Maria Cinque, Filippo Cacace, Michele Crudele, Giulio Iannello and Massimo Bernaschi
Mobile Learning in a Hospital Environment
Proceedings of Mobile Learning 2005, Malta, 28-30 June, 2005

Copia esclusivamente ad uso personale o di ricerca

MOBILE LEARNING IN A HOSPITAL ENVIRONMENT

Maria Cinque, Filippo Cacace, Michele Crudele, Giulio Iannello
University Campus Bio-Medico
via Longoni, 83 - 00155 Roma - Italy
[m.cinque, f.cacace, m.crudele, g.iannello]@unicampus.it

Massimo Bernaschi
Italian National Research Council
viale del Policlinico, 137 – 00161 Rome - Italy
massimo@iac.cnr.it

ABSTRACT

We report about the experimental use of wireless networks and portable devices by medicine and nursing students during training sessions in a University Hospital. In particular, we describe our research activities aimed to improve the usability of the portable devices and to enhance the connectivity through the use of seamless handoff techniques among heterogeneous networks.

KEYWORDS

Hospital Information System; content adaptation; IPv6; vertical handoff.

1. INTRODUCTION AND METHODOLOGY

Since 2002 we introduced in our Campus wireless networks and portable devices starting a number of projects for assessing the use of this technology. One of them is the *Hospital Information System for Students* (HISS) project, which was funded by HP. We installed wireless devices in the University Hospital so that from every room of all the wards a connection could be set to a separate LAN, different from the one used by the Hospital Information System, for security reasons. Each student participating in the project, during training sessions was equipped with a wireless LAN enabled Personal Digital Assistant (PDA) capable of fingerprint authentication. Some of them, especially the teachers (nurses and physicians) used a Tablet PC.

Among the expected issues there was, first of all, students' increasing familiarity with the new technologies they will encounter in the future while working in hospitals. We also aimed at giving them a better tool for learning the medical topics they were dealing with in the wards. Furthermore we wanted them to define the user interface for medical applications on handheld computers. This goal had a predicted positive effect: instead of involving in the interface design actual nurses and physicians, always busy in their daily tasks (and whose time is costly), we used feedback from the students to develop new approaches in view of a real operational Hospital Information System for handheld computers.

From the learning point of view we were interested in examining whether the students using handheld computers were achieving better results in their examinations. However, we soon realized that this last goal was too complex to accomplish, because too many factors are involved in the learning phase and comparing groups with and without handhelds requires many students and an enormous amount of data. Since in our Campus the teaching methodology is strongly based on training, we decided that it was better to shift from the classroom to the wards. Learning on the job has always been considered a basic methodology for medical related professions. An important part of the teaching is accomplished in the wards, while visiting patients. The typical way of memorizing what is said or done by teachers, nurses or physicians is to take a written note on an exercise book. This leads to unstructured data and makes it difficult to rapidly access specific information. Postproduction is usually needed to reorganize the notes in a practical way for easy recovery of any part of it.

Our first chore was to convert the written note into an Electronic Patient Record (EPR) suitable for handheld computers. We developed the structure and contents of EPR studying some existing models like Ward-in-Hand (Ancona *et al.* 2000) and Bedside Florence (Policlinico Gemelli 2002) and addressing the specific needs of our University Hospital. We held periodical meetings with teachers, tutors, physicians, nurses and dieticians in charge of their departments. We also followed the daily hospital activity of the three main groups of actors: physicians, nurses and dieticians. We concentrated on the tasks that may require a mobile device: we selected all the information that they usually write at the bedside, therefore excluding other longer data, for example the patient's entrance and exit letter which can be better written on a desktop computer. Furthermore, we based our analysis on existing paper models in order to reduce the impact of innovation and achieve a higher acceptance degree by both teachers and students. In order to achieve valuable results in a short time we used rapid prototyping to develop a simulated HIS restricted to the clinical information.

By monitoring students using pocket PCs during their training in the hospital, which is a quite different activity from the one in a classroom, we analyzed how they managed the new devices and which effects this training produced on the activities done. The progress of the students using the devices was measured through the increasing number of tasks they used it for.

Attention was paid to feedback: a system for collecting comments, bug notices, proposals and other information from the users, was set up. Experienced tutors closely followed the monitoring activity so that quantitative data were integrated with qualitative evaluations directly gathered from observation of students and teachers activity.

2. SOME TECHNOLOGICAL ISSUES

Although the project confirmed the potential advantages provided by wireless and mobile technologies for students and teachers, a number of limitations of current technology became apparent. The most critical issues we found were: *i)* 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; *ii)* security, coverage and quality of service of *wireless connectivity.* Hereafter, we describe how we addressed these issues and the results of our experience.

2.1 Adaptive users' interfaces

After designing the actors and the use cases, the main problem was content adaptation depending on mobile devices features and the frequent changes in the interface definition. We were aware that the development process in writing the software had to be adaptive, because the students would discover new solutions and redefine the structure many times. Since we were not bound to real production and we had no strict deadlines, we were free to try different solutions (on-line and off-line; XML and RDBM; access trough WLAN, GPRS, UMTS; interface adaptation for pocket and desktop PC's). Eventually we based our system on ASP.NET, C#, XML and SQL server. The web-based application, accessible through a wireless LAN, included both generic and specific data entry masks. By using XML we built thirty different masks simply combining a few tags: <Section>, <Title>, <Voice>, <VoiceName>, <Value> for the different structural parts; <SmallText>, <MediumText> and <BroadText> for data input; <Drop> corresponding to the object DropDownList in ASP.NET and <Check> corresponding to CheckBoxList in ASP.NET (see Figure 1).

Fig. 1 XML data visualized on the pocket PC

The possibility to rapidly change the contents through an XML schema, without varying the code, allowed us to improve, day by day, the application: for example, in ten days of work with the physicians the anamnesis module changed four times and the general examination module five times.

Besides content adaptation, we carefully studied the way to present them to the users. The design involved ergonomic and technical factors. The interface, very simple at the beginning, was enriched thanks to users' feedback In the final 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 the database; answer a multiple sections mask with drop down lists, check lists or text boxes based on XML schema.

Our next goals in this area are: full adaptation capability and context awareness, that is the content server will transparently deliver information in a format suitable for a specific device and user; standardization of the recorded clinical information, beginning from the classification of pathologies – which is now based on the Italian version of ICD9-CM – in order to apply HL7. We are aware that the final implementation of any record system must be based on tasks and attitudes in the particular healthcare environment (Rossi Mori *et al*. 2000).

2.2 Connectivity: requirements and integration of heterogeneous networks

A really ubiquitous and seamless access to the Hospital Information System for Students demanded somehow conflicting requirements:

- access had to 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 had to be seamlessly maintained through different subnets and Handoff had to be fast enough not to cause service degradation;
- security requirements had to be enforced on all networks;
- no additional configuration effort had to be required to final users.

We found that IPv6 could provide a comprehensive solution for many of these issues. IPv6 is the *next generation* version of the IP protocol (IPv6, 1998). 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 IP layer that enable a system to select security protocols, determine the algorithms to use, and put in place any cryptographic keys required. Since these services are provided at network 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 (IPsec, 1998). However the deployment of IPsec for IPv4 networks is very limited since many IPv4 stacks 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 (Mobile IPv6, 2004). It includes many features for streamlining mobility support that are missing in IPv4, like 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 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 had 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 employed NAPT-PT (NATPT, 2003), 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 2).

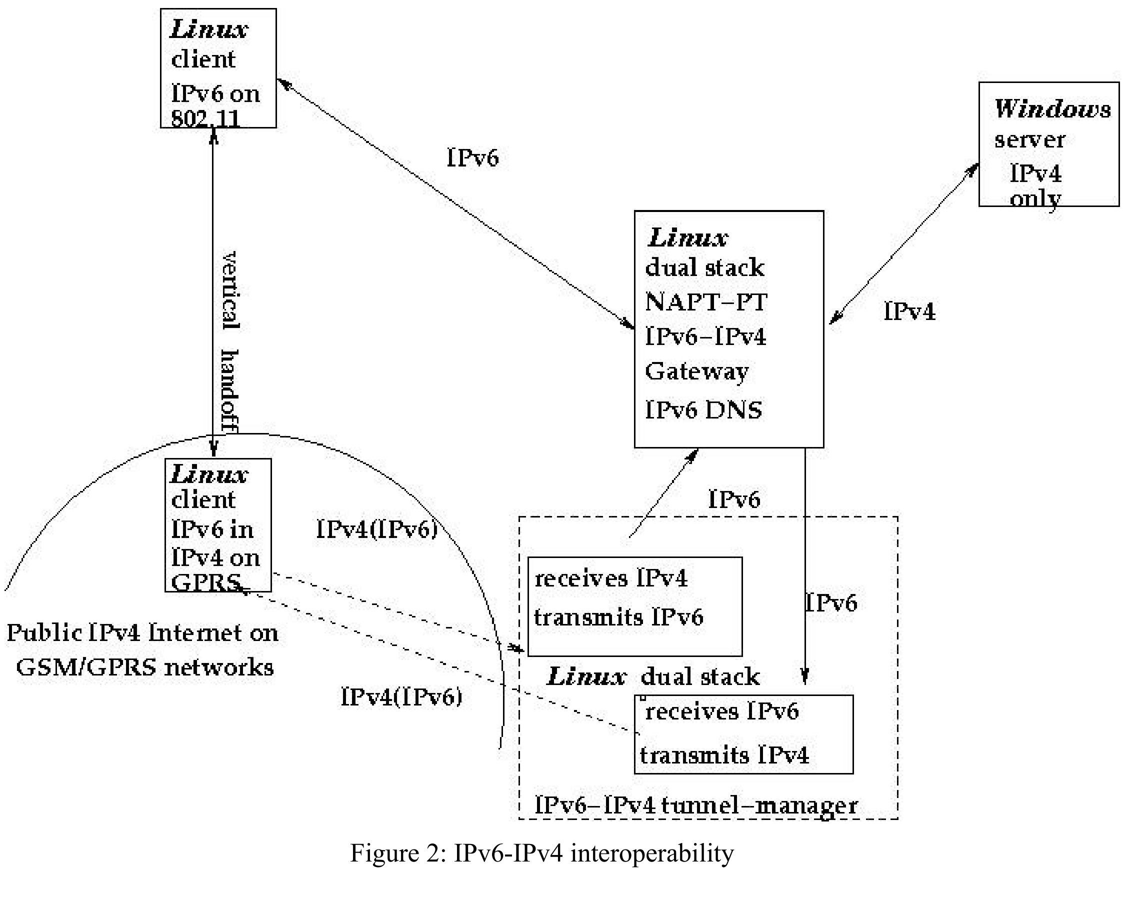

Figure 2: IPv6-IPv4 interoperability

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 were posed by the requirement of supporting bi-directional vertical handoffs between 802.11 networks and public IP networks based on GSM/GPRS and UMTS. 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 2) in charge of extracting IPv6 packets 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 and UMTS networks is the time required by the *vertical handoff* between wireless (or wired) LAN and the GSM/GPRS or UMTS 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 "mobile' students. To understand the motivations of this delay, we carried out an in-depth analysis and set up a test-bed to make experiments. We found that the efficiency of vertical handoffs depends mostly on movement detection, and precisely on the capability of detecting that the current access network is going to become unusable before it actually does. The ordinary IPv6 method to discover router reachability, based on the reception of Router Advertisements messages, is not well suited to this task since it works at level 3 (network layer). To address this issue, we developed a software module, named Mobility Manager, which works at level 2 (data link layer) monitoring directly the link status in order to react more quickly. The Mobility Manager (MM) is a user-level application in charge of: *i)* monitoring connection parameters through appropriate system calls; *ii)* performing handoff decisions with appropriate timings using MobileIPv6 primitive operations; *iii)* dispatching notifications about connectivity changes and network parameters to any application residing on the mobile system that notifies its interest in these events through a specific Application Programming Interface (API). The detailed description of the MM module is beyond the scope of the present paper. We mention only that our experimental tests prove how, by using the Mobility Manager, the time required by the handoff is dramatically reduced (*i.e.,* it becomes equal to ~ 0.2 s., that is to about 10% of the original time) for both TCP and UDP based applications. However, the MM scope is limited to the lower layers of the network stack. The application/session adaptation is performed separately by each adaptive application that: *i)* receives notifications from the MM; *ii)* decides how to adapt. We expect to employ the MM to enhance the support to mobility for any kind of application of the HISS, starting on streaming applications. For legacy applications, the MM will deliver event notifications to an Application Mobility Interface (AMI), in charge of performing adaptation at session layer and/or issuing adaptation commands for the legacy application.

3 MOBILE LEARNING

Once we addressed the main technological issues, we started the real testing of our HISS.

3.1 Formal training and informal education

In the first days of the experimental phase we asked the tutors of each department to divide the students into two groups: one should use the pocket PC; the other should continue to collect the information on paper.

The students tried different ways of collecting data (on-line and off-line); many of them used iPAQ 5500 and some Symbol PPT 2800. We recorded that users tend to prefer a smaller device, with colour display, to a faster one (usability seems more important than performance). The comparison between off-line and on-line activity offered interesting results. In the off-line case, the software on the handheld required synchronization with a desktop PC. Thus, the "back office" work was much harder. But from the point of view of the users, the off-line solution avoided all the problems related with network performance. Therefore we envisage a new scheme for the future: data is saved off-line anywhere and automatically synchronized as soon as the device is on an active cell.

Besides the modules created for the project, which were accessible on-line, the students learned to use all the software installed on the iPAQ (including recording vocal notes) and other trial applications (Handbase, Medical Pocket PC) which were selected and installed by Bioengineering students. We also acquired Pocket PC versions of medicine manuals, like Washington or Harrison therapy manuals. A specific database with drugs principles and prescriptions was commissioned to an external firm and was personalized according to the users' needs. These resources were very useful not only for the students, but also for their teachers: it was an application of continuing medical education.

In the last years we have been producing streaming video based lessons for nurses (http://research.unicampus.it/Edunurse/videolessons.asp) in order to give them access to University level resources and the capability of reaching the "laurea" level (Campus Bio-Medico was the first Italian University to establish a University level course for nurses). We later adapted these videos in order to stream them on handheld computers so that a nurse in a ward, during a relatively calm period (such as a night turn) can easily access the video on demand library of lessons.

3.2 Users' feedback on wireless training

The evaluation methodology was based on users' observations, interviews with them, questionnaires filled by students and their tutors. Furthermore, we tried to monitor the users' feedback using categories created by Everett Rogers, a theorist who spent over thirty years studying the diffusion of innovations, from qwerty keyboards to new agricultural methods in developing countries. According to Rogers (1995), the characteristics of an innovation, as perceived by the members of a social system, determine its rate of adoption. Five attributes of innovations are: (1) relative advantage; (2) compatibility; (3) complexity; (4) trialability; (5) observability.

Interesting results came from a test submitted to all the first year dietetics students. The students were asked to indicate the main advantages and drawbacks 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. Usability was also indicated as one of the criteria of preference of a handheld: the pocket PC does not need a stand and it is not "uncomfortable" (not heavy to carry in comparison to a normal PC). Furthermore 80% of the interviewed students think that the presence of a keyboard would not help them in data entry. The three main requirements of innovation acceptation (advantage, compatibility and acceptable complexity) were therefore fulfilled. The students we interviewed considered less important the other two indicators – trialability (the degree to which an innovation may be experimented on a limited basis before making an adoption/rejection decision) and observability (the degree to which the results of an innovation are visible to others).

As to nursing students, great importance was given to the "relative advantage" factor. In the first phase only 60% of them felt to be advantaged by the use of PDA's. Since the attitude of some tutors towards the HISS project was negative, the students' feelings were biased. In this case we had to work on the tutors to achieve good results with the students. Only when the tutors began to perceive the innovation as being better than the activity it superseded (writing on a piece of paper and then rewriting it on a PC, or deliver it to the physicians), they motivated the students to use the new system.

A crucial indicator for PDA acceptance was "accuracy". We demonstrated to the tutors that students using handheld devices for data entry in structured masks were more accurate than those writing on a blank piece of paper; the first ones noticed more things (having different questions to answer) and were more precise.

The most critical approach was by medicine students. The complexity of the tasks and the different approach in data entry contributed to a very low degree of acceptance of the new technology. Therefore, after an ineffective extensive phase (all the students in all the wards), we tried an intensive approach. A pilot project started in the surgical ward. All the medical staff was involved, not only the students and their tutors. This phase showed that the presence of a leading figure is a key element for the acceptance of innovation: the fact that the director was keen on using the devices motivated all the staff.

4 NEW DIRECTIONS OF DEVELOPMENT

4.1 Companion projects

The positive effects of the project went beyond our expectations. Two companion projects started, following the enthusiasm of some members of the staff: the first one, for the surgery department physicians, has changed completely the way of rapid data entry at bedside, which was previously done on a sheet placed on a wooden tablet. The second one, carried out in collaboration with the Campus Information System software developers, is carrying out the complete conversion of all dieticians' activities (such as bedside-kitchen communication) to an electronic version.

The application for PDA created to support the activity of surgeons was tailored on the needs of a ward in which daily documentation and maintenance of medical record quality is a crucial issue. Our hypothesis was that the use of handheld devices could enhance the communication and the quality of health records: physicians could improve their access to information by wireless connected PDAs, so that patient data could be available wherever decisions needed to be made. After an accurate analysis of the staff's needs, we observed that contents and the ways to represent them needed to be rethought and redesigned to fit the new delivery channels: in order to convert the written note into EPR (Electronic patient record), we needed a structure. Thus, it was first of all on the paper that we tried to convert the records of the staff from unstructured to structured data. We studied their daily recordings and created a paper form. Later on we created an electronic prototype with context-aware presentation of data and where reading and writing were made easier trough an adaptable interface. Thanks to the collaboration of members of the staff the prototype was tested for two months and many functions were improved. Afterwards, the first version of the programme was released to enter in the current "production" phase.

The application created to support the dieticians' activities allows daily recording of patients' data, monthly planning of menus, research activities on particular subjects, as Crohn's disease, bedside-kitchen communication. The application can be used both on Desktop PCs and PDAs, adapting the presentation layer to the terminal device. The system allows automatic association among the diet registered for a patient and the predefined menu of the day for the pathology indicated; furthermore the dieticians can eliminate some items of the menu or substitute them with other ones. On the computer in the kitchen is displayed a whole report concerning all the dishes to be prepared for the patients in the hospital.

The conversion of the dieticians' activities to an electronic version allows them to spare 35% of their time and 30% of the paper they used to print the menus. The time spared is now employed in other activities, such as tutoring and research. Even the restoration service that prepares the meals for the hospital had advantages from this innovation: one of their employees, who normally dedicated one hour per day to check the menus, was destined to other mansions.

4.2 HISS extension

At the end of 2005 a new activity started, addressing specifically to Bioengineering students, who are following the still on-going activities of HISS. The name of project is MoPS (*Mobile Problem Solving*) since the main course impacted, besides Informatics and Networks, is Problem Solving, which is a core course of Bio-engineering curriculum. The course includes both activities in the classroom and observation/intervention on the field, and involves all the knowledge that students have so far acquired, representing the first chance to test on the field all their theoretic formation and to get in touch with *real world* situations at various level: physicians, nurses, trainees, IT department, etc.

After the introduction of wireless technologies, the course has enhanced its structure: students equipped with Tablet PCs participate in periodical briefings held in the classroom, then go to the hospital for observation, take notes and images of the problems, and send them to the tutors when needed. The introduction of wireless technologies has helped to achieve a fundamental goal of this course: immediate interaction for faster problem solving. Keeping in touch with their tutors, Bioengineering students are able to aid other students, physicians and nurses in their daily activities, observing and reporting problems by using wireless Tablet PCs in a cooperative environment.

For this project we didn't develop any software, as we did for HISS. Both tutors and students work in Moodle, a course management system that allows different kind of interaction: chat, forum, newsletter, video lessons, on-line resources, virtual interaction. It is basically a software package designed to help educators create quality online courses. Furthermore we are testing other open-source and commercial applications: project management instruments, chat and cooperative environments (MS NetMeeting, IVisit, Skype, Google Talk, Sun Forum etc.).

Figure 3: Moodle Interface

The fundamental learning and teaching issues that the project addresses are both ethical and technological. The focus is on enabling the students to do something useful for the entire Hospital community (physicians, nurses, other hospital workers, patients). Instructors can constantly keep in touch with students equipped mobile devices, helping them troubleshooting and monitoring their ability to solve problems and to react to users difficulties. The use of wireless technology ensures fast localization (with VoIP on the WLAN, or by instant messaging) and immediate access to useful information.

4.3 Support for audio based services

From a technology viewpoint, the most interesting challenge is to provide a valid support for interactive multimedia learning sessions based on audio and videoconferencing services. These applications have additional requirements with respect to Web or streaming applications. In particular they *i)* are *delay* sensitive; *ii)* require synchronization of different media (*e.g.*, audio, video); *iii)* may require synchronization of different sources. Since the mobile clients used by the students may experience significant variations in network features like the usable bandwidth or packet delay, it is even more difficult to fulfil the aforementioned requirements in an environment like the HISS. For instance, a 64 kbps codec for human voice can be used on a WLAN, but it is beyond the current capabilities of a UMTS network whose maximum bit-rate in up-link is just 64 kbps, so when moving to a network that offers a lower bit-rate, a "*naïve*" audio application may undergo serious packet loss and service degradation as a consequence of the network congestion. We expect to address these issues in an integrated, cross-layer framework within which we deal with: *i)* delay and synchronization issues at the application layer; *ii)* bandwidth requirements at the session layer; *iii)* vertical handoff optimization at the network layer. In order to gain a better insight into this class of problems, we decided to carry out tests of real mobility situations using an *in-house* developed Voice over IP (VoIP) application that implements several strategies for *jitter* buffer management and packet dropping. Our aim was also to determine whether the notifications of the Mobility Manager (see section 2.2) could help the VoIP application to devise the best strategy in mobile situations. For this reason, our VoIP application is able to receive notifications from the MM about handoff and estimated delays on the destination network through the MM API. Detailed results of this activity are reported in (Bernaschi *et al.,* 2006). For the purposes of the present paper, it is sufficient to say that the solution proved to be effective for tuning parameters concerning audio stream reproduction and buffer management.

5 CONCLUSIONS

Four years ago wireless technologies were introduced in our Campus and since then many projects have been carried out in the different departments.

The HISS project, which was developed in our University Campus during the academic year 2003-2004, achieved the following goals: enhancing the hospital level of technology by improving the accessibility to the information system at different levels (students, nurses, physicians) through mobile technologies; improve teaching and learning in the wards through a faster access to clinical data; designing new interfaces for small devices for collecting and examining data at the bedside; a deeper comprehension of security issues; analysis of geographical mobility needs; performance evaluation. More than one hundred students (of different departments) used mobile devices in order to record data concerning more than 1500 patients to accomplish 30 different tasks.

But the issues of the project were not only technological and pedagogical. Besides being the acronym of a system for students, HISS became a powerful metaphor: the hiss, i.e. the whisper, the buzz, spread itself and involved more people and more tasks than expected. Today every student can use wireless devices to access the Hospital Information System or to look for didactical resources on the University database

During the MoPS project we will examine the effects of introducing a mobile computing data-acquisition and analysis tool into problem-solving laboratory. To test the impact of this project on students learning and determine the effects of the computer tool, two groups will be selected: the test group will use a computer tool to collect and analyze data in the hospital, whereas the control group will use traditional equipment (pen, paper, telephone). The curriculum will be kept as similar as possible for the two groups. The groups will be examined for effects on performance on conceptual tests and grades, attitudes towards the laboratory and the laboratory tools, and behaviours within cooperative groups.

Both projects are producing also an important outcome from the learning point of view: since our is a "teaching hospital", the projects have revealed very useful to bridge the knowledge dimension (University) with the professional training (Wards), i.e. they enhanced the relationship between the academic and the working environments, allowing the 'official knowledge' to be enriched by the 'tacit knowldege' (information shared among professional which was recorded using PDA or tablet PCs).

We expect that in one year from now, everybody in our Campus - teachers, students and Hospital personnel (physicians, nurses and dieticians) - will communicate with wireless devices in a cooperative environment.

We feel that other institutions may benefit from our experience by being encouraged to use their students as generators of specifications for real world software applications. More information about the HISS project is available at http://research.unicampus.it/HISS.

ACKNOWLEDGEMENTS

We thank HP for providing all the hardware for the project, under the Applied Mobile Technology Solutions in Learning Environments – 2003 Grant Initiative. A special thanks goes to Andrea Riccio, who wrote most of the software for HISS. Thanks also to all the tutors who patiently followed their students while working with the handheld devices. The application for the surgical ward was developed by Roberto Valenti, who also created the software for the dieticians with the support of the Campus Information System developers.

This work was also partially funded by the Ministero dell'Istruzione, dell'Universita' e della Ricerca (MIUR) with the FIRB project WEB-MINDS and the QUASAR project (PRIN 2004 Funding Program).

REFERENCES

Ancona, M., Dodero G., Gianuzzi V., Minuto F., and Guida M., 2000. Mobile computing in a hospital: the WARD-IN-HAND project, *Proc. of ACM Symposium Applied Computing*, pp. 554-556;

Bernaschi, M., Cacace, F., Cinque, M., Crudele, M., Iannello, G., Venditti, M., 2004. Interface design and mobility in ubiquitous access to HIS, *Medicon 2004*, Ischia (NA), July 31-August 5;

Bernaschi, M., Cacace, F., Iannello, G., Vellucci, M., 2006. Mobility Management for VoIP on Heterogeneous Networks: Evaluation of Adaptive Schemes, submitted to *IEEE Transactions on Mobile Computing.*

IETF, 1998. IPsec: http://www.ietf.org/rfc/rfc2401.txt

IETF, 1998. IPv6: http://www.ietf.org/rfc/rfc2460.txt;

IETF, 2004. Mobile IPv6: http://www.ietf.org/rfc/rfc3775.txt;

Karahanna, E., Straub, D., and Chervany, N., 1999. Information technology adoption across time: A crosssectional comparison of pre-adoption and post-adoption beliefs. *MIS Quarterly* 23, 183–207;

Munoz, M. A., Rodriguez M., Martinez-Garcia A.I., Gonzalez V.M., 2003. Context-Aware Mobile Communications in Hospitals, *IEEE Computer*, 36 n. 9, pp. 38-45;

NATPT, 2003. Internet site address: http://naptpt.sourceforge.net;

Policlinico Gemelli, 2002. *Wireless ward system allows nurses to record and retrieve data instantly at patients' bedside* Policlinico Agostino Gemelli Case Study on Microsoft Business. At http://www.microsoft.com/resources/casestudies/CaseStudy.asp?CaseStudyID=12245 January 31, 2002;

Rogers, E., 1995. *Diffusion of Innovations*. Free Press, New York;

Rossi Mori, A., Consorti, F., Ricci F., 2000. Sharing clinical information. From local EPR to task oriented solution, *Proc. of EuroRec'01*, Aix-en-Provence, 2000.