INTERFACE DESIGN AND MOBILITY IN UBIQUITOUS ACCESS TO HIS

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Abstract: **Hospitals represent an environment where wireless and mobile technologies may dramatically improve the quality of service in many respects. At the Campus Bio-Medico University we have been introduced the experimental use of wireless networks and portable devices and several research activities are ongoing to deal with the critical aspects that still prevent the widespread use of these technologies. In this paper we present the main goals of our activity and the methodology we are following to pursue them. We also present the results achieved so far concerning the improvement of the user interface and the enhanced connectivity obtained through the use of seamless handoff techniques.**

Introduction

Ubiquitous access to data and services, usually referred to as ubiquitous computing, has been made possible in recent years by a number of technology advances. Hospitals represent an environment where ubiquitous computing may dramatically improve the quality of service in many respects: ubiquitous access to data and services provided by the information system may reduce the need of movements inside the wards, improve communication among people, prevent errors and delays. As to patients, the opportunity to be cared mostly at their own bedside leads to a patent improvement of their quality of life inside the hospital. A further potential advantage is the ability to provide additional services for the patients through the infrastructure supporting ubiquitous computing.

The whole complex of these reasons encouraged the development of a number of projects aiming to introduce wireless networks and portable devices in the wards, particularly in the area of staff communication. For example, in [1] the focus is on empowering mobiles devices, by extending the instant messaging paradigm, to recognize the context (location, timing, role) in which hospital workers perform their tasks. Reference [3] describes an application middleware for immediate high-quality multimedia communications in a hospital: by integrating a multimedia framework with an event-based notification system, the authors obtain a platform that can provide seamless, context-sensitive communications, which can adapt to users location. With "Bedside Florence" [11] nurses are able to electronically record notes and vital parameters such as blood pressure and temperature right at the bed of a patient.

The first goal of our project is making easier the access to the hospital Information Systems: the WARD-IN-HAND project [2] shares the same aims, and proposes as key elements "hands-free" interfaces through the use of voice and pen-based human-computer interaction and the use of widely available hardware and software to reduce costs. We extend this approach to a technically more evolved environment, particularly with respect to mobility.

Although these projects confirm the potential advantages provided by wireless and mobile technologies in the hospital environment, a number of technical limitations characterising the first installations still prevent their widespread use. Critical issues in this respect are: a) the ability of *user interfaces* available on portable devices to support daily activity of non specialised personnel with different background and needs as it is the case of doctors, nurses, dieticians and other people working in a hospital; b) security, coverage and quality of service of *wireless connectivity.*

At the Campus Bio-Medico University we have been introduced the experimental use of wireless networks and portable devices since more than one year and several research activities are ongoing to deal with the critical aspects mentioned above. In this paper we present the main goals of our project and the methodology we are following to pursue them. We also present the results achieved so far concerning the improvement of the user interface and the enhanced connectivity obtained through the use of seamless handoff techniques.

Project Goals and Methodology

The main goal of our project is to achieve ubiquitous access to the Hospital Information System and find effective solutions to the technical limitations that may reduce its usefulness in the daily activity of the sanitary personnel.

To pursue our goal we decided to carry out our activity as a pilot project initially addressed to provide a simulation of the Hospital Information System in our University Clinic, and to make it accessible through wireless devices for educational and training purposes. This phase of the project, called *Hospital Information System for Students* (HISS) involves the Faculties of Medicine (students of Medicine, Nursing and Dietetics) and Engineering (students of Biomedical Engineering) and has been funded by Hewlett-Packard, under the

Applied Mobile Technology Solutions in Learning Environments – 2003 Grant Initiative.

This choice has several advantages. First, we are more free to experiment new solutions since we are not bound to the requirements of a true production environment. At the same time, since the system is used in real training activity, we may test the system in real working conditions and have feedback from people with the same background of final users. Last, students and their teachers, also involved in the project, are more reactive than professionals to the stimuli provided by the new technologies, increasing the impact of the solutions that will be developed from this activity.

In order to achieve a valuable result in a short time we used rapid prototyping to develop a simulated HIS restricted to the clinical information, leaving aside all the administrative modules (admission, billing, etc.) and some specialized areas (radiology, laboratory, etc.). In fact, the clinical information is mostly used while visiting a patient in a room and seems suitable for presentation on a small display.

In all the wards and rooms we have installed wireless connection to a specific LAN (different form the actual hospital information system LAN, for security reasons). Each student participating in the project, during training sessions, is equipped with a wireless enabled pocket PC with a biometrics device for authentication. Some of them, especially the teachers (nurses and physicians) will use tablet PCs.

An important point is feedback. A system for collecting comments, bug notices, proposals and other information from the users, has been set up. The monitoring activity is closely followed by experienced tutors so that quantitative data is integrated with qualitative evaluations directly gathered from observation of students and teachers activity.

Interface design

Our first chore was to convert the written note into EPR (Electronic Patient Record). The structure and contents of EPR have been developed not only studying various existing models (Ward-in-Hand, Bedside Florence) but also taking into account the specific needs of the Campus University Hospital. The analysis was brought out following different methods: periodical meetings with teachers, tutors and the medical operators responsible for each department and through direct following of three main groups of actors (physicians, nurses and dieticians) and their daily activity in the hospital. We concentrated on the tasks that need the use of a mobile device: we selected all the information that medical operators usually write at bedside, thus excluding many other data, for example the admission registration or the demission letter, which can be better written on a desktop PC. Once the actors and the use cases had been individuated, the main problem was represented by contents adaptation depending on mobile devices features (see next section) and by frequent changes in contents.

At present state of implementation there are three ways of collecting information from a patient: write into a free text box; search a (complete or partial) string in DB; answer a multiple sections questionnaire with drop down lists, check lists or text boxes based on a XML schema. The possibility to change rapidly the contents through a XML schema, without varying the code, has permitted to improve, day by day, the application: for example, in 10 days of experimentations with the physicians the anamnesis module has changed 4 times, the general examination 5 times. Also the design of interface, very simple at the beginning, has been improved during the experimental phase thanks to users' feedback. The main innovations concerned: multiple sections questionnaires to avoid too long html pages; substitution of text boxes with drop down lists or check lists of options; distinction between common and uncommon options; text boxes of different seize (short, medium and large) at the end of the lists to insert additional information (values, observations, descriptions); different modules to modify or to read the recorded information; automatic view of the clinical information requested by a specific department.

Although these innovations increased interface flexibility, a further step is needed to achieve full adaptation capability and context awareness. A promising approach in this respect is represented by the CC/PP (Composite Capabilities/Preferences Profile) framework [9], proposed by the World Wide Web Consortium. Such a framework has been conceived at the outset with the goal of effectively managing information related to mobile devices and provides a model for the formalization (in RDF XML format) of profiles, as well as a mechanism to automatically send such profile to a content server. Based on profile information, the content server can transparently deliver information in a format that is the most suitable for that specific device and that particular user. We have developed a first content adaptation prototype based on the CC/PP framework that we plan to embed in the HISS system in the next experimentation phase.

After studying the best way to present the contents to the users, our next chore will be the standardization of the clinical information recorded (at various level beginning from the classification of pathologies, which is now based on the Italian version of ICD9, up to healthcare protocols such as HL7). Information originating from healthcare activities may be organized within record systems in relation to health issues, episodes of care, episodes of illness, etc. Implementation of record systems depends on tasks and attitudes within each particular healthcare environment [10].

Connectivity: requirements and integration of heterogeneous networks

A really ubiquitous and seamless access to the HIS demands somehow conflicting requirements:

- access must be guaranteed when moving through different subnets, based on different technologies: Ethernet LANs, IEEE 802.11 WLANs, and 2.5/3G cellular data networks (for geographic access).
- sessions must be seamlessly maintened through different subnets. Handoff must be fast enough not to cause service degradation.
- security requirements must be enforced on all networks.
- no additional configuration effort must be required to final users.

A comprehensive solution to many of these issues is provided by IPv6 [4]. IPv6 is the *next generation* version of the IP protocol. The principal benefit of IPv6, and the main reason for initial deployment, is a vastly increased address space compared with its predecessor IPv4. However IPv6 offers much more than a large address space. From the security viewpoint IPsec, part of the IPv6 specification, provides security services at the IP layer that enable a system to select security protocols, determine the algorithms to use, and put in any in place cryptographic keys required. Since these services are provided at the IP layer, they can be used by any higher layer protocol (*e.g.* TCP, UDP, etc). This is a clear advantage with respect to other existing solutions working at transport (*e.g.* SSL) or application level (*e.g.* ssh for remote access) as it is completely transparent to the final user. IPsec is available also for IPv4 as an add-on [5]. However the deployment of IPsec for IPv4 networks is very limited since many IPv4 stack available today do not have IPsec or support only a limited subset of it. A similar situation there is for the support to mobility. Mobile IPv6 is defined in [6] and although this is still a draft it includes many features for streamlining mobility support that are missing in IPv4 including Stateless Address Auto-configuration and Neighbor Discovery.

Actually, mobility support in IPv6 as proposed by the Mobile IP working group, follows the design for Mobile IPv4. It retains the ideas of a home network, home agent, and the use of encapsulation to deliver packets from the home network to the mobile node's current point of attachment. While discovery of a care-of address is still required, a mobile node can configure its a care-of address by using Stateless Address Autoconfiguration and Neighbor Discovery. Thus, foreign agents are not required to support mobility in IPv6. For all these reasons we think that IPv6 is the strategic solution for the HISS environment. However we need to take into account that transition mechanisms are required because a number of HIS systems/services still run plain IPv4 and support neither mobility nor security extensions. To this purpose we are experimenting NAPT-PT [7] a transition mechanism that can be located at the boundary between an IPv6 and an IPv4 network. It translates IPv6 packets into IPv4 packets and vice versa. IP headers are translated and transport layer headers are modified with new port numbers. This allows transparent communication between IPv6 nodes that at the present time are the mobile clients of the HISS environment and the IPv4 nodes that are the *legacy* platforms of the hospital information system (see Figure 1).

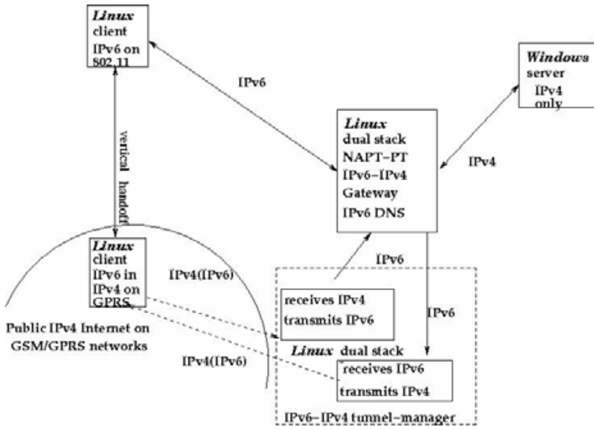

Figure 1: IPv6-IPv4 interoperability

The main benefit of this approach is the simplicity: the mechanism is easy to configure, since clients needs only to use a DNS server that support IPv6 addresses.

Two special challenges are posed by the requirement of supporting bi-directional vertical handoffs between 802.11 networks and public IP networks based on GSM/GPRS (and UMTS in the near future). The first problem is that most of the providers who offer IP over GSM/GPRS do not support IPv6 at this time, so there is the need of *tunneling* IPv6 traffic in IPv4 packets when the Mobile IPv6 clients make use of the GSM/GPRS network. Obviously IPv6 packets must be extracted so they follow the same route (through the NAPT-PT gateway) when they reach the hospital network. To this purpose we added one more component to the architecture: an IPv6-in-IPv4 tunnel manager (see Figure 1) in charge of extracting the IPv6 packet when they reach the hospital network and encapsulate them in IPv4 packets when they leave the network. This could appear as a tricky approach (IPv6 packets are encapsulated in IPv4 packets, then they are extracted and translated by the NAPT-PT gateway in IPv4 packets). However, we feel that support for IPv6 will be available in GSM/GPRS networks much earlier than IPv4-only networks and systems completely disappear, so we expect to keep the NAPT-PT for a long time whereas we will get rid of the tunnel manager in a (hopefully) short time. This assumption motivates the choice of using two separate components.

The second problem related to the support of GSM/GPRS networks is the time required by the *vertical handoff* between wireless (or wired) LAN and the GSM/GPRS network. Although cards exists able to support multiple networks, the time required by existing switching procedures can be in the order of seconds, that is obviously too long to offer a *seamless* connectivity. To understand the motivations of this delay, we carried out an in-depth analysis and set up a test-bed to make experiments [8]. As a result, we implemented a new mechanism in which the handoff is triggered at level 2 (data link layer) instead of level 3 (network layer) as in other proposed solutions. In such a way the time required by the handoff is dramatically reduced (between 0.2 and 0.4 s).

Evaluation and conclusions

In the first days of the experimental phase we asked the tutors of each department to divide the students in two groups: one should use the palm; the other should continue to collect the information on paper. Interesting results come from a test submitted to all the dietetics students of the first year. The students were asked to indicate the main advantages and disadvantage of using a pocket PC instead of a paper questionnaire. The majority of them indicated two main advantages: a) speed in finding the answers; b) time spared in the transcription of data from paper to PC. The usability was also indicated by one of the criteria of preference of the palm to the paper questionnaire: the palm doesn't need a support and it's not 'uncomfortable' (not heavy to carry in comparison to a normal PC). Furhtermore 80% of the interviewed didn't think that the presence of a keyboard could help them insert the data. The three main requirements of innovation acceptation (advantage, compatibility and acceptable complexity) were fulfilled.

The portable device was used by a sample of 80 students. In the first period we tried different ways of collecting data (on-line and off-line) and different devices (HP 5500 and Symbol PPT 2800).

The comparison between off-line and on-line experimentation offered interesting results. In the first case, the use of a local software made it necessary to synchronize each palm with a desktop PC. Thus, the 'backstage' work was much harder. But from the point of view of the users, the off-line solution left out all the problems connected with network performance. From this experience we elaborated a new model that could be tested in the next experimental phase: the data could be saved off-line and synchronized on-line as soon as the device finds the network.

To improve network performace and availability access to HISS through heterogenous networks is currently in the experimentation phase. Our IPv6 enabled clients can seamlessly access HISS through both wireless access points and GPRS VPNs without changing session or re-logging. We plan to evaluate both technical issues (TCP performance during handoffs among different networks, advantages of data link handoff triggering) and usability aspects (user perception of network performance in real cases, geographical acces to HISS for patients follow-up at their homes, ecc.). At this time the mechanism works only under Linux but the design can be implemented in other operating environments and support other interconnection technologies (like Bluetooth).

Another planned technical enhancement is the chance to define a *custom policy* of the vertical handoffs. Most of the Mobile IPv6 implementations associate a *priority* to each available network interface and force the use of the interface with the highest priority among the available ones. In general there is a well defined *natura*l ordering among the interfaces (*e.g.,* a 802.11 interface should be preferred to a GSM/GPRS interface) however there are situations in which a more flexible policy can be useful: for instance if power consumption is a concern, it could be better to use a GSM/GPRS interface than a (more powerful but much more consuming) 802.11 interface.

Acknowledgments

This work has been carried out under the financial support of Hewlett-Packard, under the Applied Mobile Technology Solutions in Learning Environments - 2003 Grant Initiative, and of the Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR) in the framework of the FIRB project WEB-MINDS).

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