A review of ubiquitous applications and technologies oriented towards disabled and senior people

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Abstract. Forthcoming wireless networks will combine high capacity heterogeneous networks, with almost universal availability, with the property of roaming and interaction aimed to mobile users. In this context of ubiquitous networking, applied research will undoubtedly bring the attention to the end-user, who will become the center of services and applications. People-aware scenarios will offer services according to the *user profile*. Indeed, specific collectives, such as *disabled/handicapped or senior people*, may benefit specially from these smart wireless environments, due to their property of adaptivity. In this paper we aim to review the most important projects and technologies in this field. We provide a brief taxonomy of the most prominent developments in the area, including a description of envisioned and current systems, and a discussion on wireless technology issues and profile management and standardization.

1 Introduction

One of the goals of the forthcoming fourth generation networks (4G) is the aggregation of heterogeneous networks, with almost universal availability and the capability of roaming and interaction. In this context of ubiquitous/pervasive networking, research interest will undoubtedly move to the end-user, who will become the focus of services and applications. That is, there will probably be a shift from a data-centric network paradigm to a user-centric paradigm. The potential applications of these new wireless networks include the adaptation of environments to the user capacities. That is, offering each person a portfolio of services which will depend on the particular characteristics of his/her context. Such people-aware scenarios will offer services depending on the *user profiles.* Envisioned services include not only information processing but also undelying physical adaptation for the benefit of the end user. In ubiquitous environments this property is fostered, managing user information to drive the adaptation performed by the environment.

Specific collectives, such as disabled or senior people may clearly benefit from the smart environments created in the context of ubiquitous networks, due to their property of adaptivity. For instance, a disabled person with limited mobility in the proximity of a smart environment may have personalized aids like automatic door opening or automatic elevator call with an implicit indication of the destination floor, that is, and action that may be difficult because of his/her disability. In addition, a person with limited or no vision at all may use special cash machines, *with ubiquitous intelligence*, which may activate sound aids, or the presentation of specific format texts (e.g. high-contrast colors). Examples of applications for old people span from location services in indoor environments for sick people (e.g. with the *Alzheimer* disease) to the use of electromechanical reserved seats in buses or trains. Such applications are possible if the network is able to manage context-aware information from the surroundings and the users.

Among the key aspects of these applications stand out that they do not require direct user participation (the action seamlessly occurs), and, thus, the service platform is valid for any user level, ranging from expert to beginner ones. Furthermore, the final service depends on the user profile, which must be known by the network in order to conduct its operation in a suitable way. Therefore, the entire platform is made of a set of wireless network technologies combined with mobile devices (that can be wearable or integrated in user objects) which enable the required infrastructure for the aforementioned services: user discovery, profile management, data exchange, security, location, monitoring, persistence detection, etc.

In this work we survey the currently available technological proposals and alternatives for these services, summarizing the applications for disabled and senior people that these systems will enable. Then, in Section 2 a description of envisioned and current systems oriented towards disabled and senior people is offered. Afterwards, in Section 3 a suitable architecture for these platforms is depicted. A discussion on wireless technology issues that will enable such ubiquitous applications is provided in Section 4, completed by describing the standardization efforts by regulatory bodies, in Section 5. Finally, the paper is concluded in Section 6 with a summary of foreseen applications.

2. Description of current and envisioned systems

Nowadays there exist many on-going projects whose goal is to help disabled people and to shape a more intelligent environment. In this section we summarize some of them and provide a brief overview of the technologies these systems are using. We have classified the selected system samples into three broad categories:

1. Improvement, in general, of quality of life of disabled and senior people.
2. Assistance to movement of blind people.
3. Real dynamic environment adaptation to disabled people.

The first category includes a very common type of systems whose goal is to improve quality of life by making regular duties easier for disabled and senior people. Associations of disabled people, as the "Organización Nacional de Ciegos

Españoles", ONCE, have made some attempts to contribute to this field. ONCE and Fagor **[1]** have developed electrical appliances with voice synthesizers onboard, designed specially to solve accessibility issues of vision disabled community, since the technological evolution of this type of products in our days is creating additional barriers for this people.The appliances are prepared to communicate by radio-frequency, using the Bluetooth standard, with a portable system commissioned to convert every action made to the appliance controls to talked information audible for the user about the selected programs, function status or device faults. By using a standard technology (Bluetooth) the user can employ standard devices, as headphones or mobile phones.

ONCE has committed itself to develop different applications onboard the corresponding devices, which are able to reproduce as voice messages the exchange of information between appliance and user. In addition, these applications allows to turn the device into a remote control for the appliances. This way, users may employ easy-to-use devices, such as standard mobile devices, or some others specifically designed for vision disabled people (for example those from Owasys) as well as PDAs or standard PCs.

There can be found several other systems that help disabled people, but few of them require little active intervention by the user. In fact, with these systems the environment does not actually adapt to the person. It just provides information, usually depending on personal characteristics, and allows the user to actively interact with it. These systems are almost totally based on devices as comfortable to be carried as possible. The user interface is also as easy as possible to avoid difficulties and annoyances to the user. A PDA or a Smart Phone is the main device used for interaction with the user in a number of systems, since their usage is growing up and they are simple to use as long as they are provided with a proper interface.

The system in **[2]** is based on the use of Smart Phones to interact with the environment. A phone is used as an active and passive device. It is passive as a control device for all the systems in a house. It is active as an intelligent agent guiding and taking care of the user. For this system it is essential the integration of multiple emergent technologies, as the Java Smart Phones, broadband services (xDSL, cable), LAN and WiFi networks, domotic networks (EIB, X10), microcontrollers equipped with RF communications to implement sensor networks, etc. Through a *home server* the user can interact with the elements in the house. This *home server* acts as a gateway for EIB, X10 or others microcontrollers, using wired or wireless networks, and it plays a decisive role since it has to make possible the integration of all the components and technologies. As its function is to act as a gateway for all the systems, it implements a *middleware proxy* for each type of service, and this way provides a common interface among the telephone and the different systems. In short, with this system an easy to use device is expected to be used as a kind of universal control and integral personal assistant.

To facilitate interactions with our environment, **[3]** acts like an intelligent intermediary. It takes advantage of the capabilities of the mobiles, in order to see through their cameras, hear with their speakers and sense other devices using wireless systems like Bluetooth or WiFi. Having these capabilities, the mobile device takes the necessary information out of the environment and offers it to the user.

The Mobilthon project **[4]**, promoted by France Telecom R&D associated with the AFM (French Association against Myopathies), has the intention to facilitate the daily lives of people suffering from myopathies. The safety system imagined by France Telecom R&D includes sensors discretely integrated into the clothing of the person. These sensors detect not only falls, but a sudden or unusual leaning of the body as well. They are linked by Bluetooth technology to a mobile, which can signal a hazardous situation to a predefined list of people. Depending on the seriousness of the situation, several alarm levels are planned.

Within this first category there are other systems: **[5]**, **[6]**, **[7]**.

Regarding the second category, systems which help people with some kind of vision disability to travel, they are passive from the point of view of the user. It is the case of OntoNav**[8]**, an integrated indoor navigation system. It is user centered, in the sense that both the routes are given to the user depending on his physical and perception capabilities, his specific preferences, and, obviously, his current location. This system focuses on the configuration and selection of the best possible route for a person with a particular profile, so this person can store it in his PDA, for example, from which he requests the route for walking inside the building.

POLI environment **[9]** also follows this idea, providing a workspace for the integration of present and future mobile devices into a system to make easier for the vision disabled people the movement in an urban environment. No particular device is considered, though it was initially designed for PDAs communicating by infrared with the environment devices that provide location information to the device. It is already being considered the use of Bluetooth and WAP for the communications with the POLI Gateways. The user can connect to these gateways to obtain more complex remote information.

In **[10]** it is presented a system that assists blind users in orienting themselves in indoor environments. The system uses a sensor module that can be handled like a flashlight by a blind user and can be used for searching tasks within the three-dimensional environment. By pressing keys, inquiries concerning object characteristics, position, orientation and navigation can be sent to a connected portable computer, or to a federation of data servers providing models of the environment. Therefore, a WLAN card was integrated in the portable computer and the connected sensor module described above was extended by a digital compass and a 3D inclination sensor.

Within this second category there are other systems: **[11]**, **[12]**, **[13]**, **[14]**, **[15]**.

From the point of view of an environment that must adapt to the user, all of these systems have a clear drawback: they require an active interaction from the user. Even though the interface can be very intuitive and friendly, this reduces remarkably their adaptation possibilities, since a minimal user active interaction is required in order to be completely transparent to the user.

Finally, the next systems represent more accurately the idea of the environment really adapting to the user needs.

The Sentinel system **[16]** is focused on mobility assistances and is passive with respect to the user. It separates the user interface and the functionality in order to provide universal access to the applications. It achieves it by dividing the system into a information processor device (in the environment) and a user interface device (specific to the user). The environment information is stored in XML format and uses standard communications like GRPS, IrDA, Bluetooth, IR-RS-232 and HTTP, that is, it uses an open architecture. The user device processes the information transmitted by the environment devices, which allows the access to larger computational or storage resources, transferred to the user device.

Let us see an example of the system operation: a user has to go to a specific office inside a building. He comes in the building, and the entrance device transmits to the user device (for example, a mobile phone) by Bluetooth information about the environment, as an URI that points to an XML file. Optionally, the user device can transmit user identity information, and can access to the building data system and generate the route to arrive to the correct place. Then, the user starts the route inside a dynamic environment, where the phone receives signals from cheap and small devices surrounding it, which at least send their identity code. This code along with the stored URI are sent by GPRS to a web site and processed. A location description is returned to the phone. This process involves the acquisition of mobility information as well as its processing along with a history of the previous environment interactions. Such a journey will be dynamic and it will change according to the final destination, the previously found devices and their type. Each device can be from different manufacturers.

P-ITS **[17]**. It is a pedestrian-centered traffic system based on ubiquitous and wearable computing techniques. It focuses on making an environment safer and more comfortable to blind pedestrians. The system is based on terminals located on the streets and wearable computers, as well as the ITS infrastructure. These two types of terminal communicate with each other via short range wireless communication such as Bluetooth. The street terminals and the wearable computers exchange their data. The wearable computer drives the user considering its information and that from the street terminals. On its turn, the street terminal changes traffic infrastructure, such as traffic lights, according to the information supplied by neighbouring wearable computers. This way, P-ITS can be configured to provide services to obtain a smooth and comfortable environment for pedestrians.

Three service models are proposed for this system:

- Extended "five senses". Street terminals around the user can provide him with information which a conventional walking aid device cannot. This means that the user can reinforce his five senses by wearing a gigantic aggregate of sensors named "city".
- Production of smooth traffic. P-ITS makes the pedestrian-centered traffic system possible by means of a dynamic control of traffic infrastructure, such as traffic lights. As an example, a traffic light change its duration of green light for disabled pedestrians.
- Promotion of mutual help. P-ITS can notify a driver that a person walking in front of his car is deaf in order to avoid the driver to push the horn since the pedestrian cannot hear, and the system can tell the hearing impaired person that a car is approaching behind him to move away. When the pedestrian terminal knows its user capabilities and location, P-ITS allows to match the needs of two users. For example, a hearing disabled person can find another person who can translate his/her sign language to English on the streets.

In **[18]** it's proposed the home automation in a house or living environment with Bluetooth wireless technologies. Remote and local controls are useful to keep home comfortable and to support the elderly and the disabled people. There is a server PC controller and several client devices that operate between them through the remote monitoring and controlling. The client circuit consists of PC interface, sensor circuit and PWM (Pulse Width Modulation) circuit. Server PC receives a measured temperature data, and illumination sensor data from the client sensor module at every sampling time and it computes a command according to the algorithm. In addition, the server PC could access to an external PC with an internet connection. It can control home devices when the user is in the outdoors.

These systems are a sample of the developments aiming to adapt the environment to the user as transparently as possible. But, as can be seen only a few of them seem to achieve this objective. Other systems: **[19]**, **[20]**, **[21]**.

3. System architecture

Many of the on-going projects and proposals reviewed in Section 2 show a similar system architecture. Figure 1, shows this common general architecture, suitable for most of the systems. There are three basic components: user devices, profile processor and environment sensor and actors. The user devices automatically transfer the user profile (usually in the form of XML files) to the profile processor. The latter is responsible for processing the user profile and adapting the environment to his needs. The profile processor may use resources distributed in a network. Finally, the environment reacts and adapts to the user needs driven by the profile commands.

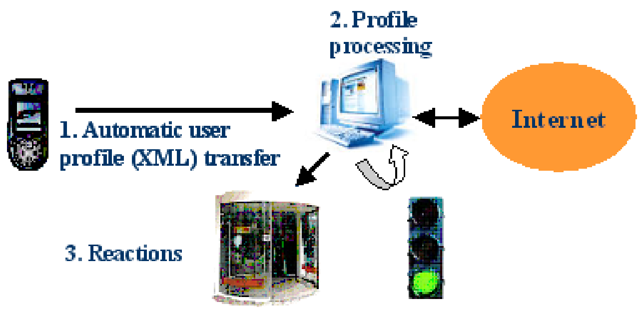

Figura 1. System architecture

Additionally, there may be sensors in the environment whose measurements are sent to the profile processor and used together with the user information.

4. Technology issues and mobile devices

Many different devices must communicate and exchange the information necessary to achieve the enviroment adaptation, as we have seen in the previous sections. Apart from the “common” technologies seen in the sample systems, like Bluetooth, PDA’s, Smart Phones, WiFi, etc., nowadays there exist others technologies not so generally used and known:

- **IEEE 802.15.4 (Zigbee)**. A protocol part of the IEEE 802.15 Wireless Personal Area Networks standard. There is a lack of available products that implement this standard, but there will be in a short time. Zigbee has low power consumption, short range (10 to 70 meters), integrated security mechanisms, and Zigbee modules are expected to be cheap. It cab set up sensor networks in a mesh topology of 255 nodes with a shorter discovery time than Bluetooth. It can be used to have enough of these devices deployed in a location moderately large to provide information to the user terminals.

- **UPnP and Jini**. These two techonologies are middleware software that allows an easy interconnection of different devices which provide information to the each other. It allows to create a group of components that provide a service infrastructure in a distributed system. These technologies are specially indicated for interconnecting devices more complex than just sensors. It could interconnect user terminals with different devices in the environment.

- **Radio Frequency Identification (RFID)**. This a technology used to store and retrieve remote data that uses devices called RFID tags. These tags are not equipped with power supply, so they are passive devices and respond to the read/write antenna delivering a little piece of information, usually a few bytes. This could be used to carry the user coded profile and having it read by the devices of the environment to process this profile and change its conditions to this profile. This way the user does not have to carry any terminal, apart from this RFID chip integrated anywhere (a credit card sized element, a key ring, etc.).

- **Microcontrollers/microprocessors**. The user terminals may be either standard devices (PDAs, mobile phones) or a more compact and particular design, possibly needed in the long term. In this case, specific microcontrollers wireless capable, with moderate process capacity and very low power consumption should be used. There is a wide range of microcontrollers available, such as the 8051, PIC, 68HCXX families which can be used in simple terminals. Microprocessors can be used if more complex terminals are needed, like ARM, which has low power consumption. All of them have at their disposal programming facilities and the possibility to connect with numerous types of peripherics, and they can manage input/outputs, sensors, communication devices, etc.

- **EIB, X10, domotics and automatism communication buses**. These buses are intended to control devices at home and buildings, like lighting, air conditioning, heating, etc. With these standardized systems it is relatively easy to implement a control infrastructure for the building installations. A widely use of these systems is very likely in the short term, so the facilities that these systems provide should be taken into account to implement a system that makes the environment (the building in this case) adapt to the user.

5. Profile management and standardization efforts

The environment must know as accurately as possible, the user characteristics, capabilities or disabilities, in order to act as it is expected. Thus, it seems necessary to create some kind of standard user profiles, where these special characteristics are defined. In this case, the goal is to standardize the level of disability of a person, since the environment must accordingly react in different ways.

So far there has been little standardization effort on the level of disabilities, although there is available some kind of classification of these levels. We can find some examples in the documents that must be filled in by the disabled people to receive some kind of assistance. In these documents, it must be given the degree of physic or mental disability suffered. Altough they are not standard, two examples are the documents that must be filled in some states of the U.S.A. **[22]**.

The World Health Organization (WHO) has been developing an International Classification of Functioning, Disability and Health (ICF) **[23]**. The main objective of this classification is to provide a standardized and unified language as a reference for the description of health and states related to the health, in order to improve the communication among users, including disabled people. This classificasition is expected to be used for data comparison among countries, sanitary disciplines and services. Finally, it also provides with a systematized coding scheme to be applied in the sanitary information systems.

6. Conclusions

In this paper a number of ubiquitous applications for disabled people have been reviewed. The principal idea, present in many of the previously discussed projects, is the interaction with the urban environment in general. That is, the urban environment becomes more accessible to the people, principally to the disabled ones: the traffic lights wait longer for the disabled people to cross the road, the buses can take the appropriate actions automatically, etc. This behaviour can also be extended to the public buildings, sport centers, elevators, lighting in public areas, the adaptation of vending terminal (bigger letters, voice messages), etc.

The real potential of this option lays on the interconnection of several devices within the environment to coordinate multiple actions depending on the personal profile. Therefore, the entire environment can adapt and even predict the needings of the user just analyzing his profile.

More work can be done in the adaptation of the home to the specific personal necessities, leveraging the domotics systems and interconnecting them by wireless communication. For example, some generic electrical appliances, taking into account the user profile, may provide information in the optimum format, and adapt their operation to the user needs, without any configuration.

RFID systems are a suitable solution for applications that require neither to monitor continuously the presence of the user nor interactivity with this user. In this case, the RFID tag may be integrated into some digital cards widely used, for example, the identification card of some countries, like the Spanish digital National Identity Card that every citizen will have shortly.

Another important option to take into account is the integration of these systems with already used communication systems. This is the case of combining them with the common GPS/GPRS carried by PDAs or mobile phones. The location and request services may consider the user profile in their implementation.

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