Networking and Communication in Smart Home for People with Disabilities

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Abstract. People with disabilities need several assistive technical aids to increase their autonomy and perform daily living tasks. This paper describes the role of networking and communication in the smart home concept which allows people with disabilities and elderly people to retain a certain level of independence within their daily environment, such as at home, work, school, outside and so on. The purpose of our research activity is to explore the difficulties by determining the most suitable approach to federate the different communication protocols available indoor and outdoor environments. In this paper we are presenting our main concept in the design of the smart home architecture. We also describe our approach to design an open software environment adapted to people with disabilities. This approach is based on the service discovery protocol UPnP (Universal Plan and Play) to discover devices in smart home. It is based also on wireless technologies and protocols (Wifi, Bluetooth, etc.) to enhance mobility and dependency. Some solutions are adapted to favor integration of new modules and devices, and to improve the communication between the different layers of our software architecture.

1 Introduction

In order to enhance their quality of life, people with disabilities and elderly people need to be independent and autonomic in their environment. That implies a freedom of moving using wheelchairs, a compensation of upper arm impairments using robots, environmental control systems for home appliances, and so on, without the intervention of another person. Our work does not lie in this last point only, but also in the federation of all these assistive helps within the framework of an intelligent environment defined as the smart homes concept.

Smart homes is the term commonly used to define a residence that uses a home controller to integrate various automation systems (controlling devices together). Integration of the home systems allows communication with one another through the home controller. This enable single button and voice control of various home systems simultaneously, in pre-programmed scenarios or in operating modes.

Several research projects investigated this domain by using multi-agents systems in order to design the smart home architecture [1][2]. This solution can resolve some problems of communication between existing modules, but seems complex and does not solve the problem of accessibility and multimodality. Our solution is based on a multi-layer architecture, which improves accessibility and supports multimodality with a software configuration tool and a voice recognition module [3]. The Human Machine Interface (HMI) represents an essential layer in our architecture that allows interaction between user, external events, and the system [4]. Interaction with physical devices is ensured by the COM layer (COMmunication) through a particular module called Ametsa (UPnP gateway), able to send commands via IP-enabled, infrared (RC5), and power-lined controlled devices [5]; or through the industrial CAN protocol (Controller Area Network) when it deals with a robot manipulator called MANUS robot. Below, we detail our running designed prototype and how networking technologies are used to cope with communication needs.

2 Software Architecture of the Smart Home: a layered structure

The Smart Homes concept is composed of modular software components [7]. This architecture is based on our experience on controlling the Manus assistive robot [6]. The concept has been adapted to the smart environment to control various heterogeneous systems corresponding to different networking protocols. This modular software architecture offers several advantages to the developers and consequently to the users:

? Adding or developing any input device driver does not require high background of the controlled system since each action has a user oriented description in XML [4].

? Remote maintenance of any device through the Internet is facilitated through a Tele-maintenance Unit (TMU). This module was designed for robotic purpose, but has not been developed yet.

? An HMI supervisor allows coupling modalities to control any appliance. For example, coupling voice recognition for device selection and shin control to perform the corresponding movement the wheelchair.

This software architecture is decomposed in three main layers (figure 1):

2.1 User Layer

Input Devices: Manage user interfaces events according to any input device (keypad, joystick, voice recognition, etc.) selected and configured with the ECS (Environment Configuration System) software according to each end user.

Feedback: Gives user information about status of his environment (ex. input and output devices states) via visual representation (text, icons and images) or via audio feedback (sound). This module allows using direct pointing devices (Mouse, Trackball, etc.)

2.2 HMI Layer

This layer supervises the whole system: it converts user events into actions according to selected output devices (Manus, TV, VCR, etc.), transmit the information to the feedback module, manage multimodal aspects, manage errors situations, manage the synchronization of modules, etc.

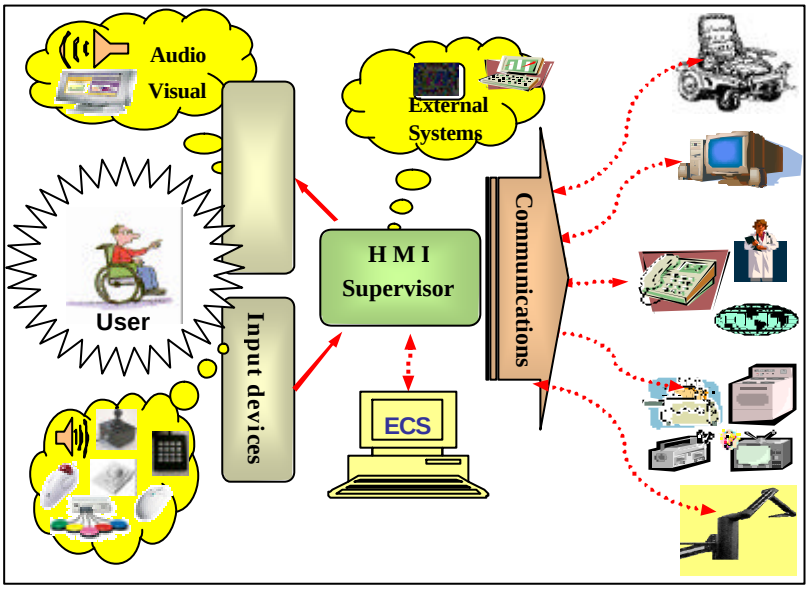

Fig. 1. Modular software architecture

2.3 Communication Layer

Deals with specific characteristics of any output device according to its communication protocol (CAN, infrared, radio protocol, etc.). Indeed, traditional home services are proposed by home devices manufacturers by means of a proprietary control device which may be accessed either directly or from the phone network. Services allowing the (remote) control over lights, heating or shutters are usually proposed and implemented by proprietary means. On the other hand, home services are gaining more and more interest in the computer science community. In particular, several service discovery systems have been proposed that use open and standard Internet communication protocols in order to discover available devices and to send

commands to them. Although these solutions are independent from device manufacturers, the lack of home devices understanding Internet protocols has restricted the proliferation of home appliances of such systems, which still restricted to computer applications.

Home services take profit of new technological developments in communication networks. These services are not only dedicated to a large public of users but also to specific users such as dependent people (persons with disabilities and elderly people). These services aim at improving their ability to evolutes in their indoor environments and compensate their handicap. Today, as a consequence, many products are available on the market allowing the control of the heating, lightning or automatic shutter systems at home through wired and wireless communication networks. Occasionally, it is possible to access the control panel from outside, mainly through the telephone network (DSL). This allows setting up adapted services, such as remote monitoring.

3 Communication and networking

In this section, we describe the various methods and solution adapted to our approach. That relates to the solution adopted for discovery and control of the devices available in user environments. We will also explain the role of the COM layer, enabling the integration and the connection of various modules, while showing its implication to the dynamic aspect of the architecture. At the end, we will highlight the role of wireless technologies in mobility through WiFi and Bluetooth protocols by the use of the handhelds devices.

3.1 Discovering and controlling system

In the computer sciences domain, the concept of services provided in houses raised the interest of many protagonists. In opposition to domestic devices manufacturers, they consider that domestic equipments able to understand the Internet protocol already exist and propose tools to assist the user in the process of discovery and utilization of systems. Such opened and standard systems are independent from domestic devices builders. However, the low development of such domestic devices has slow down the development of home controlling applications. This situation limits the use of such systems to computers.

In order to ensure the independence from home devices manufacturers, the COM layer is mainly based on the Ametsa service which offers a generic interface allowing clients to be aware of the arrival/removal of devices to/from the network and to send specific commands to devices. Ametsa uses a service discovery system based on UPnP [8]. UPnP functionalities are used to be aware of arrival or removal of devices and to send or receive commands to/from available devices. As many home devices are not able to manage Internet protocols, we have developed gateways which translate UPnP protocols on the corresponding (proprietary) protocol of devices.

As shown in figure 2, UPnP communication protocols are used by a control application, called Ametsa Core, that supervise all available devices and allows

sending commands, via UPnP protocol, to physical devices represented as Gateway devices, based on X10 and X2D power lines protocols, infrared RC5 protocol, etc.

Moreover, in order to allow non IP devices management, we developed a gateway framework that translates UPnP protocols used by Ametsa to the corresponding protocol.

Control commands are sent by the use of the CORBA API offered by Ametsa [9]. These calls are translated into UPnP messages which are sent to the concerned UPnP protocol stack.

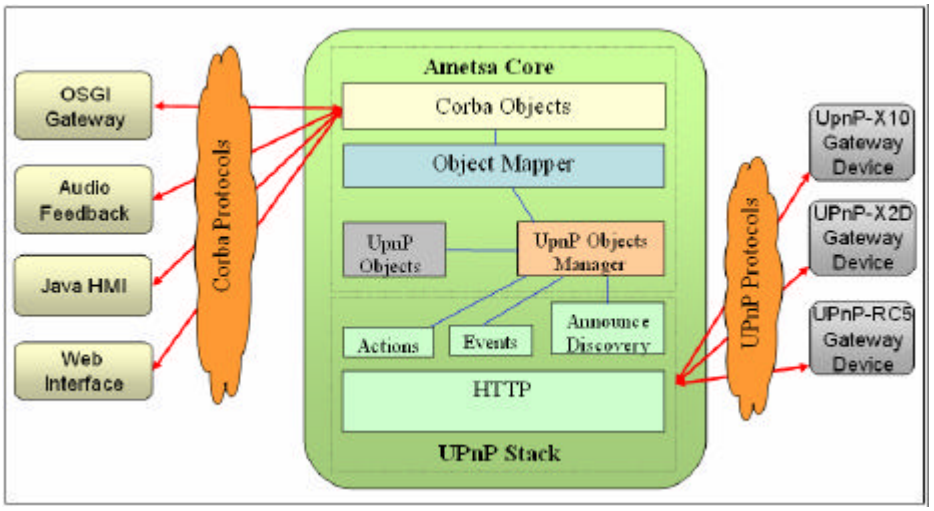

Fig. 2. Architecture of the devices discovery and control system

Ametsa uses an UPnP Stack in order to be informed of the arrival/removal of devices to send corresponding control actions. Gateways use UPnP protocols to inform Ametsa on their arrival/removal status, their resulted actions processed, and on the corresponding effective communication protocol.

All these functionalities are actually running on a common prototype which should be installed in the Rehabilitation hospital of Garches for validation with implication of users having four limbs impairments.

3.2. Generic communication system

Above, we saw the conceptual architecture of smart environment and we attempted to outline the networking design of heterogeneous communication objects in user's environment. The HMI allows the interaction between the user events, the external events and the system. The problem of devices discovering is resolved with the UPNP protocol as described above mainly dedicated for indoor environmental systems. However it is also necessary to control devices outdoor, such as control of Manus robot mounted on user electrical wheelchair, and other devices directly (e.g. control

TV, telephone, etc.) through a unified user interface used as remote controller (e.g. portable PC, tablet PC, Pocket PC, etc.).

In order to ensure networking interconnection between all these modules, we have developed an open communication platform called "COM layer" (Fig.3). This layer offers two services: Scan and Control functionalities. Scan function allows scanning of all kind of devices which can exit in the home (robot, wheelchair, devices controlled by Ametsa, etc.). The description of these devices and all their possible actions and services is based on a standard description with XML. The XML output file resulting of the scan operation is at the disposal of ECS configuration tool in order to configure and adapt the user interface. This file is built in a way which allows the HMI using it dynamically and displays the corresponding graphical user interface and enabling available input modalities.

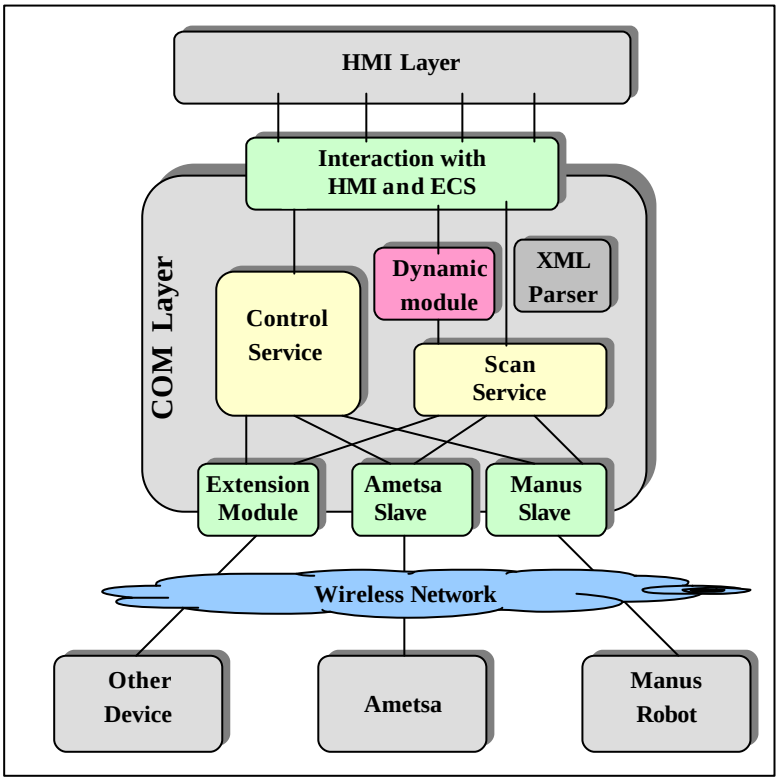

Fig. 3. Open communication layer architecture

The Control function treats the command, sent by the HMI, in order to convey it with the selected module through the suitable interaction output (e.g. Manus Slave, Ametsa Slave, etc.). The structure of the order is selected in a way that a table of correspondence is avoided. An add/remove device event cause the reuse of the scan

service by the dynamic module in order to inform the user about this event and refresh the user interface.

The interaction with the Manus robot is made through Manus slave using sockets. Currently, we are studying the evolution of this connection towards the use of CORBA communication bus, aiming to add more flexibility and safety to this connection. The COM layer uses CORBA API to connect with Ametsa gateway and control available devices. We also planned to integrate other gateways, such as Bluetooth and infrared IrDa to discover and control wireless devices. All communications and interconnections are independent of the physical layer of the networks. That's why we could adapt and introduce easily available and emerging wireless protocols in the future to fit with our smart homes concept, such as 802.11x, 2G and 3G technologies.

3.3 Mobility and portability

Wireless networking improves both communication and mobility, which are two common limitations amongst people with disabilities. This technology permits greater mobility for these people; there is no need for the installation of cables which would cause troubles if the household is fully arranged and which is therefore disturbing for these people. It avoids an over wired environment especially in the user movement field. Moreover, a wireless medium allows a high flexibility of the module or the device being connected.

On the other hand, the handhelds and wireless devices expand rapidly and support a wide range of applications and services. Besides their simple and comfort use, they become today indispensable tools for a broad spectrum of end-users ranging from the new-age teenager to the corporate road warrior. In this issue, we believe that our concept should be generic and deployed in various kinds of handhelds and wireless devices (PDA, cell phone…), thus involve a portability problem.

To validate this step, we choose Java technology for the development of majority of our modules considering its benefits on portability on several operating systems and its benefits on wireless applications. We chose the Wifi (802.11g) technology as a wireless protocol ensuring the transition and connection between some modules inside the home and we tried to deploy our application on PDA, running on a Linux platform, to control the environment. This work is under development and it should also integrate the control of the environment, not only indoor, but also outdoor, based on 2G and 3G generation of mobile communication, with an "indoor/outdoor continuing services concept" we are designing.

4 Conclusion

This paper described our research activity on the integration of networking and communication technologies in the smart homes concept dedicated to people with disabilities. In this context, we outlined the importance of an open communication platform describing our architecture. The developed prototype is based on the UPnP

protocol to discover and control devices indoor. It uses wireless technologies to enhance mobility. Its importance resides in managing different protocol and ensuring intemetworking and communication between environment's devices.

The limits of our work reside on a security problem coming from the use of wireless technologies and diversity of communication protocols. For that reason, our team are investigating the OSGI framework (Open Services Gateway initiative) [11] which can be deployed to bridge the internet, the home networking, and the devices. This framework, which is compatible with UPnP protocol, is based on services oriented infrastructure that provides a managed and extensible framework to connect various devices indoor and outdoor environments.

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