# Smart Homes: a user perspective

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## Abstract

The wide diversity of requirements from the different user groups of Smart Homes, challenges the existing service creation schemes, leading to the need to adopt a more flexible approach enabling service providers to tailor their services and interfaces according to their target user needs and preferences. HomeTalk concentrates on the modularity of open-source service creation components and advanced voice capabilities to deliver a flexible generic platform for a user-friendly Smart Home.

**Key words**: Smart home, Service creation environment, Human factors.

## 1. Introduction

Smart home environments combine components, control mechanisms and intelligence to enhance the feeling of comfort, safety and security of their residents. Many implementations explicitly focus on high-end users, while others focus on special age or disability groups [Phillips (2001)]. However, the degree of adoption of such platforms remains low, mainly due to the fact that user considered smart homes as unnecessary luxury of questionable added value, and stakeholders as a niche market. Lately, new technological and market drivers trigger a slow but steadily increasing interest of network operators and service providers towards this market [Wolf (2003)]. Nevertheless, smart home platforms and services are created with "consumers" and not "users" in mind, often ignoring service usability and human factors. In the context of HomeTalk project an extensive user survey assessed the needs of potential smart home users, including technology enthusiasts, disabled and elderly. The wide diversity of service requirements from the different user groups challenged the traditional service creation schemes, leading to the adoption of a highly flexible novel approach. This paper presents the user needs analysis -focusing on the diversity of requirements-, discusses the limitations of traditional approaches to service creation for smart homes, presents the advantages of the OSGI-based approach [Marples (2001)] -enabling providers to deliver easily customizable user-centric services addressing the needs and requirements of a wide range of users- and showcases its adaptability in different use contexts. The work presented in this paper is carried out in the context of Project IST-2001-33507 "HomeTalk" which is partly funded by the E.C. The authors wish to acknowledge all HomeTalk partners (IBM, MERLONNI, WRAP, ANCO, TID, TEMAGON, INACCESS NETWORKS) for their valuable contributions during the various activities presented in this paper. Further information about the project can be found at www.hometalk.org.

# 2. User Requirements capture and analysis

## 2.1 Methodology Overview

The HOMETALK user requirements survey followed a generic methodological approach based on ISO standard 13407 [ISO (1999)] suggesting an iterative process for "user-centered" system design. An initial end-user and stakeholder analysis was performed to identify the range of different users, stakeholders and their goals and the key user group characteristics that potentially impose requirements and constraints upon the HOMETALK design. Then, end user expectations on specific features and system services were identified. This was achieved by a series of expert interviews and user questionnaires as well as a desk study reviewing requirements from other projects researching Connected Home technologies. A discussion with system stakeholders clarified aspects of their current business model and their intentions for further developing their business. Based on the above, a refined list of system requirements that might sufficiently address the user and stakeholder needs was drawn. Both qualitative and quantitative methods were used in the survey which was conducted in Greece between September and November 2002.

## 2.2 Qualitative survey: Experts' Interviews

A total of 8 semi-structured interviews with E&D experts, including special education teachers, sociologists specialised in elderly people and kinesitherapy experts. After a brief project description, the interviewees were stimulated to express high-level considerations concerning the design of the system, making explicit notion to the characteristics that will make it accessible and usable by special user groups. A list of considerations was drawn and detailed discussion was further realised, aiming to clarify specific aspects and to collect feedback on possible design recommendations. The results of the interviews contributed to structure the appropriate user questionnaires and to better understand the key limiting drawbacks of current technological approaches.

## 2.3 Quantitative survey: Questionnaires

The questionnaire for the end users was formulated on the basis of the potential use scenarios. HomeTalk originally prepared 20 service scenarios that were further developed and combined in 4 life scenarios. These were evaluated and refined after the experts interviews and were presented to the end users in script form. The questionnaire collected users' evaluation of the services, based on a 3-level scale ranging from "Very useful" to "Not at all useful" in relation with demographic characteristics. The questionnaire addressed to Greek-speaking users contained a third part related to the preferred spoken commands to interact with ICT devices and services [ETSI, 2002]. Research scientist provided answers and support where necessary. In some cases (mostly with dexterity impaired users), users were assisted to fill-in the questionnaires.

The sample consisted of 65 users, forming three groups:

- Elderly users (over 65 years old -14 persons)
- Disabled users (all ages - 34 persons)
- E&D experts and carers (17 persons)

Standard statistical methods (frequency analysis and correlation tests) were performed in order to extract the main trends in the sample and to verify or reject initial assumptions.

## 2.4 Disabled users group: Demographics and key findings

Disabled users were chosen amongst young people to achieve higher technology literacy and interest for the project. The type of disabilities and the age distribution is shown in table 1 (note that several subject suffered several types of impairments).

***Table 1: Impairment types and age distribution***

| Disabled users | Motion disability | Dexterity impairment | Speech impairment | Vision impairment | 12-24 years | 25-34 years | >35 years |
|---|---|---|---|---|---|---|---|
| Male | 13 | 6 | 3 | 0 | 19 | 9 | 6 |
| Female | 15 | 4 | 2 | 3 | 59% | 28% | 17% |
| Total | 28 | 10 | 5 | 3 | | | |

Key findings of the survey include: One out of three has a previous experience with voice recognition tools and is generally satisfied with it (70% rated the quality as good, and 30% as medium). Very few have experience with Text-to-Speech tools. Few are acquainted with specialised equipment providing better accessibility to computers (24% special keyboards or printers, 15% accessibility features of MS Windows, 6% special pointing devices), while 38% do not use any accessibility equipment. Many users (56%) posses a personal computer at home and 41% have an Internet connection at home. One out of five maintains an electronic agenda (either on a PDA or organiser). Voice is the preferred interface for interaction with a home automation platform (59%) while a traditional pointing device (like mouse) is preferred (38%) in comparison with a touch screen (21%). They wish to communicate with detailed voice dialogues only when it is necessary (44%) and some always prefer short and quick dialogues (38%). No single-person households existed in the sample (persons living alone were assisted by a carer at least 5 days/week). Disabled users presented a high degree of technology literacy and were very willing to cooperate in the evaluation of the HomeTalk platform. They have strong requirements as to the accessibility of the services and their robustness. Most appealing services were safety and security related (Detection (fire, smoke, water leakage), emergency function, control of actuators, electronic devices remote control).

## 2.5 Elderly users group: Demographics and key findings

Subjects were chosen among active individuals living in medium to high-income districts. Even though more than 50 persons were personally contacted and asked to complete the questionnaire; it was very difficult to motivate them to participate in the survey. The elderly users sample consisted of 14 users. Due to the restricted size the results are to be interpreted only qualitatively. Some key findings of the survey include:

Among the subjects, almost nobody lives alone; the majority live with their spouses or their children's families. They do not consider having any sensorial difficulties: Even though cases of visual and hearing impairments were clearly identified, none of the subjects answered positively to the respective questions. Elderly are technology illiterate. Only 20% have used a computer or a mobile phone more often than once a week. The majority is not even willing to make a call to a mobile phone, if it is not for emergency. Only few (35%) trust or rather trust computers. They consider that using such a platform, will make them feel more secure and comfortable (35%), but also more technology dependent and lazier (14%). They think that HomeTalk services will never become available to them or that will be too expensive or too complicated for them to use. Most appealing services are Emergency function, Electronic devices remote control, Presence simulation and detection (fire, smoke, water leakage)). They were very reluctant to

introduce new technology in their everyday lives. This applies to new wiring, interventions in the central power supply board, changes in the appliances and the general way of living. Service complexity must be kept to the absolute minimum and system installation and support is absolutely necessary. Service support is necessary (through an operation support centre, or medical centre).

### 2.6 Elderly & Disabled experts and carers group: Demographics and Key findings

The E&D experts and carers group consisted of 17 subjects. Subjects were chosen among people working or living with elderly (sociologists, nurses), disabled (sociologists, teachers, kinesitherapists, nurses and parents). Having strong experience of everyday problems faced by elderly or disabled, they will be the first ones to get in touch with home automation technologies supporting E&D. Some key findings of the survey include:

They are computer literate and well acquainted with new technology. They do not generally have previous experience with voice recognition (82%) or speech synthesis tools (71%), but those who have rated the tools as of medium quality. Few are acquainted with accessibility equipment (18% special keyboards or printers, 6% accessibility features of Microsoft Windows). Voice is the preferred interface for platform interaction (65%), followed by a touch screen (23%). None preferred detailed voice dialogues, opting for short and quick dialogues (76%). They want to be informed on their mobile phones only for serious incidents in the house, like a smoke (58%) or security alert (53%). Most appealing application/services are Detection (fire, smoke, water leakage), Emergency function, Control of actuators, Central entrance opening, and White appliances trouble-shooter.

### 2.7 End-user requirements assessment and design decisions

The interviews with E&D experts and carers provided important insight to the difficulties that E&D groups face and how existing assistive devices address them (successfully or not). A key concern of the experts was the isolation that could be induced by the introduction of such platforms. Experts claimed that carers often provide much more than helping disabled to carry on everyday tasks. In this sense, their help is more of social than functional character and could not be substituted by any technological means. It was therefore accepted that new ways of communicating could contribute to the substitution of traditional physical contact. Disabled users are very well acquainted with new technologies, considering the use of computer, and particularly the Internet, as an important means of non-discrimination. Nevertheless, only few utilise particular accessibility tools. Several cases were identified where a reinvention of the wheel was performed in the effort to provide accessibility to computers or electronic devices. In the rare cases where disabled users make use of specialised devices, they expressed serious concerns about compatibility, customer care and service issues. They claimed, that they always face significant problems when they should have their specialised equipment repaired or replaced. They also expressed serious concerns about the affordability of such equipment.

The above user requirements were coupled with several constraints raised by all respective actors in the home platforms value chain - network equipment providers, application providers, network access operators, content providers, application developers, appliance manufacturers, system integrators and service providers. Although this issue is not discussed here, the overall platform design should conform to these requirements in order to build a system that can be efficiently exploited to provide real added value to end-users.

Table 2 summarises the functional system requirements based on the user and stakeholder requirements assessment and proposes the design decisions that are followed in the project.

**Table 2: Requirements and design decisions**

| User / System requirements | Design decision |
|---|---|
| Users are not willing to easily accept interventions in their houses. | No new wiring solutions should be preferred where this is possible |
| Users are very wary about the overall system cost. | Low cost solutions should be preferred where equivalent functionalities are offered |
| Users are wary about the complexity of the services but they are willing to accept technology adapted to their needs. | Services should be accessible and user-friendly and easy to use and maintain. |
| Several coexisting home network platforms. Maximum peripherals connectivity required. [TEGER, 2002] | Support of bridging functions by the platform and potentially by the RG. Multiple Network Interfaces for communication & input. |
| Interoperability between different infrastructure components | Standardised meta-data (i.e. profiles) for managing components and devices |
| Easy procedures for definition, registration, deregistration, modification of services | Availability of administration tools (i.e. Web based management.) |
| Many proprietary or non-standardised devices exist in the market | Open Specifications for the delivery of managed broadband services. |
| Possibility to select between short/quick and detailed/self-explainable voice interaction | Several operation modes according user preference. |
| Mobile access to home network, for informative, control and security reasons | Home services should be accessible through a portal supporting multiple ways of interaction |
| User want to set preferences for services | Integration of User Profiles |
| "Most useful" applications differ from one user group to another | Several application baskets according to the user group addressed. |
| End users prefer to have the system installed by a technical team | Quick to install and detailed platform installation guide. User-friendly usage guide |
| Disabled users are computer literate and very willing to cooperate in evaluation and testing. Eager to buy if they can save money from human support. | Application of Design-for-All principles to assure accessibility. Consideration of assistive technology interfaces and interoperability with standard specialised devices |
| Disabled users are wary about maintenance issues and availability of spare parts | Design and interfaces based on standards. Proprietary solutions should be avoided |

The design requirements led to the adoption of a highly flexible approach for hardware interconnection and service creation framework. The platform architecture is depicted in figure 1. The system is built around a Residential Gateway (RG), connected both to the outdoor and indoor networks. Indoor network consists of white appliances, control devices and a series of I/O devices with their respective capabilities. The RG integrates data networking, control networking, voice (using IBM ViaVoice Technology for speech recognition and synthesis) and multimodal interaction features and will host the Residential Gateway Server (RGS), which will be a central control component of the HomeTalk system serving as a backend for the user interfaces (including VoiceXML engine). It will receive the user requests from the User Interface component, process them, evaluate them in the context of the current HomeTalk service state, translate them into the appropriate form and will carry out the appropriate actions (passing the commands to the controlled devices). In the opposite direction it will collect the responses or asynchronous

events from the controlled devices, translate them into the appropriate form and will perform appropriate actions (passing the information to the UI or the commands to other devices).

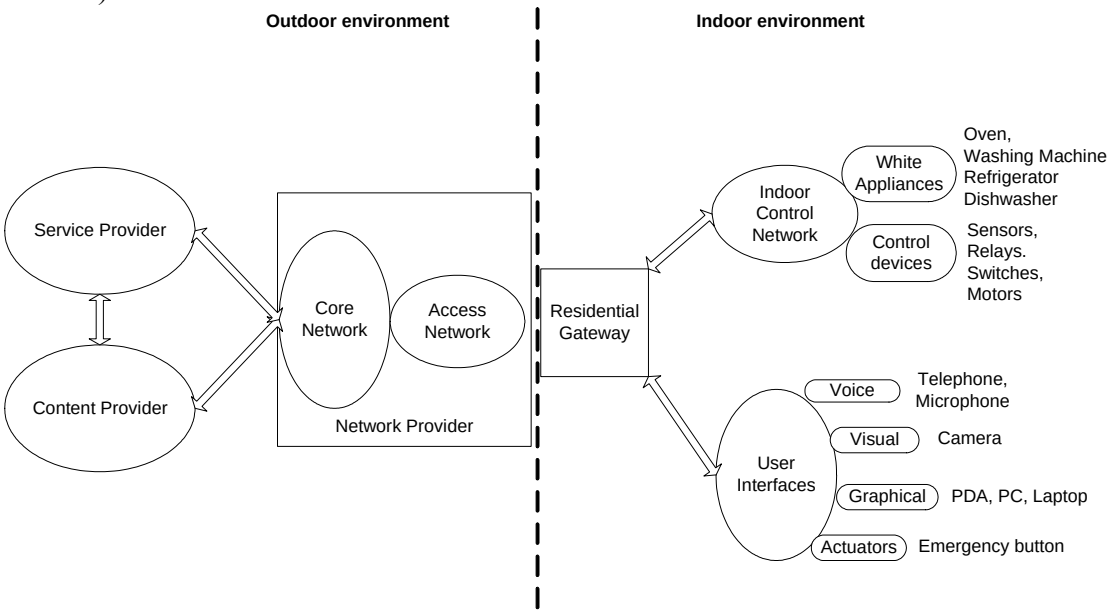


**Figure 1: HomeTalk Platform Architecture**

Multifunctional RG with modular broadband access interface, enable bundled service deployment of voice, data, entertainment and feature home automation services. They enable seamless interworking of indoor PCs, printers, laptops and PDAs with wireline and wireless access networks and connection sharing to service providers. They allow for inexpensive deployment of new services with remote configuration or software update. All interfaces to I/O devices are incorporated in the RG, therefore allowing for centralised control of the full range of user interfaces. Services can be customized according to the user profile, taking into account Human needs (communication, education, acquisition, security, entertainment), Human performance (social, perceptual, cognitive motor, memorial) and a broad range of available interfaces (keyboard, vocal, GUI).

## 3. Existing approaches and the Service Creation Framework

Traditionally, the service provider designs a service interface with his own aesthetics/ functionalities and accessibility features. No APIs exist to build new interfaces or interaction environments. The user should learn how to use the particular service and change his habits and usage principles accordingly. The new approach is based on easily customizable building blocks with open source APIs that allow to service providers to adapt services according to their users' needs. The service framework provides a context for developers to write service code to execute on the Residential Gateway. In this environment, services are swapped in and out, are dynamically updated, and must communicate in a structured and dependable way with other services. The framework should provide a rich and structured development platform for component-based software architectures and takes advantage of the ability to download code from the network. The primary goal of the service framework is to provide an environment that: Supports dynamic load or update of services without stopping the environment, is usable in limited memory devices, offers a concise and consistent component-programming model for service developers, manages dependencies between services, and is scalable. To take best

advantage of the framework, developers should design an application as a set of services, each implementing a segment of the overall functionality. These services and other extension services can then be combined and downloaded to the gateway device.
The OSGI approach is very mature in terms of functionalities and applicability. Given that the evolution of home networks seems to be driven by Home PC networks and Home automation networks [Wolf (2003)], it is apparent that the solution backed by telecom operators/manufactures, concentrates the highest probability of mid and long-term success. OSGI framework was therefore adopted for service creation. Designed to compliment and enhance virtually all residential networking standards and initiatives, such as Bluetooth™, CAL, CEBus, Convergence, emNET, HAVi™, HomePNA™, HomePlug™, HomeRF™, Jini™ technology, LonWorks, UPnP, 802.11B and VESA. OSGI leverages the value of existing wire line and wireless networks while providing flexibility toward cable, WCDMA, xDSL and other high-speed access technologies. The open source nature of HomeTalk, is maintained by choosing OSCAR framework implementation.

### 3.1 User interfaces

HomeTalk platform offers several interfaces to interact with the system. The typical in-house choice of controls includes voice (through microphones spread around the house, the voice recognition module of the PDA or through any telephone terminal connected to the in-house network), Graphical interface (through the screen of a desktop or laptop computer, or the PDA), White appliances interface (through the control boards of all installed white appliances), Actuators (through wearable wireless control buttons). All the above interfaces are assisted by cameras and projectors installed in the house that detect user activity and accordingly "assist" the interfaces to provide a more user-friendly experience. Distant interaction is limited to voice (through any fixed or mobile telephone) and graphical interface (through the screen of a computer, PDA or mobile phone connected to the Internet). The above pool of interfaces offers a unique opportunity to customize system interaction according to the particularities of the involved user (profile), the context of use [Intille (2002)] (emergency, leisure, relaxation, communication need, education/training, security, comfort etc) and the particular display that is used in each session.

### 3.2 OSGI-based Service Example: Home hospitalisation

The main objective of the service is to enable remote monitoring of patient's vital signals providing medical alarm surveillance from hospital premises and remote control of medical devices at patient's home. The service consists of two interfaces: one for the patient and his carer at home and one for the medical staff of the hospital. In this typical example of OSGi-based service, a Service Provider (in this case the hospital) offers the home hospitalisation service in a Service Aggregator portal. The later should check whether the offered service is compatible with the already existing hardware and software configuration at the patient's premises. Supposing that the patient is provided with a blood pressure meter (BPM), a glucometer and a wearable emergency button (which can be pressed in case of emergency). The BPM is connected through the serial port of the RG, the glucometer through the home Wireless LAN (IEEE 802.11), and the wireless emergency button through a Lonworks RF receiver [Dobrev (2002)]. The Service Aggregator should detect problems such as:

- Unavailability of a serial port for the BPM.
- Availability of free serial port to connect it but lack of driver to control it.
- The RG is not provided with wireless interface, thus the glucometer can't be managed.

- The RG cannot manage alarms (in the sense of sending an SMS to a mobile phone, sending e-mails or making telephone calls to the configured numbers).

When the patient or carer arrive at home and try to subscribe to the home hospitalisation service -through the Service Aggregator portal- the following warnings are received:

- A subscription based alarm management service is needed in order to have the capability to send alarm messages to the hospital.
- There is no free serial port to connect the BPM.
- The glucometer cannot be managed by the RG due to the lack of appropriate driver.

The patient subscribes to the alarm management service and removes the device that is connected to the serial port to plug the BPM. After solving connectivity problems, the patient fills some forms (to personalise the service and insert the necessary data for billing purposes) and once the service has been confirmed, the requested software is downloaded and installed in the RG and the service is automatically started. The hospital and the patient are connected to the OSGi platform using a broadband connection (such as ADSL), transparently using VPNs & IPSec for security matters. The doctor is able to control the patients devices at home using the remote control of devices service offered over the same platform. Medical devices –such as the blood pressure meter, are controlled in the same way as lights or cameras in the house. The doctor's profile only allows him to control certain devices in the house. For instance, he could adjust the lights or monitor the patient through the images registered by the cameras. The medical staff interface provides access to patient's agenda, information, Vademecum and medical history, and is also securely available to the doctor visiting the patient at home. In case the system detects an abnormal vital measurement, an alarm is sent to the hospital using the OSGi based platform capabilities to manage alarms. The patient interface has an agenda with appointments, diets and medication. All features available to the patient can be accessed by voice, through a computer or PDA, or distantly, from the mobile phone of the patient's carer.

## 4. Conclusions

The availability of a flexible open-source service creation environment combined with an extensive pool of available interfaces, offers the opportunity to service providers to create the appropriate user interfaces that will address the needs of their potential users in the best possible way. Through this approach, service providers are not limited by the restrictions raised by operators and can tailor their services according to the particularities of their target users.

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