An Interoperable Concept for Controlling Smart Homes – The ASK-IT Paradigm

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Abstract. This paper presents an interoperable home automation infrastructure that offers new levels of mobility, accessibility, independence, comfort, and overall quality of life. Building on previous experience with similar systems and existing gaps over the full potential of automated support, both at home and on the move, new concepts and objectives are defined for R&D on smart homes. The paper outlines the proposed integrated and holistic solution, discusses design and development issues, provides indicative evaluation results emerging from a case study conducted in the European ASK-IT project, and concludes by highlighting open issues and future steps.

Keywords: Smart home, Ambient assisted living, Accessibility, Infomobility.

1 Introduction

Quality of life depends heavily on the efficiency, comfort and cosiness of the place an individual calls "home". Thus, a wide range of products and systems have been invented in the past to advance human control over the entire living space. *Domotics*[1] is a field specializes in specific automation techniques for private homes, often referred to as "home automation" or "smart home technology". In essence, home environment control and automation[2] extend the various techniques typically used in building automation, such as light and climate control, control of doors and window shutters, surveillance systems, etc., through the networking of ICT in the home environment, including the integration of household appliances and devices. Such solutions are not only offering comfort and security, but when serving an elderly, an injured person or a person with disability can leverage safety and individual independence. *Assistive domotics,* represents a relatively recent effort in this direction that further specialises in the needs of people with disability, older persons, and people with little or no technical affinity, and which seeks to offer such residents new levels of safety, security and comfort, and thereby the chance to prolong their safe staying at home. Yet, a high quality of life is not only about comfort at home. The ability of moving about at will,

[1] The term "domotics" is a contraction of the words "domus" (lat.= home) and "informatics".
[2] A comprehensive state-of-the-art and market analysis is offer in Manchado et al. 2009.

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daily or not, is crucial for social inclusion. Being able to continue in high-quality employment and contribute productively to the economy is also important for self-esteem. Active participation in society, through social contacts and activities, daily economic activities such as shopping, and democratic decision-making are key to well-being.

The work presented here, motivated from the ICT tendency towards *ambient intelligence* and universal access to continuums of general and specific computer-based services and applications [5], aims at bridging the technological gap among domestic and urban environments. Our focus has been placed both on extending the access to domotic services beyond the home space and on enabling the proper fusion with *infomobility services*[3] and other key services that help individuals in maintaining their independence, especially individuals at risk of exclusion, such as elder citizens, people with chronic conditions or disability, persons living in remote areas, etc. The paper presents a novel concept for smart homes[4], conceived and prototyped as part of an integrated approach endorsed by ASK-IT[5], which offers users greater levels of freedom, mobility and inclusion.

2 Concept and Key Objectives

Researchers in ASK-IT have been working closely with older and disabled persons for many years in order to identify opportunities where ICT can help to overcome any experienced barriers and drive a good life with the least possible dependency on help from family, friends or social services. Our focus in ASK-IT has been on computer-mediated services to *mobility-impaired people*[6] (MI people, in short), such as accessibility-informed pre-trip and on-trip support for helping individuals in travel preparations and executions (e.g., to create new itineraries or collect travel information and navigation guidance regarding a tip in mind). In the same direction, the pilot system presented here has been designed to improve the typical experience of interaction with domotic systems. Ensuring ubiquitous access and control of the status of private homes, including while on the move, as a means for never leaving the house (comprising of electrical and electronic appliances, other residents, etc.) really unattended, helps individuals to feel more comfortable with getting out or getting on travelling. In other words, innovation within the ASK-IT domotic system is two-fold:

- *In-house*: use the domotic-end to deliver infomobility services at home.
- *Outside the home*: use the ASK-IT infrastructure to offer home control and home monitoring services while on the move.

Overall, this proposed approach introduces several new perspectives to R&D in home automation as it takes into consideration key concepts and principles such as:

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[3] As data sources and services to encourage and enhance everyday mobility and travel.

[4] Other terms used, often interchangeably, for "smart home" include "intelligent home", "connected home", "e-home", and "digital home".

[5] ASK-IT (Ambient Intelligence System of Agents for Knowledge based and Integrated Services for Mobility Impaired Users), is a European Integrated Project (IST-2003-511298) within the IST 6th Framework Program in the e-Inclusion area. See http://www.ask-it.org.

[6] A term used (Simões, Gomes & Bekiaris, 2006) to refer to various citizens who experience different kinds of limitations in self-powered motion or in using common transport means.

- **Mobility.** A primary objective is to take into account the emerging need of the modern citizen for enhanced mobility and render the home automation services in question portable and accessible through PDAs, smart phones, or remote access points. Further to Salomaa, Jaworek, and Maini, 2001, the term mobility may refer to: (i) personal mobility that deals with the mobility of people who may not necessarily carry a device, and (ii) computer mobility that deals with the mobility of devices. The above are inherent features of ambient intelligence systems and often addressed in conjunction since they are both concerned with enabling access to the computing space (i.e., content and computations, either public or private) from various locations [7].
- **Interoperable.** Our vision entails the objective of integrating multiple services and making them ubiquitously available offering a continuous, yet unobtrusive, experience of ambient intelligence. To this end, domotic services are integrated into a single platform, along with complementary services, such as infomobility services, eHealth, eWorking, eLearning, etc.
- **e-Inclusion.** A clear objective underlying this effort is to mobilise new technologies to overcome social and economic disadvantages and exclusion.
- **e-accessibility.** Ensuring that everyone is able to access and utilise the domotics techniques proposed here on an equal basis, especially people with disabilities and the elderly, is critical for the success and broad acceptance of the system. A combination of "*Design for All*" and "*Adaptive design*" approach is employed to this end, in which all components are designed to be used by everybody, but adaptable to particular user and context needs as a means to improve subjective usefulness and ease of use.
- **Energy saving automation.** Efficient energy management needs to be the baseline for all techniques in our home automation solutions in order to ensure the delivery of environmental friendly concepts.

3 Overview of the System

The domotic infrastructure in question has been developed as part of the Greek Pilot in ASK-IT, and has been installed at the temporary premises of *CERTH/HIT*[7]. At this stage, it temporarily consists of a single room virtually divided in four areas to simulate a full flat with the following basic rooms: living room, bedroom, kitchen and bathroom (see Fig. 1.). Although many techniques typically used in house automation are also used in HIT's Domotics Lab, additional functions are considered, such as the control of a multi-media home entertainment system, environment and user interface adaptation according to various preference settings (such as automatic scenes for dinners and parties) and to diverse user profiles (deaf, blind, wheelchair user, etc.). The ambient intelligent environment is further supported by several user-friendly and accessible interfaces (see Fig. 2.) to control home automation. In summary, interaction with the domotics functions is equally accessible through: PCs or Laptops (incl. through a wheelchair control or a joystick as an alternative to traditional mouse-based interaction offered for people with upper limp impairments), a Media center, PDAs (incl. through a wheelchair control or a joystick as an alternative to traditional

[7] See authors' affiliation.

Fig. 1. Overview of the various rooms simulated at HIT's Domotics Laboratory

Fig. 2. Fixed-location access: wall-mounted display (left) and PC/Laptop (right)

stylus-based interaction), in house wall-mounted touch panels, and mobile phones. Devices currently integrated include video cameras, one actuator (door control), one door bell, one HVAC, one Dimmable light, two Lamps, white goods (Micro, Grill, Coffe machine, etc.), while the sensors integrated include one temperature sensor, a humidity sensor, a luminance sensor and a motion detector. SMS-based services for alerts propagation have been implemented and integration with similar domotics installation in Madrid and Nuremberg has been achieved.

From a top level point of view, the system makes use of both wired and wireless network communication mediums. Two different middleware were used in order to test the feasibility and connectivity issues via wireless transmission. The first one is the OSGi and it is applied for PDA and PC devices. The second one is the JADE framework, which is based in Agent's structure. It is applied for more limited devices, such as Symbian mobile and smart phones (see next paragraph). Finally, the domotic modules are integrated with the overall ASK-IT platform providing a single user interface under the common ASK-IT client software, and thus acting as "portal" for accessing all ASK-IT services (Route planning, Searching for Points of Interest, e-Learning, e-Working, etc. – see [2]).

Fig. 3. Remote access and control to domotics (while away from home)

Fig. 4. Mobile access and control of the home environment

An innovative aspect of this work is that of mobility and freedom offered to the user with regards to home environment automation access and control. In order to support the modern citizen in travelling around the city and the world, the project has produced equivalent interfaces for Personal Digital Assistants (PDAs) and smart phones (see Fig. 3. and Fig. 4.). In this way, users can from anywhere in the world alter, or get informed about, the status of their home appliances and intelligent systems. For instance, the user may turn the oven on to warm-up the food while in car and on the way to home, and remain assured that the system will act smartly, for example if smoke is detected. Current emergency messaging solutions include direct messaging through pop-messages on the closest display and /or SMS-based text messaging as appropriate.

4 Development Considerations

As shown in Fig. 5. , we have generally two different categories of networks:

The *Local Devices Network* (LDN) connects all stationary and mobile devices inside the home to an overall network. The LDN has a heterogeneous structure, what means that more than one communication media will be used: E.g. BlueTooth, power-line, twisted-pair or ISM (free radio-frequency band). BlueTooth is required to connect a mobile phone to the LDN, available as common user interface when the MI user is at home. But because of its higher node cost and restricted communication range, BlueTooth is not appropriate to control all devices at home directly. Therefore, a gateway is used, translating the BlueTooth commands to other communication media, fulfilling the requirements for low cost and easy installation. Examples of appropriate communication media are Konnex PL132 (Power-Line), EIB (twisted pair) or RF433 (ISM radio frequency).

The *Wide-Area Networks* (WAN), such as GSM network or Internet, are used to supervise and control the domestic devices from anywhere outside the home. As access platforms, various devices are taken into account, including mobile phones, PDAs or Notebooks.

The domotic HIT's site has followed the same approach as for all ASK-IT services. The domotics web service is integrated into Data Management Module at server side

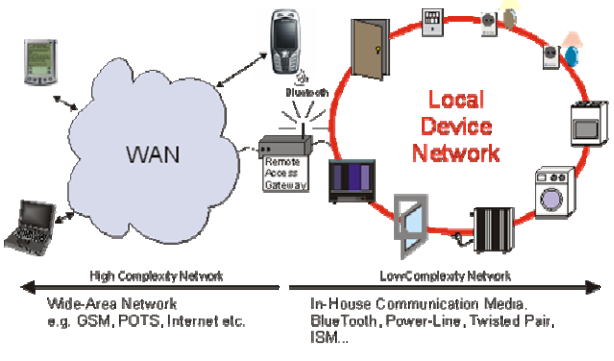


Fig. 5. ICT networking at HIT's domotic system

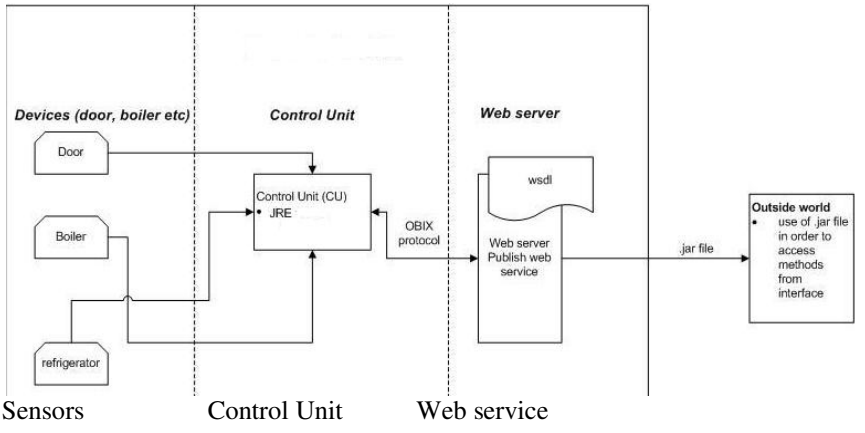


Fig. 6. HIT's domotic lab system architecture

(see [12] for a detailed presentation of the ASK-IT architecture and modules). Ontological objects have been defined in order to bind and map the ASK-IT server side with the domotic web service. The communication is handled by the PEDA agent at device side, and a JADE middleware controls the message exchange between client and server. The user can control devices remotely via GPRS or WLAN connection and changing the status of them, while he is away from home.

The HIT's domotic lab uses the OBIX protocol. The oBIX stands for Open Building Information eXchange, and it is an industry-wide initiative in to define XML and Web Services. The sensors are connected to main electrical board via a multi plug interface panel. Each sensor is wired or wireless and allocates a separate plug at the panel. The web service has been generated, contains also OBIX protocol features, as an external library. This is fully transparent to developer. The "output" to the outside world is a generated web service in the form of .jar file. The following diagram describes the general system architecture for HIT's domotic lab.

Following the overall ASK-IT approach, the user interface for the desktop application (PCs and Laptops) has been developed using Java Swing library version 1.3, while the user interface for the PDA application has been developed using Java AWT library. Adaptation is realised by employing the Decision Making Specification Language (DMSL) engine and a run-time environment [10] to offer a powerful rule definition mechanism and promote scalability by utilizing external rule files while relieving the actual UI implementation code by any adaptation-related conditionality.

The mobile user interface was developed using the MID Profile 2.0 API. The javax.microedition.lcdui.game.GameCanvas() class was used, which has the Canvas() class as the base. Each room is considered as a separate Canvas() and each device icon allocates a specific interaction area on it. The GUI provides includes a cursor to easily point and select the preferred option icon (room, device, etc.). In case the user has colour impairment, the GUI is transformed into black and white display layers.

5 Design Considerations Focusing on Accessibility

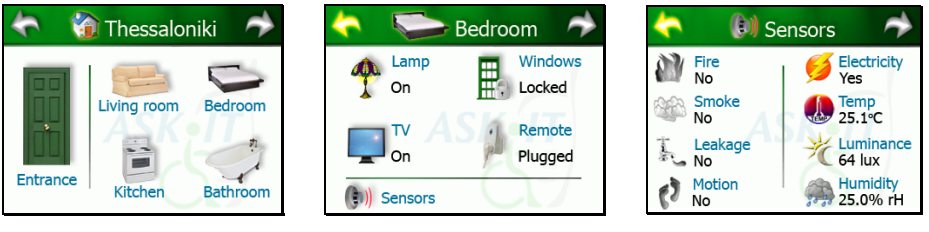
CERTH/HIT's domotic lab has also been design with particular attention, among others, to the needs of wheelchair and visually impaired users. For the design of the services of the domotics prototype in question, the differences in communication abilities of the elderly and various disability types were considered by taking into account the design guidelines collected in MOSAIC-HS for user interfaces to home environment control [1]. Fig. 7., in the interface design of the control (touch) panel, particular attention was paid to the needs of the elderly, people with low vision, and people with colour impairments (see Fig. 7.).

Furthermore, the home automation system supports adaptation through activation of different disability profiles. For instance, when the deaf user profile is activated, the various acoustic messages are additionally rendered to equivalent visual messages to the user's nearest displays, including when the door bell is ringing. In addition to the various pop-up messages on the various screens (Media Centre, PDA, etc.), the lighting system is also used to communicate such a message. In the previous example with the door bell ringing, the current room lights are flashing for 3 seconds.

In addition, physical accessibility has been considered, e.g., the wall-mounted displays are placed in a lower height so that they can be accessed by individuals on wheelchairs, following key guidelines coming from the TELAID project [6] regarding the design of public access terminals for use by elderly and disabled people (e.g., locating kiosks, display/control design, information requirements). For instance, TELSCAN's collaborative testing of booking terminals with the SAMPLUS project found that a terminal height of 90 cm would be acceptable for more people, as long as the angle of the terminal display was adjustable (about 45 and 30 degrees).

As the ASK-IT project paid particular attention to the needs of wheelchair users, a special software was developed to allow interacting with the ASK-IT devices and applications through a wheelchair steering control (joystick) by means of wireless connection (bluetooth and infrared). In this way, the system support the scenario of interchanging between steering the wheelchair (inside or outside the house) and interacting with any ASKI-IT service, including home automation options, through a PDA device for example to unlock the front door to a friend ringing the door bell.

In terms of software adaptation, the UIs can adapt to the user's profile and all input devices are interfaced as "plug and play" devices that the host machines (Media



Rooms view(homepage) *Devices view (bedroom 2 of 2)* *Sensors view (1of 2)*

Fig. 7. Icons-based, large fonts, high contrast are the main GUI characteristics of the touch panel units to ensure accessibility and usability to elderly and vision-impaired users

center, PC, PDA, etc.) recognize as standard input devices. To this end, the Unified User interfaces methodology and architecture [9] were followed and the DMSL language mentioned above was employed define the user interface of the domotics application in PDAs. This approach is further detailed in Leuteritz et al. 2009. In this context, a number of UI elements were designed in various forms (polymorphic task hierarchies) according to specific user- / context- parameter values. In this way, the user may change on the fly the text font family, size, text colours, background colours, etc. according to his/her preferences or interaction needs. Similarly, the mobile user interface may change font size, family and colours as a means to adapt to specific user preferences.

In the ASK-IT case study, the correlation of the various alternative designs of UI elements to user and context related parameters (i.e., the adaptation according to generic, predefined profiles) has been made on a normative basis. Therefore, it can not currently be claimed to be optimal, and needs to be further elaborated and verified in the future, through feedback from user trials in real contexts. However, this work has made clear that the proposed approaches allows embedding in PDA and mobile applications such decision making logics and automatic adaptation facilities for the benefit of accessibility and better user experience.

6 Preliminary Evaluation Results

Stand alone trials were conducted on 5 different occasions from 6th of June till 11th of July 2008. The ASK-IT services reviewed were: Domotics (our focus here), Planning urban/interurban/national trip, POI & social events search, E-Learning, and in-vehicle navigation support. Five (5) male and four (4) female users (mean age: 42.75±16.2) participated in the tests. Elderly users (3), wheelchair users (3), as well as people with hearing and upper/lower limb impairments participated in tests, as mobility-challenged user types within the ASK-IT framework.

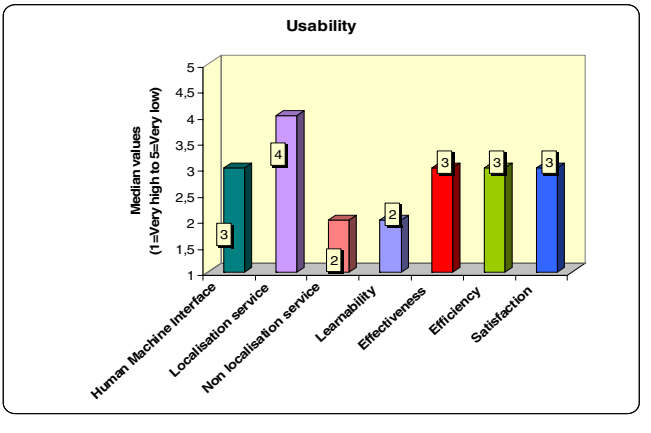


Fig. 8. Usability findings

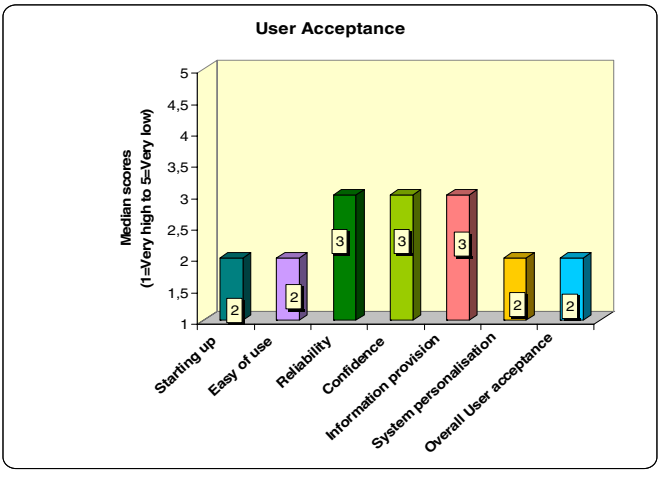


Fig. 9. User acceptance findings

In general, all participants agreed that ASK-IT offered a complete solution that satisfies their needs (see Fig.8 and Fig.9). Yet, the elderly mentioned being uncomfortable with working with such technologies and may need extensive effort for training. All participants agreed that this solution could potentially: be used frequently; make them feel more confident; take away stress and offer more freedom of movement; and offer freedom of choice. The [remote] domotics were graphically appealing to all MI groups. ASK-IT domotics was perceived as the least difficult to learn and use among the ASK-IT services and participants are willing to own such a home automation system. In fact, installation and system usage costs were the most common post-debriefing questions.

7 Conclusions and Future Work

The evaluation data from the integrated tests are still under process and shall be presented in further detail elsewhere. This process is anticipated to bring forward new dimensions with regards to concept and the design of mobility and accessibility informed domotics. For instance, early tests with indicative users showed that the provision of effective and efficient human control on the dynamic and distributed system is also critical. In particular, is now clear that it will be necessary to establish an appropriate balance between automated learning on the part of the intelligent environment, human behaviour patterns, and human intervention aimed at directing and modifying the behaviour of the environment. This aspect of the emerging technologies needs to be carefully taken into account particularly when elderly and cognitively disabled people are involved, as services that monitor the health status or the location of users may also interfere with their capacity of taking decisions. Future work will now focus on the upcoming results of the undergoing user test and fine trimming of the interaction concepts and designs of all the employed platforms. Then in future research works, efforts shall focus on the intelligence of the underlying system, on co-morbidity issues, and on

collaborative interfaces for houses shared by more than one people with diverse abilities, skills, preferences and needs. Indoor user localisation and identification mechanisms are a key issue in this direction, while the ethical issues involved require that all future concepts will have to evolve around consensus building processes among real users and technology designers.

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