350 meters between power supply and bus. The physical addressing of any device is in straight-forwardly dependent from the device position inside the network. This standard has been already used in about ten thousand applications since its definition. It is one of the three standards that have joined Konnex (see KNX later). This standard has been already used in about ten thousand applications since its definition.

3.5.3.2 BATIBUS

This standard was defined in 1989 by several companies: AIRELEC, EDF, MERLIN GERIN, LANDIS & GYR that afterwards founded the Batibus Club International. It relies on a bus system, based on a shielded Twisted Pair that transports data among central computer, actuators, sensors and domotic appliances. Any device linked to the network (called Point) is uniquely identified by three codes: address, type and extension. The messages among devices inside the network can be addressed in different ways: direct, multicast and broadcast addressing. The maximum length of the network cannot exceed 2500 meters. This standard also joined in Konnex.

3.5.3.3 EHS (European Home System)

This project started in 1987 financed by European Commission with the aim of studying a universal interconnection among electrical and electronic domestic devices. It is an open standard that implements the levels 1, 2, 3 and 7 of the Open System Interconnection model (OSI) (see Table 1). This standard supports

[18] Section reference: Project Engineering for EIB Installations. Basic principles. 4th revised edition. EIBA. Available online as Silver Bible from http://www.konnex.org.

Plug & Play technology and also provides internal robustness and tolerance to communication errors, defective appliances and relocation of devices. An EHS network is able to configure itself automatically and can recover lost information. EHS is the third standard that joined in Konnex.

3.5.3.4 KNX (Konnex)[19]

The European Installation Bus Association was formed as a 'Societe Cooperative' under Belgium law by a number of leading European companies in the field of electrical installation engineering. The sole purpose of this organisation was to create a specification suitable for all aspects of building control, create the necessary software tools for Design, Configure and Commission. The KNX standard was defined in 1999 with the foundation of the Konnex association by EIBA, BCI and EHSA. Konnex aims to realize a "unique standard" for Home and Building automation. It is based upon the best features of the three former standards: it maintains full compatibility with the EIB standard that constitutes its core; it also integrates communication technologies and configuration capabilities from EHS and BATIBUS. The electrical components and devices, produced by different companies, are guaranteed to be KNX compliant only after being approved and certified by the Konnex association.

EIB proposes an open multi-vendor system for embedded home/building control networks. At the core of EIB, is its embedded control protocol. This 'protocol' is the digital language by which any number of devices in the building may communicate with each other. In this way, the devices can cooperate to perform distributed control application functionality. The specification also defines physical communication media, over which devices may send protocol messages to their partners on the system using Twisted Pair communication and Power line communication.

The EIB Association controls and manages the EIB protocol specification, which is laid down in the 'EIB Handbook for Developers'. This is done through an open Community Process, with reviews and voting cycles to which member companies of the Association may participate. Any manufacturer can develop his own implementations if he chooses to do so. EIB imposes no direct requirements on microprocessor architecture; this means any suitable chip may be used as a platform for implementation. Alternatively, a manufacturer may prefer to focus on his application domain know-how, and just construct application-specific hardware and firmware – using certified EIB building blocks (transceivers, protocol stack implementations, protocol stack source code etc.), offered by a number of specialised system providers.

Since 1984, several projects focusing on Home Systems has been funded by the European Commission. During these first projects, the major European white and brown goods suppliers as well as the European electricity and telecommunication utilities and manufacturers of installation equipment and systems have been involved. This involvement ensures the development of an open protocol with broad application spectrum allowing equipment from different manufacturers to communicate with each other. EHSA European Home Systems Association is an open organization aiming to maintain and to promote the EHS specification. Inside EHSA, the Standard Control Committee (SCC) is in charge of the enhancement of the EHS specification and of the co-ordination activities of the Inter-Operability Group (IOG) that ensures the inter-operability between equipment at the application level.

The EHS specification has been defined in order that home appliances can communicate and share each other's resources. EHS protocol is based on a shared communication system and on unambiguous definitions of the device functionality. The specification describes completely all the communications aspects. The EHS communication model follows the structure of the Open Standard Interconnection (OSI) reference model. EHS specifies the physical layer, the data link layer, the network layer and the application layer. Due to the fact that the message length is limited, the dialogue session is short and the command language is managed by the application layer, the transport, session and presentation layer has been omitted.

[19] Section reference: KNX Journal. Available online from http://www.konnex.org.

The application layer translates the application language in data frame able to circulate over the network. The Data Link Layers, separated in two sub-layers Medium Access Control (MAC) and Logical Link Control (LLC), handles the bit stream conversion, the rules for accessing the network, the recognition of frames and provides acknowledgement and repetition mechanism. The network layer is identical for all the EHS units and manages data related to the route (i.e. the addresses to reach a unit over several sub-layers).

The specification describes completely several physical layers. Several physical layers are already defined taking into account the variety of application requirements. Power Line (PL), Infra Red (IR) or Radio Frequency (RF) physical layers can be used in an existing home for low speed communication without any cabling cost. Twisted Pair (TP) cabling solutions or coaxial cable can be used when higher speed is required or when transmitting analogue signals. For example, communication over power line is well suited between energy management system and electrical heaters, In opposite way, communication over twisted pair is safer for a security system.

The KNX standard is based on the communication stack of EIB but enlarged with the physical layers, configuration modes and application experience of BatiBUS and EHS. KNX defines several physical communication media. Each communication medium can be used in combination with one or more configuration modes, which allows each manufacturer to choose the right combination regarding the market segment and application:

TP-0, (Twisted pair, type 0)

This communication medium, twisted pair, bit rate 4800 bits/s, has been taken over from BatiBUS. The KNX certified products designed for this medium, will operate on the same bus line as the BatiBUS certified components but they will not exchange information amongst each other.

TP-1, (Twisted pair, type 1)

This communication medium, twisted pair, bit rate 9600 bits/s, has been taken over from EIB. The EIB certified products and the products certified KNX, designed for this medium will operate and communicate with each other on the same bus line.

PL-110, (Power-line, 110 kHz)

This communication medium, power line, bit rate 1200 bits/s, i.e. the length of the bit is 833 µs. SFSK (Spread Frequency Shift Keying) is used. If a ‘0’ is transmitted, a frequency of 105.6 kHz is produced by the supply voltage and the supply voltage is superimposed. If a ‘1’ is transmitted, a frequency of 115.2 kHz is used. It has been taken over from EIB. The EIB / PL-110 certified products and the products certified KNX, designed for this medium will operate and communicate with each other on the same electrical distribution network.

PL-132, (Power-line, 132 kHz)

This communication medium, power line, bit rate 2400 bits/s, and is used in the EHS standard. For this reason it has been implemented in the KNX standard as well. KNX certified components designed for this medium and EHS 1.3a certified products, will operate together but will not communicate with each other, without a dedicated protocol converter. EHSA, in collaboration with the Konnex work-group "A-mode", will incorporate this type of converter in the A-mode sub protocol.

RF, (Radio frequency on 868 MHz)

This communication medium, radio frequency with a bit rate of 38.4 kbits/s, has been developed directly within the framework of the KNX standard. The data rate is 16,384 kBits/ s. This allows the transfer the same amount of frames per second as twisted pair. The reach is sufficient for an apartment or single family home. If needed the installation of re-transmitters can extent the range.

The KNX Standard incorporates three different configuration modes:

The "S-mode" (System mode)

This configuration mechanism is meant for well trained installers to implement sophisticated functions. All "S-mode" components connected to the network are addressed by the common software tool (ETS), for planning, configuration and linking. With ETS each component can exactly be programmed, according to the specified requirements. The "S-mode" has the highest degree of flexibility in functionality and in communication links.

The "E-mode" (Easy mode)

This configuration mechanism is meant for installers with a basic training providing a fast learning curve solution but with limited functions, compared to "S-mode". The "E-mode" components are already pre-programmed and loaded with a default set of parameters. With a simple configurator, each component can be partly reconfigured, this applies mainly to parameter settings and communication links. It is possible to mix in an KNX network E- and S-mode components. The common overall software tool ETS, makes it possible to link these components together and may even reconfigure the previous configuration settings.

The "A-mode" (Automatic mode)

This configuration mechanism is specially developed for end-user applications e.g. household appliances or consumer installation add-ons, sold via the end-user sales channels. The "A-mode" components have automatic configuration mechanisms, that adapt their communication links to other "A-mode" components in the network. Each component contains a fixed setting of parameters and a library with instructions how to communicate with other "A-mode" components. More than 14000 bus devices can be connected to the bus system.

A product designed with one of the above mentioned configuration modes, in combination with one of the above mentioned communication media, results in a KNX compatible device, certifiable by Konnex Association. Members of Konnex Association are convinced that the Home and Building market requires open, flexible and interoperable solutions in the communication between controllers, actuators and sensors for standard applications on field bus level. The KNX standard is the first one which corresponds to these needs.

There are two programming possibilities for developers: Falcon and EIB OPC Server:

FALCON[20]

Falcon is a DCOM-based 32-bit access library for Windows. It offers an API for all aspects of bus/device access/management, such as group telegrams, device properties, physical addresses and many more. Thanks to the usage of DCOM and .NET, access is possible for programming environments that suitably support these models; furthermore scripting languages like VBA can be used to access KNX/EIB networks from office applications.

[20] Section reference: http://www.konnex.org/knx-tools/falcon/description/

EIB OPC Server[21]

With the EIB OPC server, it is possible to access and control the processes on an KNX/EIB network from virtually any standard process visualisation toolkit or environment on Windows platforms.

OPC stands for "OLE for Process Control. Technically spoken, the KNX/EIB™ OPC Server is an OPC Server layer put on top of eteC Falcon®, the high-level bus access component from KNX/EIB networks. The KNX/EIB™ OPC Server is fully compatible with the KNX/EIB™ Tool Software (ETS™), meaning that it can directly extract the necessary configuration information of a particular ETS™ project.

KNX different configuration modes in combination with its different communication media, makes KNX the No.1 field bus choice for all Home and Building applications in Europe. It has become basis of standards CENELEC EN50090 and CEN EN13321-1. At the same time the KNXnet/IP protocol was submitted for approval at the CEN for the future EN 13341-2 standard. On a world-wide level the KNX-protocol became certified as Final Committee Draft for ISO/IEC JTC1 SC25.

3.5.3.5 X-10[22]

X-10 is an industry standard for communication among devices used for home automation. It primarily uses power line wiring for signalling and control, where the signals involve brief radio frequency bursts representing digital information. A radio based transport is also defined.

X10 was developed in 1975 by Pico Electronics (PICO) of Glenrothes, Scotland, UK in order to allow remote control of home devices and appliances. The PICO engineers subsequently relocated to Hicksville, New York and continued with their efforts. It was their 10th project, hence the term X10, which has been used to describe the signalling technique. The X10 team subsequently named their new home automation company X10 Ltd., and relocated to Closter, New Jersey. Later X10 Wireless Technology Inc., an offshoot of the original company was established whose purpose was to broaden the market by wireless devices.

X-10 operates on power lines. The key is for every device to have an integral zero crossing detector so that all of them were synchronized together. A receiver opens its receive window twice each sine wave. That is 120 times each second, when electrical power frequency is 60 Hz (products also are available that are designed for use on 50 Hz electrical distribution systems). The binary data is transmitted by sending 1 ms burst of 120 KHz just past the zero crossing of the 60 hertz power. A binary 1 is defined as the presence of a pulse, immediately followed by the absence of a pulse. A binary 0 is defined as the absence of a pulse, immediately followed by the presence of a pulse. While the transmitted pulses are to be a full 1 ms in duration, the receivers are designed to open a receive window of only 0.6 ms. That allowed for the loose tolerances of components to shift plus or minus 200 microseconds.

In order to provide a predictable starting point, every data frame always begins with at least six leading clear zero crossings. The sequence of six "zero's" resets the shift registers that decode the received data packets. Then a start code of frame: "pulse," "pulse," "pulse," "absence of a pulse" is sent. Immediately after the start code, a letter code/house code (A–P) is sent and after the letter code, comes a function code. Function codes may specify a unit number code (1–16) or an actual command code, the selection between the two modes being determined by the last bit where 0=unit number and 1=command). One start code, one letter code, and one function code is known as an X10 frame and represent the minimum components of a valid X10 data packet.

To allow the operation of wireless keypads, remote switches, and the like, a radio protocol is also defined. Operating at a frequency of 310 MHz in the U.S. and a different frequency in the rest of the world, the wireless devices send data packets that are very similar to ordinary X10 powerline control packets. A radio

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[21] Section reference: http://www.konnex.org/knx-tools/opc-server/description/

[22] Section reference: X-10® To UPB™ Migration Document.V 1.1 09/25/03. Powerline Control Systems. Web link: http://simply-automated.com/documents/X10ToUPB.pdf.

receiver then provides a bridge which translates these radio packets to ordinary X10 powerline control packets. Taking into account retransmission, line control, etc, data rates are around 20 bit/s, making X10 data transmission so slow that the technology is confined to turning devices on and off or other very simple operations. The relatively high-frequency carrier frequency carrying the signal cannot pass through a power transformer or across the phases of a multiphase system. In addition, because the signals are timed to coincide with the zero crossings of the voltage waveform, they would not be timed correctly to be coupled from phase-to-phase in a three-phase power system. For split phase systems, the signal can be passively coupled from phase-to-phase using a passive capacitor, but for three phase systems or where the capacitor provides insufficient coupling, an active X10 repeater is sometimes used.

It may also be desirable to block X10 signals from leaving the local area so, for example, the X10 controls in one house don't interfere with the X10 controls in a neighbouring house. In this situation, inductive filters can be used to attenuate the X10 signals coming into or going out of the local area.

The X-10 specification defines 256 addresses (16 house codes with 16 unit codes). Whether using powerline or radio communications, packets transmitted using the X10 control protocol consist of a four bit "house code" followed by one or more four bit "unit codes", finally followed by a four bit "command". For the convenience of the users setting up the system, the four bit house code is labelled as one of the letters A through P while the four bit unit code is label as a numbers 1 through 16. When the system is installed, each controlled device is configured to respond to one of the 256 possible addresses (16 house codes * 16 unit codes) and it will then only react to those commands specifically addressed to it. Note that there is no restriction (except possibly consideration of the neighbours) that prevents using more than one house code within a single house. The "all lights on" command and "all units off" commands will only affect a single house code, so an installation using multiple house codes effectively has the devices divided into separate zones.

Today, several companies in addition to X10 Ltd produce X10 compatible Smart Switches & Receptacles for home automation. They are SmartLinc, Powerline Carrier Systems (PCS), Leviton, Monterey, and others. X10 Europe produce products for countries with 230 V 50 Hz power net.

There are two programming possibilities for developers: USB and serial port:

A computer can control X10 network in Europe using Simply Automate (http://www.simplyautomate.co.uk) X10 computer interface products via USB (CM11USB) or serial port (CM11E). The Computer Interface fits between the AC outlet and the computers power plug. A grounded AC socket is provided on the front of the interface for the computers power plug (3A max). A cable with an RJ11 connection on one end and a standard USB connector on the other is provided to connect the interface to any free USB port in the PC. The Computer Interface is fully two-way, both generating and receiving X10 powerline commands

ActiveHome Software is a user friendly Windows compatible software is provided with the interface which includes graphical representations of switches, modules etc. to provide point-and-click control of modules, and easy setting of scheduled events and macros. Events may be scheduled to occur at a particular time every day, on chosen days only, between chosen dates etc. The also can be programmed. This product is CE approved for use in the EU. Harmony 5.1 – is product from UK developer of home automation software iDomus (http://www.idomus.co.uk/) for Windows 2000 / XP. It has Lite, Gold, and Pro versions. There are 4 ways to interface with / modify Harmony:

- The Web API: a simple HTML based interface with Server Side Variables and control strings. It can be customised using Dreamweaver, Frontpage, Notepad etc
- The HAPI - TCP/IP sockets based low level, high speed interface
- The XML API designed for output / status monitoring only. Allows you to implement skins very simply

- The Plugin Interface API - write your own VB / Visual C++ interfaces that load directly into Harmony

All of these interfaces are described in the support sections of the iDomus website (http://www.idomus.co.uk/).

X10 was the first domotic technology and remains the most widely available. But now it seems obsolete. Data rates are very low - around 20 bit/s. To summarise, with its tiny command set and poor reliability X10 protocol is simply too limiting for today's home environment control.

3.5.3.6 INSTEON[23]

INSTEON was developed at SmartLabs Technologies over 5 years of R&D and testing. The INSTEON Alliance (http://www.insteon.net) is a forum that brings together a community of independent product developers and technologists to share best practices, contribute to the development of INSTEON and leverage marketing strengths towards the goal of developing the next generation of electronic home improvement solutions. More than 600 developers have joined the INSTEON Alliance. INSTEON is: affordable, reliable, simple to use.

Table 2. *INSTEON Specifications*

Powerline Frequency:	131.65 kHz, devices auto switch to X10 band at 120 kHz
Radio Frequency:	902- 924 MHz (ISM Band) (900 MHz is ideal for penetrating the structure of a home. INSTEON does not interfere with other devices)
RF Sensitivity:	103dbm
RF Modulation:	FSK
RF Range:	150 feet, line of sight
Speed:	10 messages per second, maximum
Supported Devices:	16,777,216 (no limit on nodes per network)
Possible Commands:	Over 65,000 (On, Off, Dim, Lock, Open, etc.)
Battery Power Consumption:	Extremely low

INSTEON's unsurpassed reliability is due to its dual-mesh network, which means that messages between devices are sent both wirelessly through Radio Frequency (RF) and through your home's existing electrical wiring. Every message is confirmed as it is received, and if any errors are detected, the message is automatically resent. The network is also redundant; every device on an INSTEON network receives and sends every message to every other device, so instead of stressing the network by adding more INSTEON devices, you actually strengthen it.

Every INSTEON device has an unique 24 bit address, all transmissions are encoded onto the network. Additionally, INSTEON is designed to support additional device based encryption technologies Every

[23] Section reference: Insteon compared. January 2, 2006, SmartsLabs Technology. http://www.insteon.net/pdf/insteoncompared.pdf,
Insteon. The details. August 11, 2005, SmartsLabs Technology. Web link: http://www.insteon.net/pdf/insteondetails.pdf.

INSTEON device is a repeater - so the signal gets through every time. Every INSTEON message is confirmed, or the transmitter will automatically retry until a confirmation is received. INSTEON messages take less than 5 /100ths of a second to get through - so things turn "on" instantly (INSTEON = instant-on). No central controller or networking setup is required - a simple plug-n-tap™ is all that is required to link one INSTEON product to another.

Reliability of INSTEON. Nearly 100%. Over 10 million signal packets were tested in over 100 homes across America. A near-perfect success rate of over 99.97% was measured. Each INSTEON message contains error detection, so lights turning on accidentally will virtually never happen. Each message must be confirmed or automatic retries will be made - making sure that your message gets through. Since every INSTEON-enabled product is a repeater, the reliability increases as you install more INSTEON-enabled products.

Affordable. Perhaps the most remarkable thing about INSTEON is its affordability. INSTEON can be integrated into any number of products easily and at a very low cost, so it will impact your life a whole lot more that it will impact your wallet. Other technologies claim to be affordable, but none of them get close to the $20 price point that INSTEON-enabled products hit.

Speed. INSTEON messages get through in less than 0.05 seconds. Humans cannot see "delays" of less than about 0.20 seconds. Therefore, there are no visible delays when using INSTEON.

X10 Ready. INSTEON is also compatible with X10 devices, so if you've already started putting together a home control network, you don't have to start from scratch. It's advanced digital signal processing means messages of up to 14 bytes get sent very rapidly, and the number of developers in the INSTEON Alliance, currently over 500, continues to grow. INSTEON-enabled products repeat INSTEON messages, but not the X10 messages.

The INSTEON network is an integrated (RF, Power line) redundant, non-supervised, peer-to-peer network. There is no need for routing tables, each device in the network receives messages simultaneously, independent of whether the message originated via a wireless or power line device. Network devices will "repeat" the signal based on message settings. Devices will start at $19.99 retail. INSTEON is a very cost-effective technology to integrate into a wide range of products. INSTEON will be introduced with an Ethernet, USB and serial bridge to allow communications with the Internet, computers and wide variety of security and wiring panels. Additionally, INSTEON supports communications with existing X-10 based devices. Smarthome expects development of additional bridges to other network technologies based on market demand.

One of the significant advantages of the new INSTEON technology is it's backwards compatibility with existing X-10 products. As an example, an INSTEON switch can turn on an X-10 lamp module and an X-10 switch can turn on an INSTEON lamp module. Homeowners can continue to purchase X-10 devices today and then migrate over time to INSTEON. Although Smarthome has not yet designed devices for voltages other than 110VAC/60Hz, the INSTEON technology supports other voltages.

Available products to connect INSTEON to a PC include PowerLinc serial and USB computer interfaces.

3.5.3.7 CEBUS[24]

CEBus (Consumer Electronic Bus) was released in 1992 by Electronic Industries Alliance (EIA) after eight years of work. The purpose of CEBus was to go over the X-10 limitations. In 1994 the CEBus Industry Council (CIC) was formed as a non-profit organization of member companies providing EIA-600 related products and service. The CIC oversees marketing, application definition, interoperability, and certification of compliance. As certification agent, CIC administer the CEBus mark and related logos.

This EIA-600 specification utilizes a description of protocol layering that corresponds with the OSI model. It defines 4 from 7 OSI layers (Physical, Data Link, Network, Application). For EIA-600, the model has been extended to include the requirements for inter-layer management and the specification of the various media used by EIA-600 devices. CEBUS standard supports several communication media and technologies: power line wiring, low voltage twisted pairs, coaxial cables, fiber optics, and infrared and radio frequency wireless devices (Figure 17).

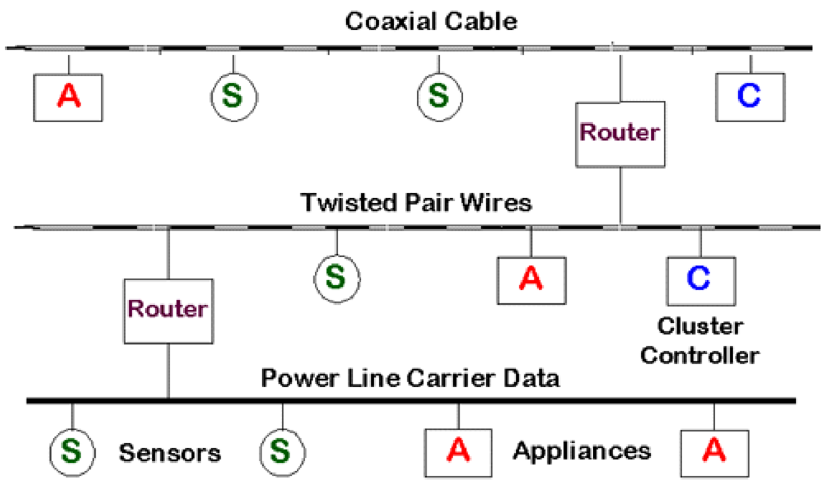

Figure 17. A typical CEBus network[25]

The Application Layer consists of four main elements as shown in Figure 18. The Application Process is the interface to the Application Layer. Services are provided by the Common Application Language (CAL) Element to the User Element of the Application Process. CAL is the language framework through which Resource Allocation and Control functions are executed. Services are provided by the Message Transfer Element to the CAL Element. The Message Transfer Element interfaces to the Network Layer either directly or through the Association Control Element.

An Application process is the element in the device domain which performs the information processing. An Application Process may be considered to be a person or a processor or a combination of the two. Connection to the Application Layer is provided by the User Element of the Application Process. The User Element calls on the services of the CAL Element to execute the desired Application Process functions. A real CEBus-compliant device should be implemented keeping in mind the nature of the underlying network. The network is a public resource with random access by all nodes on the medium. The Application Process should attempt

[24] Section reference:, EIA-600.10. Introduction to the CEBus. Standard Revision: 2-5-95. Draft copy. Available online from http://www.cebus.org/

[25] www.hometoys.com

to minimize traffic to maintain the highest overall performance for all nodes. Polling as a means of frequent updates is discouraged.

Layer System Management administers functions which have significance across layer boundaries or to the device as a whole. These functions may be of local importance, such as addressing, or of system-wide importance, such as routing information.

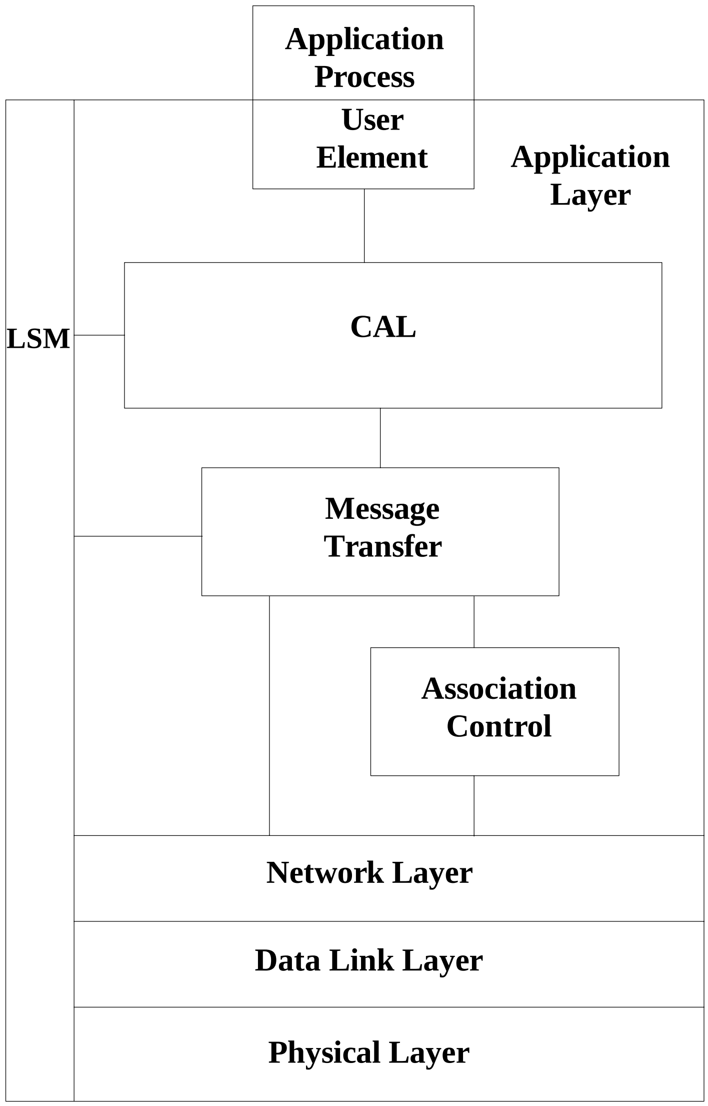

Figure 18. Application Layer Interfaces[26]

[26] From Joseph Jeon (2002) A Survey on Protocols for Home Networks based on Power Line Communication, Proceedings on the 15th CISL Winter Workshop · Kushu, Japan · February 2002

CAL is the language by which CEBus-compliant devices communicate. CAL is a robust language that is not dedicated to a particular function within the Application Layer. Instead, it provides a language for controlling devices and allocating resources. Resource Allocation is a function within the CAL Element. Resource Allocation is the general term for the function of requesting, using, and releasing network resources. These resources include, but are not limited to, Medium Access Control (MAC) individual addresses, group addresses, system addresses (house codes), and data channels. An Application Process may request the services of the CAL Element to acquire a resource. Within the CAL Element, the Resource Allocation function creates Application Service Data Units (ASDUs) using the CAL syntax that request, assign, or release network resources. The CAL Element calls on the services of the Message Transfer Element to deliver the ASDU to the destination. The Control function within CAL is responsible for constructing and interpreting those ASDUs having to do with control and operation of CEBus-compliant devices. Control ASDUs are assembled by the Control function using the CAL syntax. The CAL Element calls on the services of the Message Transfer Element to deliver the Application Layer Service Data Unit (ASDU) to the destination.

The Message Transfer Element is the communications element in the Application Layer. All ASDUs that are generated either internally or as a result of an Application Process are handled by the Message Transfer Element. The Message Transfer Element assembles Application Layer Protocol Data Units (APDUs) and passes them directly or via the Association Control Element to the Network Layer. CAL provides two main functions: Resource Allocation and Control. Requests for these services are received from both the User Element and Layer System Management. Using CAL syntax, CAL translates these requests into Application Layer Service Data Units (ASDUs) and passes them to the Message Transfer Element for delivery. The CAL element also receives and interprets incoming ASDUs.

The Resource Allocation function within CAL is concerned with requesting, using, and releasing CEBus resources. These resources include, but are not limited to Unit individual addresses, Group addresses, House Codes, and data channels. The Node Control, Data Channel Receiver, and Data Channel Transmitter Objects are used to perform the Resource Allocation function. Allocation of addresses is a significant function of CAL. The Node Control Object of the Universal Context is responsible for management of the three types of addresses in the CEBus network, Unit addresses, House Codes, and Group addresses. A device can determine its Unit address and House Code either statically or dynamically. In a dynamic device the House Code is determined by asking other devices within the home for their system address, and the Unit address is determined by selecting an address not currently used under that House Code. In a static device, the addresses are not determined by interaction with the home network, but by some other means. Group addresses can also be determined statically or dynamically. Membership in a group is determined by the home user. For instance, a bank of lights in a room may always be turned on or off together. By selecting a Group address and asking each of the lights to join the group, a single transmission can be used to manipulate all of the lights together. Note that support of group membership is NOT mandatory in order for a device to comply with this standard.

There are opportunities for development for both hardware and software interfaces:

There are three CEBus IC manufacturers, Domosys Corporation, Intellon Corporation and Itran (http://www.cebus.org/proddir.htm). The various IC products are the CEWay PL-One, CEWay PL-III, the SSC P300, the SSC R400, the IT-5000 and the IT-800 series. All of these products are Power Line (PL) solutions except for the R400 that is a Radio Frequency IC. These PL ICs' price range approximately from $4 to $8 in quantity. There are two software development tool manufacturers, Domosys Corporation and ACS. Those tools are CEBox and CEBench. These same manufacturers also offer various hardware development platforms, the CEBoard 8051, HC11 or CEWay PL-One, the RS-232 CECom, the Maxi-PLC Modules 8051 or HC11, the ISA CENode-PL x86 ISA card and the PC-104 CENode PL PCB. These development platforms are priced between $200 - $500. You can also find extremely good test tools at Domosys Corporation, ACS and CCI. These tools are the CETester, the CEBusAlyzer and the CEBugger. Although CEBus became US standard, it has not become popular worldwide.

3.5.3.8 Lonworks[27]

LonWorks (Local Operating Network works) was created by Echelon Corporation (http://www.echelon.com) in the mid-nineties. It defines a complete, open, and media independent platform to manage devices connected to a network. In 1994 Echelon and group of LonWorks users created Lonmark Interoperability Association (http://www.lonmark.org), dedicated to building interoperable products. The Association develops technical product specifications and guidelines, which ensure that products designed accordingly will interoperate. It also develops and publishes functional profiles which describe in detail the application layer interface, including the network variables, configuration properties, and default and power-up behaviours required for specific, commonly used control functions. Thus, the Association focuses on two areas:

1. specification of standard transceivers and the associated physical channels;
2. definition of standards for structuring and documenting device application programs.

The major elements of LonWorks are:

- LonTalk protocol, that is a collection of services that supports reliable communication among nodes and makes efficient use of the communications medium (ANSI/EIA709.1-B).
- Neuron chips, contained in LonWorks nodes, that process all LonTalk protocol messages, sense inputs and manipulate outputs, implement application-specific functions and store installation-specific parameters.
- LonWorks transceivers, that provide capabilities of communication with different transmission technologies.
- Network management and applications software, that greatly simplifies the traditional network approaches because the products use a standard protocol and are interoperable.

LonWorks is a general purpose and peer-to-peer network. The LonTolk stack implements seven protocol layers, similar to the ISO/OSI seven-layer reference model. The term “general purpose” alludes to its large variety of applications in trains, buildings, production plants, etc. The majority of LonWorks nodes are used in building automation, since modern office buildings are sometimes equipped with up to 70.000 nodes.

Since LonWorks is a peer-to-peer network, its network management is relatively sophisticated. There are virtually no simple “slaves” but rather peers with a distinctive need for network management. Large LonWorks networks use high speed channels (LonTalk/IP or 1.25 Mbit/s twisted pair) as backbones that - via routers - interconnect the standard 78 kbit/s twisted pair segments of the field devices. The network topology of the famous FTT10 channel is as flexible as can be, there is no need for nerving bus-, tree- or any other topology. It is robust, galvanically insulated, polarity-insensitive and - despite its costs - maybe one of the main reasons to choose LonWorks over other technologies.

Nodes can be built at relatively low costs, depending on their hardware features and their performance starling from approximately USD 10. Originally the only hardware for LonWorks nodes came from Echelon: the so

[27] Section reference: Introduction to the Lonworks® System. Version 1.0, 1999, ECHELON Corporation. Web link: http://osa.echelon.com/Program/LonWorksIntroPDF.htm.

called Neuron Chip, produced by Toshiba and Cypress. This one chip ensured consistent application by all manufacturers.

LonWorks technology is standardized in the USA under EIA 709.x and in Europe under prEN 14908-x. These standards cover the LonTalk protocol stack and the physical media. The functional profiles are not vet standardized. The protocol is therefore freely available to anyone. Meanwhile other companies start to implement LonWorks technology in hard- and software which further stimulates competition and innovation. The ANSI/EIA standard, however, allows any company willing to undertake the investment to implement the protocol in the microprocessor of their choice.

***Table 3**. LonWorks channels characteristics*

Channel Type	Medium	Bit Rate	Compatible Transceivers	Maximum Devices	Maximum Distance
TP/FT-10	Twisted pair, free or bus topology, opt. link power	78kbps	FTT-10, FTT-10A, LPT-10	64-128	500m (free topology) 2200m (bus topology)
TP/XF-1250	Twisted pair, bus topology	1.25Mbps	TPT/XF-1250	64	125m
PL-20	Power line	5.4kbps	PLT-20, PLT-21, PLT-22	Environment Dependent	Environment Dependent
IP-10	LonWorks over IP	Determined by IP network	Determined by IP network	Determined by IP network	Determined by IP network

In LonWorks networks packets can be addressed to a single device, to any group of devices, or to all devices. To support networks with two devices to tens of thousands of devices, the LonWorks protocol supports several types of addresses, from simple physical addresses to addresses that designate collections of many devices. Following are the LonWorks address types:

- Physical Address
- Device Address
- Group Address
- Broadcast Address

Physical Address. Every LonWorks device includes a unique 48-bit identifier called the Neuron ID. The Neuron ID is typically assigned when a device is manufactured, and does not change during the lifetime of the device.

Device Address. A LonWorks device is assigned a device address when it is installed into a particular network. Device addresses are used instead of physical addresses because they support more efficient routing of messages, and they simplify replacing failed devices. A network installation tool that maintains a database of the device addresses for the network assigns the device addresses. Device addresses consist of three components: a domain ID, subnet ID, and node ID. The domain ID identifies a collection of devices that may interoperate. Devices must be in the same domain to exchange packets. There may be up to 32,385 devices in a domain. The subnet ID identifies a collection of up to 127 devices that are on a single channel, or a set of channels connected by repeaters. Subnet IDs are used to support efficient routing of packets in large networks. There may be up to 255 subnets in a domain. The node ID identifies an individual device within a subnet.

Group Address. A group is a logical collection of devices within a domain. Unlike a subnet, however, devices are grouped together without regard for their physical location in the domain. There may be any number of devices in a group when unacknowledged messaging is used; groups are limited to 64 devices if acknowledged messaging is used. Groups are an efficient way to optimize network bandwidth for packets addressed to multiple devices. There may be up to 256 groups in a domain.

Broadcast Address. A broadcast address identifies all devices with a subnet, or all devices within a domain. Broadcast addresses are an efficient method to communicate with many devices, and are sometimes used instead of group addresses to conserve the limited number of available group addresses.

Every LonWorks packet transmitted over the network contains the device address of the transmitting device (the source address) and the address of receiving devices (destination address) that can either be a physical address, a device address, a group address, or a broadcast address. Multiple domains are used if the number of devices exceeds the allowed domain limit or if there exists a desire to separate the devices so that they do not interoperate. It is possible for two or more independent LonWorks systems to coexist on the same physical channel, as long as each system has a unique domain ID. Devices in each system respond only to those packets corresponding to their domain ID and do not know about or care about packets addressed with other domain IDs. Devices also respond to packets addressed with their own physical address, which is usually known only to the corresponding network installation tools. When a physical network is shared, overall network response times will be affected due to the increased number of packets, so coordinated overall network design is required.

The LonWorks protocol offers three basic types of message delivery service and also supports authenticated messages. An optimized network will often use all of these services. These services allow trade-offs between reliability, efficiency, and security, and are listed below:

- Acknowledged Messaging;
- Repeated Messaging;
- Unacknowledged Messaging.

Acknowledged Messaging. Provides for end-to-end acknowledgement. When using acknowledged messaging, a message is sent to a device or group of up to 64 devices and individual acknowledgements are expected from each receiver. If acknowledgements are not received, the sender times out and retries the transaction. The number of retries and the timeout are both configurable.

Repeated Messaging. Causes a message to be sent to a device or group of any number of devices multiple times. This service is typically used instead of acknowledged messaging because it does not incur the overhead and delay of waiting for acknowledgements. This is especially important when broadcasting information to a large group of devices, as an acknowledged message would cause all the receiving devices to try to transmit a response at the same time.

Unacknowledged Messaging. Causes each message to be sent once to a device or group of any number of devices and no response is expected. This messaging service has the lowest overhead and is the most typically used service.

Authenticated Service. Allows the receivers of a message to determine if the sender is authorized to send that message. Thus, authentication prevents unauthorized access to devices and is implemented by distributing 48-bit keys to the devices at installation time.

The LonWorks protocol implements the innovative concept of network variables. Network variables greatly simplify the tasks of designing LonWorks application programs for interoperability with multiple vendors' products and facilitating the design of information-based, rather than command-based, control systems. A network variable is any data item (temperature, a switch value, or an actuator position setting) that a particular device application program expects to get from other devices on the network (an input network variable) or expects to make available to other devices on the network (an output network variable).

The application program in a device doesn't need to know anything about where input network variables come from or where output network variables go. When the application program has a changed value for an output network variable it simply passes the new value to the device firmware. Via a process that takes place during network design and installation called binding, the device firmware is configured to know the logical address of the other devices or group of devices in the network expecting that network variable, and it assembles and sends the appropriate packets to these devices. Similarly, when the device firmware receives an updated value for an input network variable required by its application program, it passes the data to the application program. The binding process thus creates logical connections between an output network variable in one device and an input network variable in another device or group of devices. Connections may be thought of as "virtual wires." If one device contains a physical switch, with a corresponding output network variable called switch on/off, and another device drives a light bulb with a corresponding input network variable called lamp on/off, creating a connection by binding these two network variables has the same functional effect as connecting a physical wire from the switch to the light bulb.

Every network variable has a type that defines the units, scaling, and structure of the data contained within the network variable. Network variables must be the same type to be connected. This prevents common installation errors from occurring such as a pressure output being connected to a temperature input. Type translators are available to convert network variables of one type to another type. As described in the next chapter, a set of standard network variable types (SNVTs) is defined for commonly used types. Alternatively, manufacturers may define their own user-defined network variable types (UNVTs).

Network variables make possible information-based control systems, rather than old-style command-based control systems. This means that in a LonWorks system, each device application makes its own control decisions, based on information it collects from other devices about what is going on in the system. In a command-based system, devices issue control commands to other devices, so a command-issuing device, that is typically a centralized controller, must be custom programmed to know a lot about the system function and topology. This makes it very difficult for multiple vendors to design standard control devices that can easily be integrated. Network variables make it easy for manufacturers to design devices that systems integrators can readily incorporate into interoperable, information-based control systems.

LONMARK resource files are files that define the components of the external interface for one or more LonWorks devices. These files allow network installation tools and operator interface applications to interpret data produced by a device and to correctly format data sent to a device. They also help a system integrator or system operator to understand how to use a device and to control the LONMARK objects on a device. Standard resource files are available that define the standard components used in the external interface of a device. Device manufacturers must create user-defined resource files for any user-defined components defined within the external interface of their devices.

There are four types of resource files:

- Type File
- Functional Profile Template
- Format File
- Language File

Type File. Defines network variable, configuration property, and enumerated types. LonMark standard network variable and configuration property types are defined in the STANDARD.TYP file. Type files have a TYP extension.

Functional Profile Template. Defines functional profiles that are used for describing LonMark objects. A functional profile specifies the mandatory and optional network variable and configuration property components of a LonMark object. Some of the optional components may not be present on a particular LonMark object derived from the functional profile. LonMark standard functional profiles are defined in the STANDARD.FPT file. Functional profile templates have a .FPT extension.

Format File. Defines display and input formats for network variable and configuration property types defined in a type file. Formats for the LonMark standard network variable and configuration property types are defined in the STANDARD.FMT file. Format files have a .FMT extension.

Language File. Defines language-dependent strings. There is a separate language file for each supported language. The language the file supports determines the extension of a language file. Two language files are currently available for the LonMark standard type files; these are STANDARD.ENU for American English and STANDARD.ENG for British English.

Each device manufacturer that uses any non-standard types or functional profiles will typically provide resource files for their devices. The manufacturer may also supply their resource files to the LonMark Association so that they may be downloaded from LonMark Association website (http://www.lonmark.org).

Resource files must identify which devices they apply to. For example, the standard resource files apply to all devices. Manufacturer-specific resource files are typically associated with all devices from the manufacturer, or may be associated with a class of devices from the manufacturer, or with a specific device. This makes it possible for a user to have many resource files from many manufacturers; the files are automatically associated with the correct devices based on program ID.

The strength of the LonTak protocol with its large variety of transport services (acknowledged, authenticated, etc.), addressing schemes (physical addresses, logical addresses, group addressing, broadcast, etc.) and network structures (routers, many different transport channels, etc.) almost necessarily lead to powerful middleware that demands quite some processing power on the management station: LonWorks Netvork Services (LNS), an object oriented database system, where many network management and integration tools are based on. It registers and manages all network resources like nodes, channel parameters or configuration properties. One of the most popular management tools is Echelon‘s LonMaker Installation Tool. Its user interface is based on Microsoft’s Visio whose schematics help organizing the network structure in a graphical and visual way. A powerful competitor to the LNS-based tools is ICELAN2000 from IEC, a professional network management tool.

LonWorks has wide system limits, enabling large amounts of data to be transmitted to a large number of devices and subnets (Table 4).

Internationally, the work by Echelon Corporation and the LonMark association has produced an architecture that operates in the building management and control area. LonWorks too has defined gateways and can be used to manage equipment, systems and applications in the home. It has also been used on a very large scale in Italy for Automatic Meter Reading (AMR) where the meter could be used as a low level gateway.

***Table 4**. LonWorks system limits*

Parameter	Number
Devices in a subnet	127
Subnets in domain	295
Devices in a domain	32385
Domains in a network	2^{48}
aximum devices in system	$32K*2^{48}$
Members in groups	
Unacknowledged or Repeated	NoLimit
Acknowledged or Request Response	63
Groups in a domain	255
Channels in a network	NoLimit
Bytes in a network variable	31
Bytes in an application or foreign frame message	228
Bytes in a data file	2^{32}

There are two types of software possibilities for developers: OpenLDV and LNS:

LNS applications may be written in any language that supports COM Components or ActiveX controls, including Microsoft® Visual C++ (versions 6.0-7.1) and Microsoft Visual Basic 6.0. The OpenLDV driver interface provides a unified Windows driver interface for sending and receiving low-level LonTalk messages through Echelon's family of network interfaces. LNS based network tools have higher performance levels than those that use OpenLDV.

The use of this standard is totally royalties free.

3.5.3.9 Universal Power Bus (UPB)[28]

UPB was designed by Power line Control Systems, Inc. (PCS, http://www.pcslighting.com) of Northridge, California. UPB devices send messages over the power line by coding data in the timing of high amplitude pulses. UPB sends two bits of information in the millisecond before each power line zero crossing. The value of the two bits is coded by sending a large signal pulse at one of four possible time positions. UPB transmitters typically generate the 40-volt signal pulse by discharging a capacitor into the power line, which

[28] Section reference: The UPB System Description. Version 1.1 09/19/03. Powerline Control Systems. Web link: http://simply-automated.com/documents/UpbDescription_V1.1.pdf.

creates a broadband ringing waveform. UPB uses pulse position modulation. If pulse occurs 1080 µs before zero crossing, the dibit value is 00. If pulse position start 160 µs later (920 µs before zero crossing) , the dibit value is 01. The next two positions with period 160 µs encode 10 and 11. A tolerance of time position is ±40 µs.

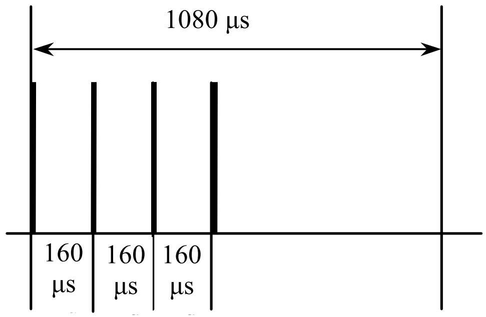

Figure 19. UPB pulses start time[29]

Triac line dimmers create power line noise spikes when they switch on. These spikes look a lot like UPB pulses (Figure 19) and can cause communication problems. UPB messages are variable length, containing from 8 to 26 bytes:

- Preamble – 1 byte;
- Control – 2 bytes (8-12 bits – message 6-24);
- Network ID – 1 byte;
- Destination ID – 1 byte;
- Source ID – 1 byte;
- Message Data ID – 1 byte;
- Message Data Arguments – 0-18 bytes;
- Checksum – 1 byte.

The raw bit rate of UPB is 480 bps, with two bits being sent every zero crossing when power net frequency 60 Hz. It takes 133 milliseconds to send an 8-byte message and 16.625 milliseconds for each additional byte. It takes 433 milliseconds for a maximum-length 26-bytes message. UPB protocol allows for 250 House Addresses, 255 Device Addresses, and 254 Link Addresses.

House Separation – Multiple houses on one transformer will be separated by means of an addressing scheme allowing for at least 256 systems (houses) on each transformer. UPB system incorporates over 64,000 total address space vs 256 for conventional X-10. There will also be applicable encryption incorporated into the DLL layer and if necessary at the higher network layers.

Interaction – UPB communication can be used in the presence of all X-10, CEBus, or LonWorks compatible equipment with no interference between either UPB equipment or X-10, CEBus, or LonWorks equipment.

[29] www.smartlabsinc.com/files/INSTEONCompared20060102a.pdf

The UPB technology uses a completely different frequency range than any of the wide-band, narrow-band, or spread spectrum technologies. The physical method of UPB communication is entirely different than the modulation-demodulation techniques of all X-10, CEBus, or LonWorks.

Peer to Peer – No central controller necessary for single point-to-point control or group (scene) control.

Simplicity – the UPB solution uses "off the shelf" components for transmission, receiving and control circuits, including standard microprocessors. No ASIC's (application specific integrated circuits) are necessary.

Note: UPB products are available only for North America market.

3.5.3.10 HAVI

HAVI, short for Home Audio-Video Interoperability, was developed by eight of the world's leading manufacturers of audio-visual electronics (Grundig, Hitachi, Matsushita, Philips, Sharp, Sony, Thompson and Toshiba). HAVI is based on i.LINK interface and allows:

- plug & play connectivity;
- interoperability among different brand appliances;
- universal user friendly interface to manage audio and video devices.

3.5.3.11 HBS

It was released in 1988 by Electronic Industries Association of Japan as reply to European EHS and American CEBus. It defines a quite complex system that uses wirings composed of two coaxial cables and eight twisted-pair cables to connect home appliances. It is limited to Japan.

3.5.3.12 BACnet[30]

Active development of BACnet was started since June of 1987 when the first meeting of Standard Project Committee (SPC) 135P took place at the ASHRAE (American Society of Heating Refrigerating and Air-Conditioning Engineers) Annual Meeting. In spring 1995, ASHRAE published the result of this effort: the first version of the BACnet Standard (ANSI/ASHRAE Standard135-1995). Over the last years, BACnet has been improved continuously. Updated standard was published in 2001. In 2003 BACnet become an international IS0 standard (Building automation and control system – Part 5. Data communication protocol. IS0 16484-5:2003).

Despite that BACnet was developed in US, it became international standard. Currently there are three BACnet Interests Groups (BIGs) in North America (BIG-NA), Europe (BIG-EU) and Australia/Asia (BIG-AA) which locally convey the application of the standard. The BACnet Testing Laboratories (BTL) provide certification services and list devices which are interoperable in respect of the BACnet standard. In Europe these certificates are provided by the WSPCert in Stuttgart by order of the BIG-EU.

Interoperability between devices of different vendors was one of the main objectives of BACnet. Usually the decision for a specific vendor restricts future enhancements due to noninteroperable devices. By providing a solid standardized basement, the manufacturers of building automation equipment should be encouraged to build truly interoperable devices.

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[30] Section reference: Newman, H., M., BACnet: Answers to Frequently Asked Questions, Heating /Piping /Air Conditioning , (March 1997), 47-51. http://www.bacnet.org/Bibliography/HPAC-3-97.pdf.
Goldschmidt, I.The development of BACnet. Strategic Planning for Energy and the Environment. Vol. 18, No. 2,1998, 16-24. Association of Energy Engineers, Atlanta, GA.

BACnet is based on object-oriented model. Important concepts in BACnet standard are objects and devices. An object is simply a collection of information related to a particular function that can be uniquely identified and accessed over a network in a standardized way. All information in a BACnet system is represented by such data structures. The object concept allows us to talk about and organize information relating to physical inputs and and outputs, as well as non-physical concepts like software, or calculations. Objects may represent single physical “points,” or logical groupings of points that perform a specific function.

Although there are many of potentially useful object types which might be found in building automation, BACnet defines 23 standard object types in some detail. This set of standard objects represents much of the functionality found in typical building automation and controls systems today. A "BACnet Device" is simply a collection of objects that represents the functions actually present in a given real device.

BACnet is based on a client-server model. BACnet messages are called service requests. A client machine sends a service request to a server machine that then performs the service and reports the result to the client. BACnet currently defines 35 message types that are divided into 5 groups or classes. One of classes is Object Access Services with such servises as Read Property, Write Property and others.

The SPC committee had to decide which networking technologies should be selected out of the dozens available. This was done simply by looking at the cost/benefit aspects of each candidate, the experience the various vendors had had with each one, and the realities of the marketplace. The set of technologies specified in BACnet was chosen because it seemed to span the real-world requirements of building control systems in terms of speed, throughput, cost, familiarity, etc. The options are:

- Ethernet;
- ARCNET;
- Master-Slave/Token Passing (MS/TP);
- Point-to-Point (PTP);
- Echelon’s LonTalk;
- BACnet/IP and “Virtual LAN’s”(allows for TCP/IP, ATM).

The protocols Master-Slave/Token-Passing and Point-to-Point are BACnet protocols for low-cost EIA-485 and dial-up communications. BACnet/IP protocol is important, because it provides not only the specification for transporting BACnet messages between IP devices but also the framework for embracing other new networking technologies with a minimal impact on existing BACnet technology.

The BACnet standard defines a unified way of publishing the functionality of BACnet devices. It provides a template which is called Protocol Implementation Conformance Statement (PICS). With this document the manufacturers are able to describe the behaviour of a device in detail.

BACnet specifies a six-level hierarchy of device capabilities based on the implementation of certain BACnet objects and services. A Conformance Class 1 device, for example, only needs to have a single object and be able to understand and carry out a request to read and send back the values of that object’s properties (ReadProperty). A Conformance Class 2 device, besides having Conformance Class 1 capabilities, needs to be able to carry out a request to change the value of an object’s properties (WriteProperty). Higher numbered conformance classes have additional capabilities. This hierarchy could correspond to the capabilities that might be associated with a smart sensor at the Class 1 end and a full-featured, general-purpose direct digital controller at the Class 6 end.

Early on, it became apparent that something more than conformance classes was needed to specify BACnet capabilities. For example, suppose you have a simple Class 2 device like a smart actuator, but you want it to be able to control the device connected to it based on a time schedule. As mentioned earlier, the ability to do time-related things over the network, such as setting a device's clock and altering schedules, requires a certain collection of BACnet objects and services. Each such collection, for a specific function, is called a functional group. There are currently 13 functional groups in the standard, covering such things as what objects and services would be required to act as a BACnet handheld workstation, a PC workstation, a device capable of initiating or responding to alarms and events, a device capable of supporting virtual terminal logins, and so on.

Within a building there are various ways to use the BACnet protocol. In Europe, BACnet is famous as a "management backbone" while the field devices - connected via some gateway - are still based on KNX or LonWorks. American installations use MS/TP devices for seamless BACnet connectivity. On this account, also the network nodes which are used in those regions are different: BACnet devices in Europe are sometimes more complex than those used in North America.

3.5.3.13 Z-wave[31]

Z-Wave is a routed radio network designed by ZenSys AS (http://www.zen-sys.com), from Denmark. Z-Wave is designed for relatively few nodes (20 to 200) that communicate on average every 5 to 15 minutes. Message latency requirements are relaxed to 200 milliseconds or more. Zensys and other companies have established the Z-Wave Alliance (http://www.z-wavealliance.org). Z-Waves radio use an unlicensed carrier frequency 868.42 MHz in Europe and 908.42 in the U.S. Data is modulated onto the carrier at 9600 bps using binary frequency shift keying (BFSK). The minimum length of a properly formatted Z-Wave message is 9 bytes, but a routed message requires 12 bytes plus repeater data plus the payload.

The Z-Wave network is self-organizing and self-healing. To achieve self-organization, Z-Wave nodes have software that discovers the node's neighbours and informs the network's Static Update Controller (SUC) about them. A Source Routing Algorithm (SRA) in devices capable of initiating communication finds message pathways and generate routes based on a network topology database. Self-healing requires software to dynamically generate new routes around temporarily unavailable nodes. Moving nodes have software routines that can request new neighbour searches automatically. This software, which is part of the Z-Wave stack, resides in on-chip memory.

Z-Wave devices do not have unique addresses when purchased. There must be a procedure whereby the network's Static Update Controller assigns addresses to devices being installed on the network. Z-Wave specifies that network installation should be accomplished either centrally using some kind of installer tool, or locally using the devices themselves. Z-Wave chips have 32K bytes of flash memory, with provision for adding more memory externally. To reserve as much memory as possible for the application code in a Z-Wave device, the Z-Wave communications stack must be kept as small as possible. Therefore, Z-Wave defines a number of different device types that have varying capabilities and stack sizes. The main Z-Wave device categories are Controllers, Routing Slaves, and Slaves. Chips have an integrated FSK radio and an 8051 processors core. ZenSys also offers complete RF modules built around the chips for inclusion in products. To create devices firmware, product developers typically use a C compiler. ZenSys provides a collection of API routines to help with this task.

Managing the routing of messages on a network is complicated, especially if some devices in the network are mobile. Z-Wave uses source routing, so any device capable of initiating communication must know which routes are currently possible, choose the best route, and then embed the routing information into the messages that it sends. Such routing algorithms have been well developed for a variety of networks, but they require a

[31] Section reference: Z-Wave Protocol Overview. System Design Specification. Document Part Number: 903100105. Document Revision: 01.05. Zensys A/S, Denmark. Web link: http://www.zen-sys.com/index.php?page=242.
Jorgensen T., Johansen, N.T., Z-WaveTM as Home Control RF Platform. Zensys A/S, Denmark. Web link: www.zen-sys.com/media.php?id=321

lot of code. Lots of code means lots of memory on a chip, and therefore higher build costs for devices that use the chip. Z-Wave Controllers can initiate communication with all nodes, and so they have the largest stack. The master controller, called a SUC (static update controller), performs network management, distributes network topology information to secondary controllers, and supports central or local device enrolment. Mobile controllers use a portable controller stack that allows devices to request rediscovery of moving nodes. There can also be a SIS (SUC ID server), which can automatically distribute network topology information to multiple controllers, but that software usually runs on a PC. Unless there is a SIS in the Z-Wave network, users have to manually copy network topology data from the master controller to any secondary controllers in the network whenever they add or remove Z-Wave devices. Routing Slaves can initiate communication with a subset of nodes using a smaller Z-Wave stack. They depend on the SUC for network topology information. Slaves have the smallest stack and can only respond to communications. Z-Wave also defines Installers for doing centralized network setup and Bridge devices for connecting to other kinds of networks.

By defining devices with reduced functionality in order to minimize cost, Z-Wave has given up the simplicity of peer-to-peer networking. This trade-off is understandable in response to the complexity of routing, but because different devices have different capabilities, users have to know more about how the network functions. Perhaps the most restrictive issue for users is the requirement for a single master controller in a Z-Wave network.

There are several possibilities for developers:

Advanced Control Technologies (ACT, http://www.act-solutions.com) offers serial and USB interfaces for Z-Wave European frequency. Z-Wave USB Interface (ZCU010, ZCU011) allows communication from computer USB port to control Z-Wave enabled products (868.42MHz). Based on Version 1.21 of the Z-Wave™ API Library. Protocol description available in Version 3.20 of Z-Wave™ Developers Kit. Similar Z-Wave Serial Interface (ZCS010) allows communication from computer serial port. As control software can be used HomeSeer Technologies (http://www.homeseer.com) - HomeSeer v2.0 Home Automation Software.

3.5.3.14 ZigBee[32]

ZigBee is newest home automation standard. ZigBee is the set of specs built around the IEEE 802.15.4 wireless protocol. The name "ZigBee" is derived from the erratic zigging patterns many bees make between flowers when collecting pollen. This is evocative of the invisible webs of connections existing in a fully wireless environment.

The standard itself is regulated by a group known as the ZigBee Alliance, with over 200 members worldwide. The list of members at the high table board of directors includes Texas Instruments, Philips, Ember Corporation, Motorola, Siemens, Freescale Semiconductor, Inc., Samsung, Honeywell and Mitsubishi Electric. Two European heavyweights — ST Microelectronics and Schneider Electric — recently have joined the ZigBee Alliance’s board of directors, increasing their involvement with the wireless sensor and home control networks effort. Chinese communications equipment group Huawei has also been upgraded to Promoter Level at the alliance. Alliance now include six of the 10 largest semiconductor companies in the world producing product for installation in OEM devices.

ZigBee devices are actively limited to a through-rate of 250Kbps, compared to Bluetooth's much larger pipeline of 1Mbps, operating on the 2.4 GHz ISM band, which is available throughout most of the world. Due to its low power output, ZigBee devices can sustain themselves on a small battery for many months, or even years, making them ideal for install-and-forget purposes, such as most small household systems.

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[32] Section reference: ZigBee Specification. ZigBee Document 053474r06, Version 1.0 December 14th, 2004. ZigBee Alliance. Available from http://www.zigbee.org/.

The ZigBee stack architecture is made up of a set of blocks called layers. Each layer performs a specific set of services for the layer above: a data entity provides a data transmission service and a management entity provides all other services. Each service entity exposes an interface to the upper layer through a service access point (SAP), and each SAP supports a number of service primitives to achieve the required functionality.

The ZigBee stack architecture, which is depicted in Figure 20, is based on the standard Open Systems Interconnection (OSI) seven-layer model but defines only those layers relevant to achieving functionality in the intended market space. The IEEE 802.15.4-2003 standard defines the lower two layers: the physical (PHY) layer and the medium access control (MAC) sub-layer. The ZigBee Alliance builds on this foundation by providing the network (NWK) layer and the framework for the application layer, which includes the application support sub-layer (APS), the ZigBee device objects (ZDO) and the manufacturer-defined application objects.

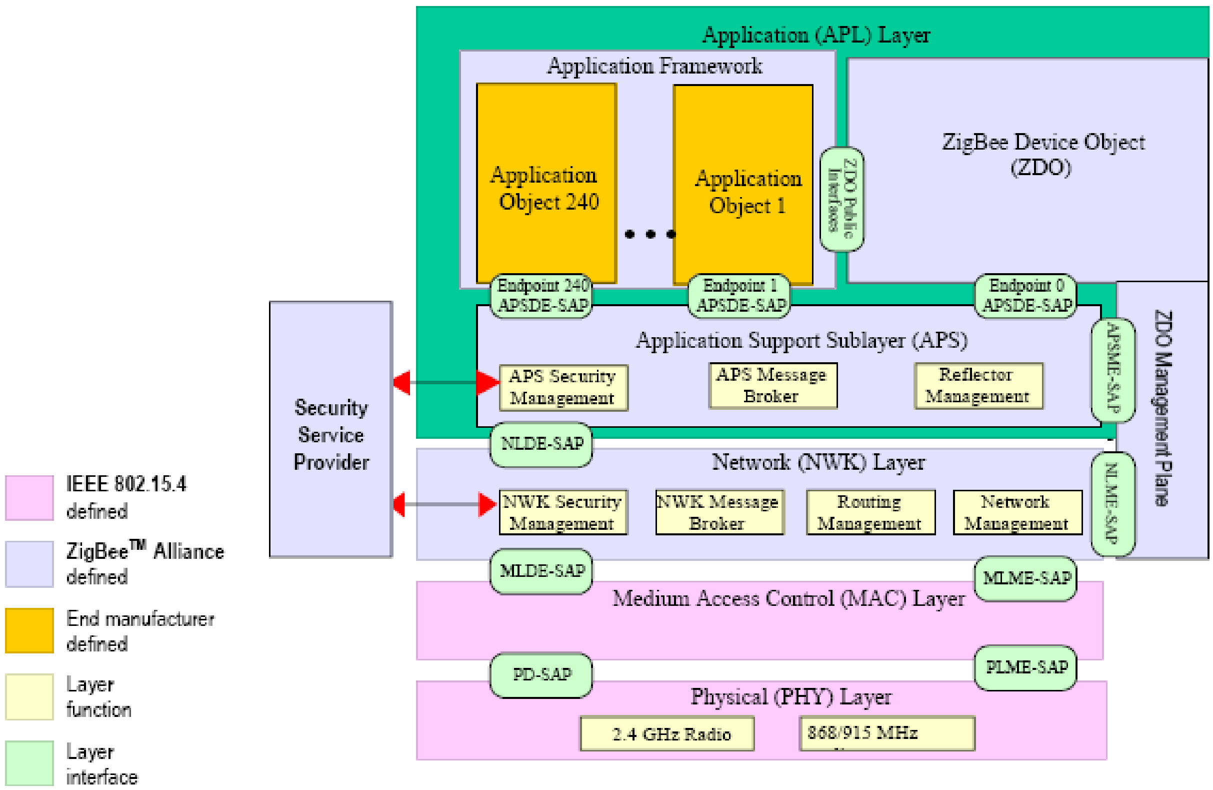

Figure 20. ZigBee stack architecture[33]

ZigBee is wireless protocol. IEEE 802.15.4-2003 has two PHY layers that operate in two separate frequency ranges: 868/915 MHz and 2.4 GHz. The lower frequency PHY layer covers both the 868 MHz European band and the 915 MHz band that is used in countries such as the United States and Australia. The higher frequency PHY layer is used virtually worldwide.

[33] www.meshnetics.com/zigbee-faq/

The IEEE 802.15.4-2003 MAC sub-layer controls access to the radio channel using a CSMA-CA mechanism. Its responsibilities may also include transmitting beacon frames, synchronization and providing a reliable transmission mechanism

The responsibilities of the ZigBee NWK layer shall include mechanisms used to join and leave a network, to apply security to frames and to route frames to their intended destinations. In addition, the discovery and maintenance of routes between devices devolve to the NWK layer. Also the discovery of one-hop neighbours and the storing of pertinent neighbour information are done at the NWK layer. The NWK layer of a ZigBee coordinator (see "Network topology") is responsible for starting a new network, when appropriate, and assigning addresses to newly associated devices.

The ZigBee network layer (NWK) supports star, tree and mesh topologies. In a star topology, the network is controlled by one single device called the ZigBee coordinator. The ZigBee coordinator is responsible for initiating and maintaining the devices on the network, and all other devices, known as end devices, directly communicate with the ZigBee coordinator. In mesh and tree topologies, the ZigBee coordinator is responsible for starting the network and for choosing certain key network parameters but the network may be extended through the use of ZigBee routers. In tree networks, routers move data and control messages through the network using a hierarchical routing strategy. Tree networks may employ beacon-oriented communication as described in the IEEE 802.15.4-2003 specification. Mesh networks shall allow full peer-to-peer communication. ZigBee routers in mesh networks shall not emit regular IEEE 802.15.4-2003 beacons. This specification describes only intra-PAN networks, i.e., networks in which communications begin and terminate within the same network.

The ZigBee application layer consists of the APS, the Application Framework (AF), the ZDO and the manufacturer-defined application objects. The responsibilities of the APS sub-layer include maintaining tables for binding, which is the ability to match two devices together based on their services and their needs, and forwarding messages between bound devices. The responsibilities of the ZDO include defining the role of the device within the network (e.g., ZigBee coordinator or end device), initiating and/or responding to binding requests and establishing a secure relationship between network devices. The ZDO is also responsible for discovering devices on the network and determining which application services they provide.

ZigBee provides another level of sub-addressing, which is used in conjunction with the mechanisms of IEEE802.15.4. An endpoint number can be used to identify individual elements in device with one radio. Each identifiable subunit in a node (such as the switches and lamps) is assigned its own specific endpoint in the range 1-240.

Physical devices are described in terms of the data attributes that they contain. For instance, a thermostat might contain an output attribute “temperature” which represents the current temperature of a room. A furnace controller may take this attribute as an input and control the furnace according to the temperature value received from the thermostat. These two physical devices, including their attributes, would be described in the relevant device descriptions for those devices.

The simple room thermostat described has temperature-sensing circuitry, which can be queried by the external furnace controller. It advertises its service on an endpoint and the service is described in the simple description implemented on that endpoint.

A more complex version of the thermostat may also have an optional “heartbeat” report timer, which causes the device to report current room temperature after a set period. In this example, the ReportTime attribute specifies when reports are to be sent and writing a suitable time value to this attribute sets the frequency of these temperature reports. This implementation would advertise its services (in a list of cluster identifiers) on a different endpoint.

In order to allow product differentiation in the marketplace, manufacturers may add clusters containing extra attributes of their own in the context of one or more private profiles. These manufacturer-specific clusters do not form part of this or any other ZigBee specification and interoperability is not guaranteed for these clusters. Such services would be advertised on different endpoints from those described above.

Profiles are an agreement on messages, message formats and processing actions that enable applications residing on separate devices to send commands, request data and process commands/requests to create an interoperable, distributed application. For instance, a thermostat on one node communicates with a furnace on another node. Together, they cooperatively form a heating application profile. Profiles are developed by ZigBee vendors to address solutions to specific technology needs.

Profiles are simultaneously a means to unify interoperable technical solutions within the ZigBee standard, as well as to focus usability efforts within a given marketing area. For example, it is expected that vendors of lighting equipment will want to provide ZigBee profiles that interoperate with several varieties of lighting types or controller types.

There are opportunities for development for both hardware and software interfaces:

Well known companies as Texas Instruments, Renesas Technology Corporation, NEC Engineering, Freescale Semiconductor, Microchip, Mindteck (India) Limited offers chips and RF modules for ZigBee devices. For example Microchip integrated ZigBee with PIC family microcontrollers and offers PICDEM™ Z Demonstration Kit. 'UZBee' 802.15.4 / ZigBee USB adapter (Figure 21) from Flexipanel (http://www.flexipanel.com/ZigBeeModules.htm) allows control ZigBee devices from PC computer.

Figure 21. 'UZBee' ZigBee adaptor[34]

3.5.3.15 JINI[35]

Sun Microsystems introduced Jini in 1998. Anyone interested in Jini can participate and contribute to the standard by joining the Jini Forum (www.jini.org). Sun Microsystems acts as the steward for this forum. Jini is Java based system.

The purpose of the Jini architecture is to federate groups of devices and software components into a single, dynamic distributed system. The resulting federation provides the simplicity of access, ease of administration, and support for sharing that are provided by a large monolithic system while retaining the flexibility, uniform response, and control provided by a personal computer or workstation.

The most important concept within the Jini architecture is that of a service. A service is an entity that can be used by a person, a program, or another service. A service may be a computation, storage, a communication channel to another user, a software filter, a hardware device. Members of a Jini system federate to share

[34] http://www.rfsolutions.co.uk/acatalog/UZBee_ZigBee_USB_Dongle.html

[35] Section reference: Jini™ architecture specification. Version 1.2, December, 1995. Sun Microsystems Inc. Web link: http://www.sun.com/software/jini/specs/jini1_2_1specs.zip.

access to services. Jini systems provide mechanisms for service construction, lookup, communication, and use in a distributed system.

Services are found and resolved by a lookup service. The lookup service is the central bootstrapping mechanism for the system and provides the major point of contact between the system and users of the system. A lookup service maps interfaces indicating the functionality provided by a service to sets of objects that implement the service.

A service is added to a lookup service by a pair of protocols called discovery and join—first the service locates an appropriate lookup service (by using the discovery protocol), and then it joins it (by using the join protocol).

Jini technology consists of an infrastructure and a programming model that address how devices connect with each other to form an impromptu community. Jini uses the Java remote method invocation (RMI) protocol to move code around the network.

We can view the Jini lookup service as a directory service or broker. Jini uses three related discovery protocols. When an application or service first becomes active, the multicast request protocol finds lookup services in the vicinity. Lookup services use the multicast announcement protocol to announce their presence to services in the community that might be interested. The unicast discovery protocol then establishes communications with a specific lookup service known a priori over a wide-area network.

However, a Jini lookup service is not just a simple name server. It maps the interfaces that clients see to service proxy objects. It also maintains service attributes and processes match queries. Clients download the service proxy, which is usually an RMI stub that can communicate back with the server. This proxy object lets clients use the service without knowing anything about it. Hence, there is no need for device drivers in case the service provided is a device (such as a printer). Although service proxy objects represent a typical scenario of service invocation, the downloaded service object can be the service itself or a smart object capable of speaking in any private communication protocol.

Jini grants access to its services on a lease basis. A client can request a service for a desired time period, and Jini will grant a negotiated lease for that period. This lease must be renewed before its expiration; otherwise, Jini will release the resources associated with the service. Leasing lets Jini be robust and maintenance-free when faced with abrupt failures or the removal of devices and services.

A series of operations, either within a single service or spanning multiple services, can be wrapped in a transaction. The Jini transaction interfaces supply a service protocol needed to coordinate a two-phase commit. How transactions are implemented—is left up to the service using those interfaces.

The Jini architecture supports distributed events. An object may allow other objects to register interest in events in the object and receive a notification of the occurrence of such an event. This enables distributed event-based programs to be written with a variety of reliability and scalability guarantees.

3.5.3.16 Bluetooth[36]

Bluetooth wireless technology is a short-range communications technology intended to replace the cables connecting portable and/or fixed devices while maintaining high levels of security. The key features of Bluetooth technology are robustness, low power, and low cost. The Bluetooth specification defines a uniform structure for a wide range of devices to connect and communicate with each other. Bluetooth consortium was founded in 1998 by Ericsson, IBM, Intel, Nokia and Toshiba. Bluetooth wireless technology is the simple choice for convenient, wire-free, short-range communication between devices. It is a globally available standard that wirelessly connects mobile phones, portable computers, cars, stereo headsets, MP3 players, and more. Thanks to the unique concept of “profiles”, Bluetooth enabled products do not need to install driver software.

[36] Section reference: http://www.bluetooth.com/Bluetooth/Learn/Basics/

3.5.3.17 Ethernet

This standard, named also IEEE 802.3, was development with the purpose of connecting and sharing in efficient and simply way network devices and network resources. It is the most widespread LAN technology in use from the 1990s to the present. Nowadays Ethernet is used also in home automation systems thanks to its versatility and to the great number of devices and applications.

3.5.3.18 Home Plug Alliance

HomePlug is an industry Alliance comprised of industry leaders at each level of the value chain - from Technology to Services & Content. The Alliance's mission is to enable and promote rapid availability, adoption and implementation of cost effective, interoperable and standards-based home power line networks and products.

3.5.3.19 Home RF

The Home Radio Frequency Working Group developed a single specification (Shared Wireless Access Protocol-SWAP) for a broad range of interoperable consumer devices. SWAP is an open industry specification that allows PCs, peripherals, cordless telephones and other consumer devices to share and communicate voice and data in and around the home without the complication and expense of running new wires.

3.5.3.20 Wi-Fi

In 1999, several industry leaders came together to form a global, non-profit organisation with the goal of driving the adoption of a single worldwide-accepted standard for high-speed wireless local area networking. This organisation is known as the Wi-Fi Alliance.

3.5.3.21 Universal Plug and Play (UPnP) [37]

UPnP (Universal Plug and Play) is an extension of Microsoft-initiated standard Plug-and-Play for network devices. It aims to enable the advertisement, discovery, and control of networked devices, services, and consumer electronics. In UPnP, a device can dynamically join a network, obtain an IP address, convey its capabilities on request, and learn about the presence and capabilities of other devices. A device can also leave a network smoothly and automatically without leaving any unwanted state behind. UPnP leverages Web technologies, including IP, TCP, UDP, HTTP, and XML. It uses the protocol stack shown in Figure 22.

[37] Section reference: Helal, S. Standards for Service Discovery and Delivery, IEEE Pervasive Computing, July 2002, pp. 95-100.

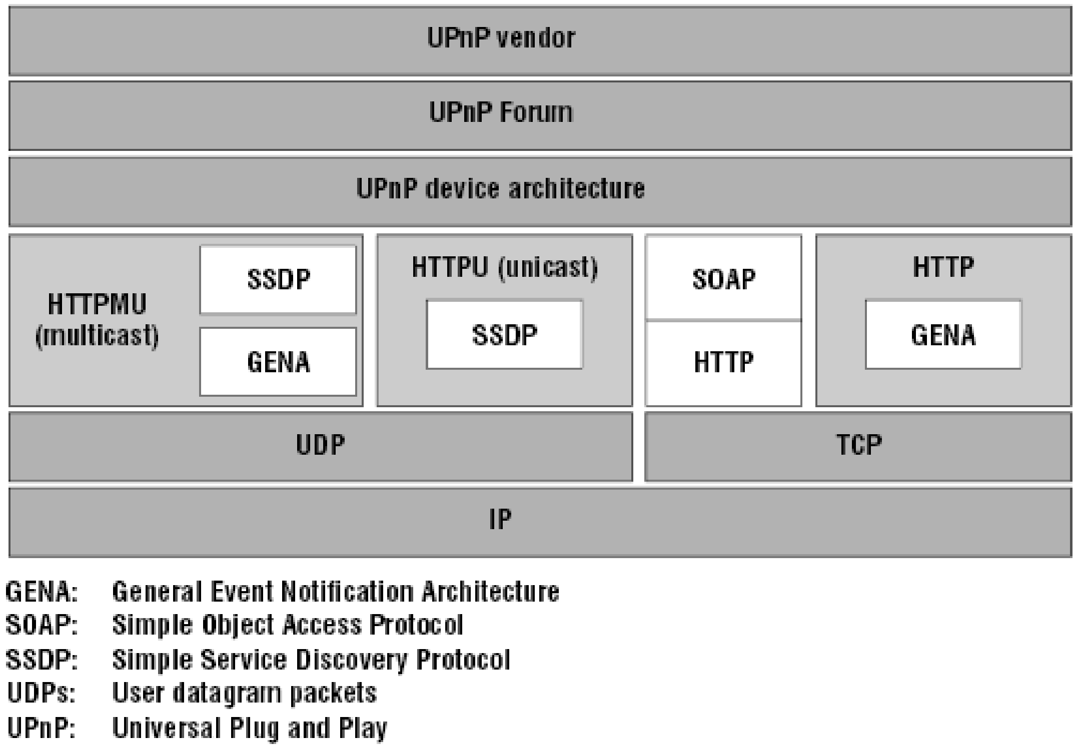

Figure 22. UPnP stack[38]

Joining and discovery in UPnP. UPnP uses simple service discovery protocol (SSDP) for service discovery. This protocol announces a device's presence to others and discovers other devices or services. SSDP uses HTTP over multicast and unicast UDP, referred to as HTTPMU and HTTPU, respectively. A joining device sends out an advertisement (ssdp:alive) multicast message to advertise its services to control points. Control points function similar to Jini's lookup services. A control point, if present, can record the advertisement, or other devices might also directly see this multicast message. In contrast to Jini, UPnP can work with or without the control points (lookup service). It sends a search (ssdp:discover) multicast message when a new control point is added to a network. Any device that hears this multicast will respond with a unicast response message.

UPnP uses XML to describe device features and capabilities. The aforementioned advertisement message contains a URL that points to an XML file in the network that describes the UPnP device's capability. By retrieving this XML file, other devices can inspect the advertised device's features and decide whether it is important or relevant to them. XML allows complex and powerful description of device and service capability as opposed to Jini's simple service attribute.

UPnP service description. After a control point has discovered a device, it learns more about how to use it, control it, and coordinate with it by retrieving its XML description file. Control is expressed as a collection of Simple Object Access Protocol (SOAP) objects and their URLs in the XML file. To use a specific control, a SOAP message is sent to the SOAP control object at the specified URL. The device or the service returns action-specific values. A UPnP description for a service includes a list of actions to which the service responds and a list of variables that model the service's state at runtime. The service publishes updates when

[38] www.microsoft.com

these variables change, and a control point can subscribe to receive this information. Updates are published by sending event messages that contain the names and values of one or more state variables. These messages are also expressed in XML and formatted using the General Event Notification Architecture.

UPnP features an additional higher level description of services in the form of a user interface. This feature lets the user directly control the service. If a device or service has a presentation URL, then the control point can retrieve a page from this URL, load the page into a browser, and (depending on the page's capabilities) let a user control the device or view the device's status. Another important feature of UPnP is automatic configuration of IP addresses. AutoIP lets a device join the network without any explicit administration. When a device connects to the network, it tries to acquire an IP address from a Dynamic Host Configuration Protocol server. However, in the absence of a DHCP server, an IP address is claimed automatically from a reserved range for local network use. The device claims an address by randomly choosing one from the reserved range and then making an ARP request to see if anyone else has already claimed that address.

There are opportunities for development for both hardware and software interfaces:

The UPnP DA is intended to be used in a broad range of device from the computing (PCs printers), consumer electronics (DVD, TV, radio), communication (phones) to home automation (lighting control, security) and home appliances (refrigerators, coffeemakers) domains.

3.5.3.22 Open Service Gateway initiative (OSGi)[39]

The OSGi Alliance (http://www.osgi.org) was founded in March 1999. Its mission is to create open specifications for the network delivery of managed services to local networks and devices. The OSGi Alliance has over 80 member companies today. The OSGi service platform specification delivers an open, common architecture for service providers, developers, software vendors, gateway operators and equipment vendors to develop, deploy and manage services in a co-ordinated fashion. It enables a new category of smart devices due to its flexible and managed deployment of services.

OSGi specifications are in continuous development. The OSGi Alliance already released the fourth OSGi Service Platform specification in 2005.First specification appeared in 2000, release 2 – in 2001, release 3 – in 2003. OSGi was developed as tools that standardize the integration aspects of software so that reusing existing components becomes reliable, robust and cheap. OSGi technology is the dynamic module system for Java. The OSGi Service Platform provides functionality to Java that makes Java the premier environment for software integration and thus for development. Java provides the portability that is required to support products on many different platforms. The OSGi technology provides the standardized primitives that allow applications to be constructed from small, reusable and collaborative components. These components can be composed into an application and deployed.

OSGi Framework. The Framework forms the core of the OSGi Service Platform Specification. It provides a general-purpose, secure, managed Java framework that supports the deployment of extensible and downloadable service applications known as bundles. OSGi-compliant devices can download and install OSGi bundles, and remove them when they are no longer required. Installed bundles can register a number of services that can be shared with other bundles under strict control of the Framework. The Framework manages the installation and update of bundles in an OSGi environment in a dynamic and scalable fashion, and manages the dependencies between bundles and services. It provides the bundle developer with the resources necessary to take advantage of Java's platform independence and dynamic code-loading capability in order to easily develop, and deploy on a large scale, services for small-memory devices. The Framework is divided in a number of layers:

[39] Section reference: About the OSGi Service Platform. Technical Whitepaper. Revision 4.1. 11 November 2005. OSGi Alliance. Web link: http://osgi.org/osgi_technology/download_specs.asp?section=2#Release4.

- Execution Environment;
- Modules;
- Life Cycle Management;
- Service Registry.

The Execution environment is the specification of the Java environment. The Modules layer defines the class loading policies. The Life Cycle layer adds bundles that can be dynamically installed, started, stopped, updated and uninstalled. The Service Registry layer adds a Service Registry.

Bundles. The OSGi framework consists of installable core System Bundle, a selectable set of optional Management Bundles, and the Service Bundles that the application's programmer can implement if necessary for a specific application domain. The OSGi System Bundle must be installed to enable the other Service Bundles to be installed. To be valid, a System Bundle, as every other service bundle in the OSGi environment, must implement the interface "Bundle".

Services. On top of the Framework, the OSGi Alliance has specified many services. Services are specified by a Java interface. Bundles can implement this interface and register the service with the Service Registry. Clients of the service can find it in the registry, or react to it when it appears or disappears. The following sections give a short overview of the OSGi Release 4 services. More information can be found in the OSGi Service Platform Release 4 book or PDF download. Note that each service is defined abstractly and is independently implemented by different vendors:

- Framework Services;
- System Services;
- Protocol Services;
- Miscellaneous Services.

Framework Services are a Permission Admin Service, a Package Admin Service and a Start Level Service. These services are (an optional) part and direct the operation of the Framework.

- Permission Admin – The permissions of current or future bundles can be manipulated through this service. Permissions are activated immediately once they are set.
- Package Admin – Bundles share packages with classes and resources. The update of bundles might require the system to re-calculate the dependencies. This Package Admin service provides information about the actual package sharing state of the system and can also refresh shared packages. I.e. break the dependencies and recalculate the dependencies.
- Start Level – Start Levels are a set of bundles that should run together or should be initialized before others are started. The Start Level Service sets the current start level, assigns a bundle to a start level and interrogates the current settings.
- URL Handler – The Java environment supports a provider model for URL handlers. However, this is a singleton making it impossible to use this in a collaborative environment like OSGi that potentially has many different providers. This service specification enables any component to provide additional URL handlers.

System Services provide horizontal functions that are necessary in virtually every system. The Log Service, Configuration Admin Service, Device Access Service, User Admin Service, IO Connector Service and Preferences Service are examples of system services.

Protocol Services. The OSGi Alliance has defined a number of services that map an external protocol to an OSGi service.

- Http Service – The Http Service is, among other things, a servlet runner. Bundles can provide servlets, which becomes available over the Http protocol. The dynamic update facility of the OSGi Service Platform makes the Http Service a very attractive web server that can be updated with new servlets, remotely if necessary, without requiring a restart.
- UPnP Service –The OSGi UPnP Service maps devices on a UPnP network to the Service Registry. Alternatively, it can map OSGi services to the UPnP network
- DMT Admin – The Open Mobile Alliance (OMA) provides a comprehensive specification for mobile device management on the concept of a Device Management Tree (DMT). The DMT Admin service defines how this tree can be accessed and/or extended in an OSGi Service Platform.

Miscellaneous Services:

- Wire Admin Service – Normally bundles establish the rules to find services that they want to work with. However, in many cases this should be a deployment decision. The Wire Admin service therefore connects different services together as defined in a configuration file. The Wire Admin service uses the concept of a Consumer and Producer service that interchange objects over a wire.
- XML Parser Service – The XML Parser service allows a bundle to locate a parser with desired properties and compatibility with JAXP.

There are opportunities for software development:

The OSGi specifications are so widely applicable because the platform is a small layer that allows multiple Java™ based components to efficiently cooperate in a single Java Virtual Machine (JVM). It provides an extensive security model so that components can run in a shielded environment. With the proper permissions components can reuse and cooperate, unlike other Java application environments. The OSGi Framework provides an extensive array of mechanisms to make this cooperation possible and secure.

3.5.4 Summary of communication protocols

The following table summarises the findings of the section on the properties of the differing Smart Home network protocols (Table 5).

***Table 5**. Summary of Smart Home network protocols*

Standard	*FW*	*PhL*	*PowL*	*Coax*	*RF*	*IR*	*OF*	*TP*	*# Max Devices*	*Data Rate*	*Region*	*Certification*
EIB			X	X	X	X		X	61455	9600 bps	Europe	-
BATIBUS			X	X	X	X		X	1000	-	Europe	-
EHS			X	X	X	X		X	Milions	64 kbps	Europe	-
KNX			X		X	X		X	61455	-	Europe	yes
X.10			X		X				256	-	U.S.A.	yes
CEBUS			X	X	X	X	X	X	Billions		U.S.A	yes
LONWORKS			X	X	X	X	X	X	-	4000 bps up to 1.5 Mbs	U.S.A	yes
HAVI	X								-	400 Mbs	U.S.A	yes
HBS	X			X				X	-	-	Japan	no
BLUETOOTH					X				-	2.5 MB	International	yes
ETHERNET				X			X	X	Billions	10 MBs to GBs	International	yes
HOME PLUG ALLIANCE			X		X				-	200 Mbs	Internationl	yes
HOME PNA		X							-	128 MBs	International	yes
HOME RF					X				-	11 MBs	International	no
Upnp	*	*	*	*	*	*	*	*	*	*	International	yes
Wi-fi					X					54MBs	International	yes

(*) Note: UPnP is highly dependent on the attached devices

Legend:

FW	Firewire
PowL	power line
OF	optical fiber
CoaC	coaxial cable

PhL	phone line
RF	radio frequency
TP	twisted pair
IR	infrared

4 Comments and Summary

4.1 COGAIN Involvement in Smart Home Standards

From the survey of Section 2, the most relevant organisations for COGAIN to work with to push forward gaze based interaction and control of the personal environment of a user were identified as the ICTSB based "**Design for All and Assistive Technologies** [http://www.ictsb.org/DATSCG_home.htm] group and the **SmartHouse Standards** [http://www.ictsb.org/SHSSG_home.htm] group.

COGAIN is now involved and a member of both of these groups with the aim of integrating gaze based systems into Smart Homes.

4.2 Controlling the Interface

Following the survey of existing interfaces and protocols in environmental control, we need to examine which of these interfaces and protocols might be suitable for interfacing with gaze based control.

Possibly the simplest method of controlling a Smart Home environment would be to simply control the existing interface via gaze. This approach was outlined previously in Section 3.2, Figure 3. From this, the survey of interfaces (Section 3.3) was broken down into four typical existing interface types, these were:

- Computer based graphical user interfaces that require cursor-based pointing;
- Speech based interfaces that require clear speech commands;
- Physical button or touch screen interfaces that require a physical contact with the interface;
- Scanning based interfaces that could be controlled by a single remote switch.

Each of these will be examined in turn to determine if gaze control would be practical directly on these interfaces.

4.2.1 Controlling Graphical Interfaces

The criteria for successful gaze control of graphical user interfaces can be demonstrated by examination of existing graphical interfaces that are designed specifically for gaze based control. An example is the GazeTalk gaze driven text entry system (Figure 22)[40]. Here we see that the graphical user interface is divided into effectively 12 squares, resulting in very large target buttons to be controlled by gaze. This is done as gaze is typically inaccurate when compared to a standard desktop hand mouse, with cursor placement inaccuracies of one to two centimetres on the screen, and in some cases inaccuracies of many centimetres.

Comparing GazeTalk to the graphical interfaces for environmental control systems found in the survey (Section 3.3.1.1) shows that all, apart from the dedicated gaze driven interfaces, of these graphical interfaces exhibit considerably more complex, smaller, and more closely spaced buttons than GazeTalk. This complexity and closeness of layout essentially precludes direct gaze based control of these existing interfaces

[40] http://www.cogain.org/results/applications/gazetalk/

as the user would have considerable difficulty selecting and manipulating the many control icons on the interfaces. This is particularly true when low-cost gaze tracking systems are used, typically these have low accuracies of several centimetres on screen. Also, many users have problems maintaining high accuracies due to either physical or environmental conditions degrading racking even with high-cost gaze racking systems (see COGAIN WP3 deliverables[41]).

Hence, within the bounds of COGAIN, it may be said that there appear to be no suitable de-facto standard commercial graphical user interfaces to environmental control systems that lend themselves directly to gaze control (as shown in Figure 3) and also to any from of 'plug and play' approach to differing environmental control systems. From this, there is a clear need to find a more suitable interface that could be driven by gaze.

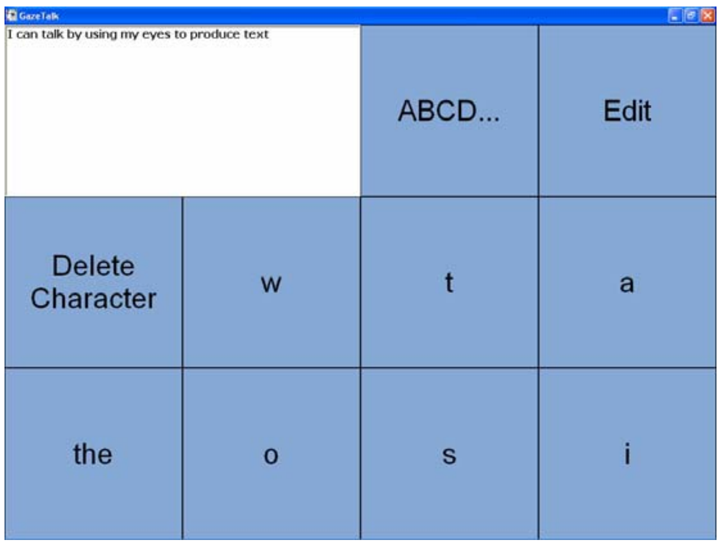

Figure 23. GazeTalk text entry system

4.2.2 Controlling Speech Based Interfaces

Due to the nature of many of the disabilities addressed by COGAIN, many of the target user groups suffer from profound paralysis up to and including the loss of speech and the loss of clear speech, either due to breathing via a respirator or due to throat and breathing muscle loss of control. Thus, speech based interfaces do not lend themselves well to the target user groups. In addition, such interfaces rarely are compatible with gaze based supplementary or augmented control.

Within the bounds of COGAIN, due to the loss of clear speech for many users, speech based interfaces may be discounted.

[41] Donegan, M., Oosthuizen, L., Bates, R., Daunys, G., Hansen, J.P., Joos, M., Majaranta, P. and Signorile, I. (2005) D3.1 User requirements report with observations of difficulties users are experiencing. Communication by Gaze Interaction (COGAIN), IST-2003-511598: Deliverable 3.1. Available at http://www.cogain.org/results/reports/COGAIN-D3.1.pdf, and Donegan et al. (2006) D3.2 Report on features of the different systems and development needs. Communication by Gaze Interaction (COGAIN), IST-2003-511598: Deliverable 3.2. Available at http://www.cogain.org/results/reports/COGAIN-D3.2.pdf

4.2.3 Controlling Touch Based Interfaces

In much the same way as speech based interfaces may be discounted, any interface that requires physical movement and contact from the user may be discounted, as the users involved within COGAIN may not be able to physically move sufficiently to control physical interfaces. Methods such as using gaze controlled robotic arms to manipulate touch screens or physical buttons may be possible, but are overly complex and cumbersome, with alternative methods offering great chances of success.

Within the bounds of COGAIN, due to the loss of physical movement for many users, touch based interfaces may be discounted.

4.2.4 Controlling Scanning Based Interfaces

These interfaces require only a single on/off type of input to enable basic control. This simple property makes scanning based interfaces suitable for gaze based control. Most often gaze control is associated with directly pointing with the eyes, however, simple eye orientation or direction (looking up, down, left or right) can be used as a simple switch. This has been demonstrated within the COGAIN network with work investigating simple control signals derived from looking up or down. In this research a camera is placed close to the eye and the orientation of the eye is monitored, with commands used in a demonstration to drive a small robot left or right by looking either left or right (Figure 24)[42]

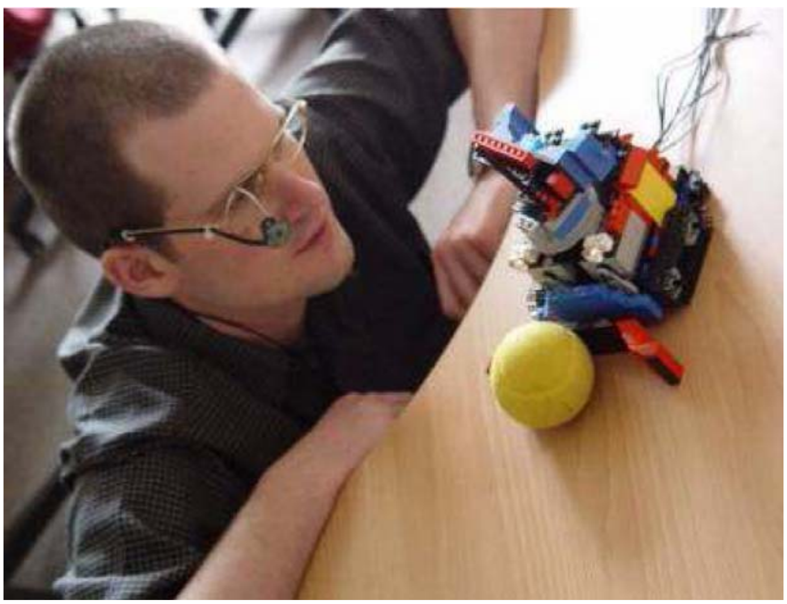

Figure 24. Using eye position as a switch

Such an interface could easily be used to control a scanning interface on an environmental control system, with the user simply, for example, looking upwards when the appropriate button on the scanning controller was illuminated. However, scanning input is a 'last resort' method of control. The eye gives a rapid and rich

[42] Fejtová, M. Novák, P., Fejt, J., Štepánková, O. (2006) When can eyes make up for hands? Proceedings of the 2nd Conference on Communication by Gaze Interaction – COGAIN 2006. Available online at http://www.cogain.org/cogain2006/COGAIN2006_Proceedings.pdf

amount of data in positional x,y space, and to limit the useful functions derived from this to a simple on/off state to control a richly featured domestic environment would be very limiting.

Hence, within the bounds of COGAIN, it may be said that scanning based interfaces may be controlled by gaze, but that to do so would underutilise the available bandwidth of communication derived from the eye, and would be limiting and not an ideal choice.

4.3 Alternative Gaze Interfaces for Environmental Control

From the survey it was clear that there were few de-facto standard environmental control interfaces to existing systems that were suitable for gaze based interaction and control. Perhaps the only system currently found suitable was X10 used by LC Technologies and ERICA, however, these systems were dedicated to only interfacing with X10, so a user would be very limited for a choice of environmental control, and would be 'locked into' using only that manufacturers system. Hence, the task of COGAIN is to research and develop new gaze-suitable interfaces that could be used as replacements for existing interfaces and also form a basis for a de-facto standard for gaze control. Within COGAIN two approaches are being investigated:

- Indirect control – the user may gaze at an interface (such as a computer screen) where representations of the real-world objects are shown and controlled by gaze via the screen
- Direct control – the user may gaze at the actual real-world objects, which then are controlled by gaze directly on the objects

Indirect control interfaces are essentially the same in operation as those graphical user interfaces discussed in the survey, except that they are specially adapted to be suitable for gaze control. Direct interfaces are an evolution away from indirect interfaces, and attempt to completely remove any computer interface between he user and their environment.

4.3.1 Indirect Gaze: GazeTalk and the Intelligent Home Interface

Within the COGAIN network, two possible solutions to the problem of interacting with a graphical user interface to an environmental control system are currently being investigated. The first in consideration is to use the existing GazeTalk system (Figure 23) by extending the functionality and placing environmental control commands in place of the letters normally found on the system. This work is scheduled to start early in 2007. The second approach is to develop a new dedicated gaze driven interface from an existing experimental environmental control system. This is also being investigated within COGAIN with the 'Intelligent Home' system[43]. The basic system interface is shown in Figure 25.

[43] Bonino, D. Castellina, E., Corno, F. and Garbo, A. (2006) Control application for Smart House through Gaze interaction. Proceedings of the 2nd Conference on Communication by Gaze Interaction – COGAIN 2006. Available online at http://www.cogain.org/cogain2006/COGAIN2006_Proceedings.pdf

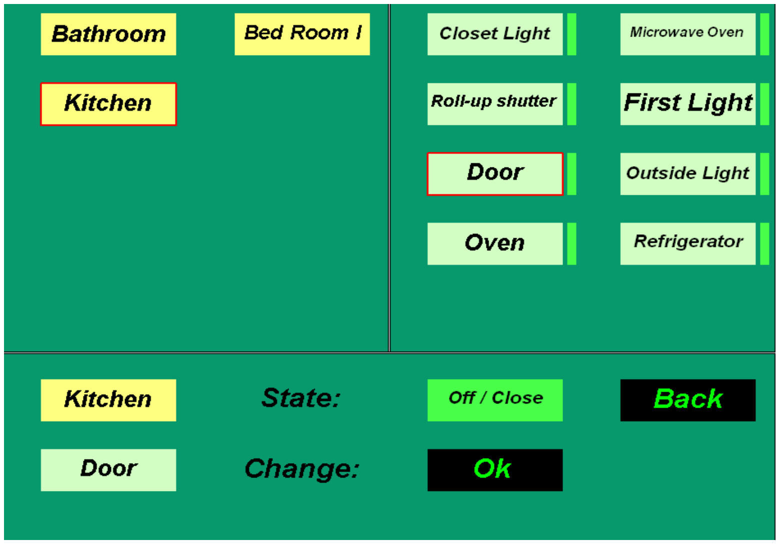

Figure 25. Intelligent home standard interface

Here the standard interface (Figure 25) is complex and designed to be used by head pointing devices, which have greater positional accuracy than gaze devices), but the user may also select the experimental gaze interface (Figure 26). On this interface the buttons used to control the environment are well-separated, and due to that separation can react to gaze pointing in their vicinity and do not need gaze to be accurately placed on the buttons. Both the GazeTalk and Intelligent Home interfaces offer possibilities for indirect gaze based control, with these interfaces replacing any existing interfaces to the central domotic system.

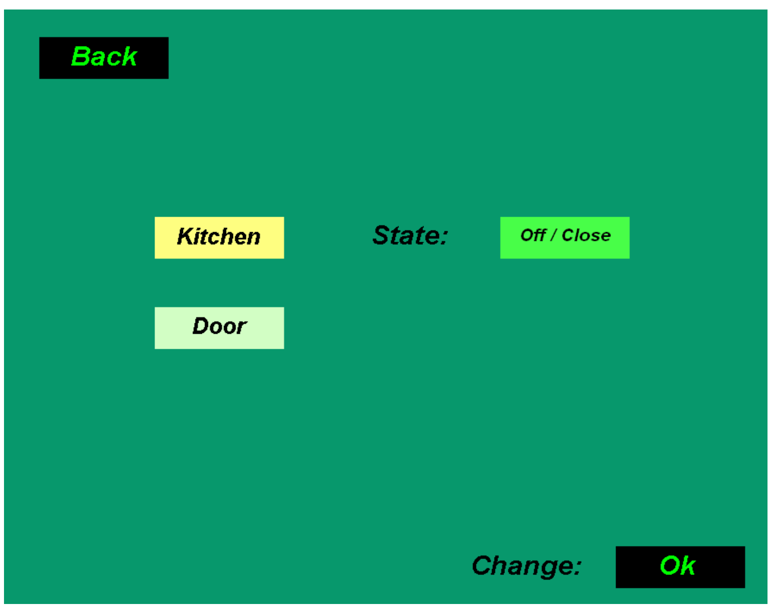

Figure 26. Intelligent home gaze interface

4.3.2 Direct Gaze: The Attention Responsive Technology Interface

The ART (Attention Responsive Technology) interface[44] aims to facilitate interaction with the environment of the user by developing a system which responds directly to users' gaze to enable interaction with the environment by responding appropriately to the user's 'attention'. In the system 'Attention' is anticipated through means of gaze tracking, with elements of the environment subsequently actuated and controlled by gaze alone via the environmental control system.

The system utilises a combination of computer recognition and eye-tracking technology to gauge the user's attention in relation to controllable objects within their environment. It uses this information to predict the user's possible intention, and then responds intelligently to facilitate interaction with the device in question. Figure 27 shows the principle of operation. Here the user looks at a controllable object (1), the interface responds by offering only the appropriate controls (2), and the user operates the object using a custom control interface (3).

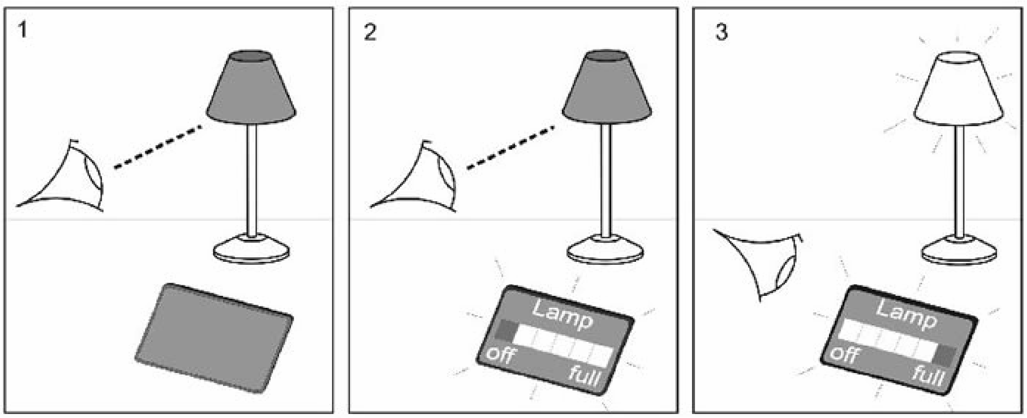

Figure 27. ART system direct interaction

The advantage of the system is that any domestic object is selected purely by looking at it directly. The disadvantage is that at the current state of development some level of indirect manipulation is required on the vision controller (Figure 28) to change the properties of that object.

Both direct and indirect approaches will continue to be developed under COGAIN, and will be the subject of future deliverables on gaze based environmental control.

[44] 'Direct Gaze-Based Environmental Controls' - Alastair G. Gale, Fangmin Shi, Kevin Purdy, COGAIN NoE, to be presented at the 2nd Conference on Communication by Gaze Interaction – COGAIN 2006: Gazing into the Future. Available online at http://www.cogain.org/cogain2006/COGAIN2006_Proceedings.pdf

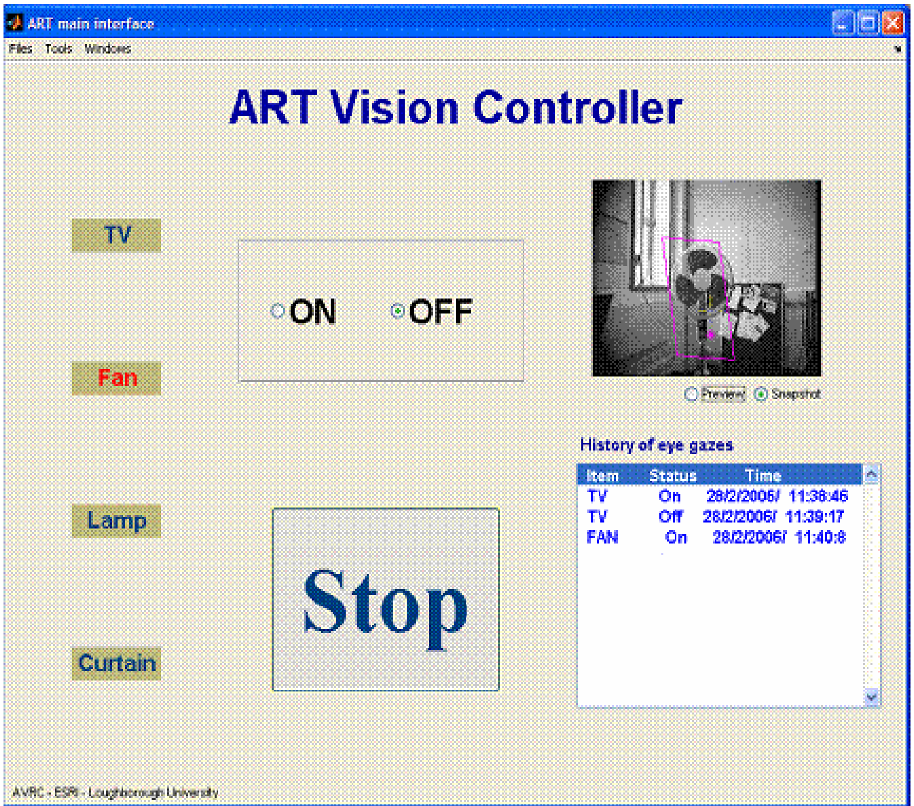

Figure 28. ART indirect controller interface

4.4 Connecting to the Networks

Following the Section 3 survey of existing protocols in environmental control, we need to examine which of these protocols might be suitable for interfacing with gaze based control. We need to determine if one single system can offer the requirements needed by COGAIN for a gaze based system that would be popular with users. It was required that the network be:

- Popular, with an installed user base
- Have an established user base including people with a disability
- Low-cost
- To carry not just simple low bandwidth but also high bandwidth
- Easy to fit
- Require little or no maintenance
- Compatible with older network systems
- Future-proof

4.4.1 A Diversity of Properties

The survey of Section 3 revealed a very wide and diverse number of network systems and protocols that may be used in any given Smart Home. There appeared to be particularly popular and established systems (such as

X10), although these systems were found to be fairly limited in speed, bandwidth, number of devices, and possibilities for communication media (choice of wires/wireless etc). There were newer systems (such as ZigBee) which offer a great possibility for home control but are not yet popular in installations. Between these lay a range of systems of differing capabilities. Despite the thorough survey, there did not appear to be one overriding popular system that could be adopted as a COGAIN protocol for the network that could fulfil all of the requirements for a gaze based system that would be successful with a high uptake.

Due to this diversity, it is logical for COGAIN to step back from attempting to adopt a single network system and protocol to support with gaze control. Instead COGAIN should aim to support as many of the differing systems (and hence their users) as possible.

4.4.2 A Bridge to Many Diverse Systems

The key to adopting as many systems as possible is for COGAIN to develop a *bridge* between gaze based systems and environmental control systems. Such a bridge would wrap the interfaces and protocols of the many diverse systems found in the survey, interacting with each of these systems, and translating their differing commands and data into a single unified COGAIN 'Smart Home Standard Driver' standard interface and protocol that would be compatible with gaze control.

As introduced in Section 3, there are three possible methods of integrating eye gaze control into such systems:

- The first (option 1) is to simply use gaze as a means of controlling the existing system and interface without modification
- The second (option 2) is to bypass the existing interface and replace the system interface with a gaze-friendly custom interface into the central domotic system.
- The third (option 3) is to bypass the core system and integrate gaze control into the communication protocols with the environment.

Option 1, (as shown in Figure 3, Section 3) involves control of the existing interface and can be ruled out as the examination of the interfaces in use (Section 4.1.2) has shown that these are not suitable for gaze control. Option 3, (as shown in Figure 5, Section 3) involves direct connection to the communication network and protocols and can also be ruled out as the examination of the protocols in use (Section 4.1.4) has shown that there are too many and too diverse a range. This leaves Option 2, (as shown in Figure 4, Section 3) as the best option. Here, in order to interface with the existing Smart Home networks, the easiest method would be to connect to them via their application programming interfaces (API's). Those systems that present an API will allow communication and control of the systems by external software, developed by COGAIN. This would then interface any supported Home System with any gaze driven system via a single standard COGAIN interface. In addition, the COGAIN single standard interface would allow the connection of dedicated gaze driven interfaces, such as those in Section 4.1.3, to be easily interfaced with any environmental control system, enabling gaze control of Smart Homes for COGAIN users.

Hence, COGAIN should develop a single Smart Home standard driver that will connect to existing system API's and allow control of these diverse networks and protocols by gaze based systems.

The role of the COGAIN driver can be illustrated by taking the diagram of Figure 4, Section 3 and showing where the COGAIN bridge is placed between the core domotic system and any gaze driven interfaces. This placement is illustrated in Figure 29.

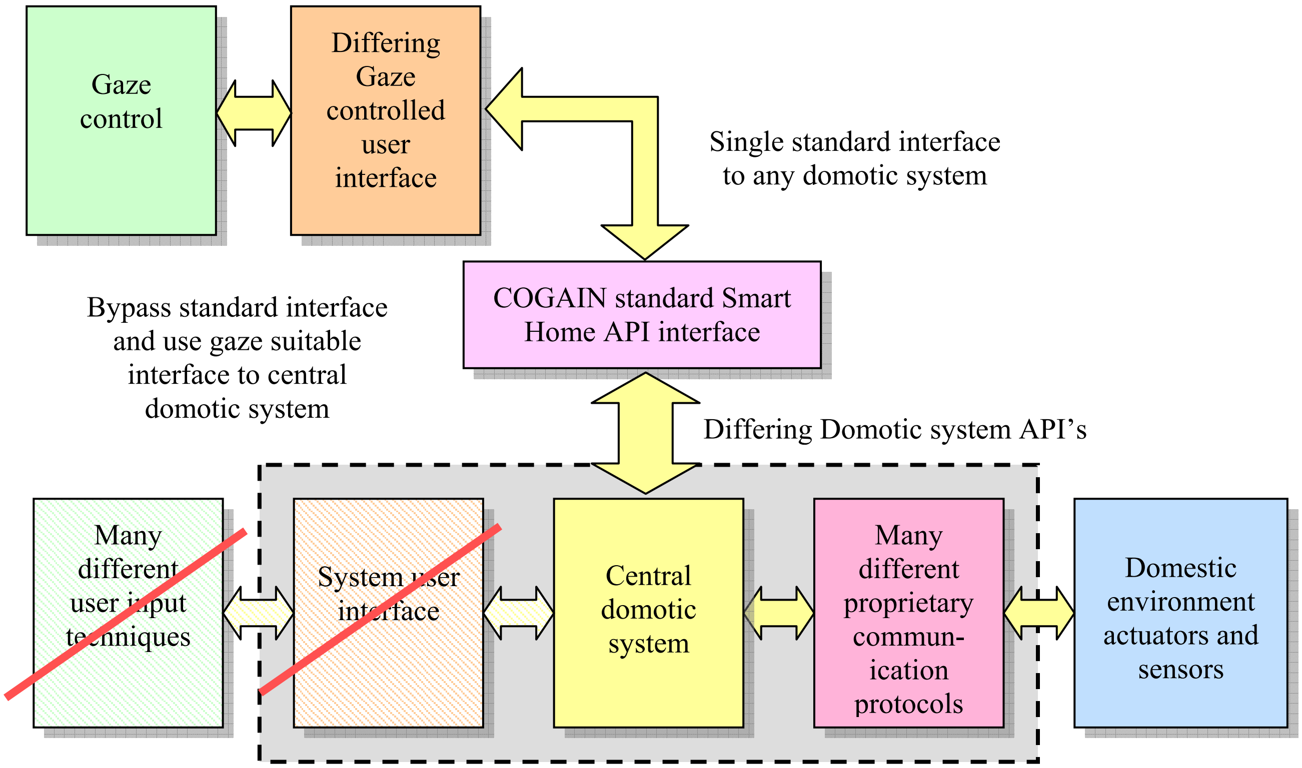

Figure 29. COGAIN Smart Home standard interface

4.4.3 Systems That Support the COGAIN Bridge

From the survey of Section 3, networks and their specified protocols that easily permit the connection of a bridge by offering an API can be found, these are listed:

- KNX (Konnex), EIB, BATIBUS, EHS
  - FALCON, 32-bit access library for Windows. It offers an API for all aspects of bus/device access/management, and thanks to the usage of DCOM and .NET, access is possible for programming environments that suitably support these models; furthermore scripting languages like VBA can be used to access KNX/EIB networks from office applications.
  - EIB OPC Server allows access and control the processes on an KNX/EIB network from virtually any standard process visualisation toolkit or environment on Windows platforms.
- X-10
  - Simply Automate (http://www.simplyautomate.co.uk) X10 computer interface products via USB (CM11USB) or serial port (CM11E).
  - ActiveHome is Windows compatible software which includes graphical representations of switches, modules etc. to provide point-and-click control of modules, and easy setting of scheduled events and macros. Events may be scheduled to occur at a particular time every day, on chosen days only, between chosen dates etc. The also can be programmed. This product is CE approved for use in the EU.
  - Harmony 5.1 is software from iDomus (http://www.idomus.co.uk/) for Windows 2000 / XP. It has Lite, Gold, and Pro versions. Incorporates a Web API: a simple HTML based interface

with Server Side Variables and control strings. It can be customised using Dreamweaver, Frontpage, Notepad etc, TCP/IP sockets based low level, high speed interface, XML API designed for output / status monitoring only. The Plugin Interface API - write your own VB / Visual C++ interfaces that load directly into Harmony

- INSTEON
  - Available products to connect INSTEON to a PC include PowerLinc serial and USB computer interfaces.
- CEBUS
  - There are opportunities for development for both hardware and software interfaces: There are three CEBus IC manufacturers, Domosys Corporation, Intellon Corporation and Itran (http://www.cebus.org/proddir.htm). The various IC products are the CEWay PL-One, CEWay PL-III, the SSC P300, the SSC R400, the IT-5000 and the IT-800 series. All of these products are Power Line (PL) solutions except for the R400 that is a Radio Frequency IC. These PL ICs' price range approximately from $4 to $8 in quantity.
  - There are two software development tool manufacturers, Domosys Corporation and ACS. Those tools are CEBox and CEBench. These same manufacturers also offer various hardware development platforms, the CEBoard 8051, HC11 or CEWay PL-One, the RS-232 CECom, the Maxi-PLC Modules 8051 or HC11, the ISA CENode-PL x86 ISA card and the PC-104 CENode PL PCB. These development platforms are priced between $200 - $500. You can also find extremely good test tools at Domosys Corporation, ACS and CCI. These tools are the CETester, the CEBusAlyzer and the CEBugger. Although CEBus became US standard, it has not become popular worldwide.
- Lonworks
  - LNS applications may be written in any language that supports COM Components or ActiveX controls, including Microsoft® Visual C++ (versions 6.0-7.1) and Microsoft Visual Basic 6.0.
  - The OpenLDV driver interface provides a unified Windows driver interface for sending and receiving low-level LonTalk messages through Echelon's family of network interfaces. LNS based network tools have higher performance levels than those that use OpenLDV.
- Z-wave
  - Advanced Control Technologies (ACT, http://www.act-solutions.com) offers serial and USB interfaces for Z-Wave European frequency. Z-Wave USB Interface (ZCU010, ZCU011) allows communication from computer USB port to control Z-Wave enabled products (868.42MHz). Based on Version 1.21 of the Z-Wave™ API Library. Similar Z-Wave Serial Interface (ZCS010) allows communication from computer serial port.
  - For control software HomeSeer Technologies (http://www.homeseer.com) - HomeSeer v2.0 Home Automation Software can be used.
- ZigBee
  - Well known companies as Texas Instruments, Renesas Technology Corporation, NEC Engineering, Freescale Semiconductor, Microchip, Mindteck (India) Limited offers chips and RF modules for ZigBee devices. For example Microchip integrated ZigBee with PIC family microcontrollers and offers PICDEM™ Z Demonstration Kit. 'UZBee' 802.15.4 / ZigBee USB adapter (Figure 21) from Flexipanel (http://www.flexipanel.com/ZigBeeModules.htm) allows control ZigBee devices from PC computer.

- Bluetooth
    - Many suppliers for this well-known system
- Ethernet
    - Many suppliers for this well-known system
- Universal Plug and Play (UPnP)
    - The UPnP DA is intended to be used in a broad range of device from the computing (PCs printers), consumer electronics (DVD, TV, radio), communication (phones) to home automation (lighting control, security) and home appliances (refrigerators, coffeemakers) domains.
- Open Service Gateway initiative (OSGi)
    - The OSGi specifications are so widely applicable because the platform is a small layer that allows multiple Java™ based components to efficiently cooperate in a single Java Virtual Machine (JVM). The OSGi Framework provides an extensive array of mechanisms to make this cooperation possible and secure.

These systems represent the most widely used systems today, and al offer some form of API connection to interface with the system, thus allowing COGAIN to incorporate these systems into a single standard bridge for environmental gaze control.

4.5 Next Steps

The next steps are to form a draft standard for the COGAIN bridge. There is much more underlying detail to each manufacturers system API. The actual details of how each API are accessed and also the formats of commands and the data structures of each API and how these are accessed and controlled are all different for each manufacturer. Having established the systems have API's, the next step is determine which functions are actually of use when gaze tracking systems are used for gaze based control. Once this is done it will be necessary to revisit these functions in greater detail to establish how these critical functions from differing systems and manufacturers can be brought together to form a common single COGAIN standard bridge.

This will be the subject of the next deliverable, D2.5 – Draft Standards for Environmental Control.