Mobile Health Care: Towards a commercialization of research results

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Abstract: During the last fours years a consortium of universities, hospitals and commercial companies has been working together for the development of innovative systems and services for mobile health care. Two major projects were financed by the European Union allowed us to develop a complete mobile healthcare system and validate it with extensive medical trials. MobiHealth[1] and HealthService24[1] have developed a generic Body Area Network (BAN) for healthcare and an m-health service platform. Biosignals measured by sensors connected to the BAN are transmitted to a remote healthcare location over public wireless networks (GPRS/UMTS), where doctors can monitor, diagnose and provide advice to patients in real time. The developed system is in the last phases of the pre-commercial validation and a commercial product is expected to be available in late 2006.

1. Introduction

Today the health sector faces serious and increasing problems in the management of resources for disease prevention, follow-up and remote assistance of patients. The cost of in-patient care is increasingly creating problems for both patients and social security organizations, while out of hospital monitoring of the patients' health state is practically non-existent. The patient has either to measure different vital constants at regular intervals or has to visit the hospital. As a result, patients who need monitoring but are not at immediate risk are obliged to stay for long periods in hospital so that regular measurements can be taken. These results in high costs for the hospitals and health insurers, lost working hours and low morale of the patient.

On the other hand, citizens are becoming more health conscious and are demanding advanced health services, as can be seen from the ever expanding para-health market, where health related services are becoming increasingly common and available to every citizen. In the last few years for example services and applications,

[1] This work was supported by the Commission of the European Union in the 5th research Framework under the MobiHelath project (IST-2001-36006) and in the eTen program under the HealthService24 project (C517352) Project sites http://www.mobihealth.org and http://www.heathservice24.com

such as physical state monitoring during sports training and the use of health call centres and on-line health consultations have been commercialized in almost all European countries.

Finally, citizen mobility at a pan-European level is increasing, with thousands of citizens crossing European country borders daily for purposes of entertainment, leisure, shopping and business. This mobility is strongly supported by the widely available communication services, like mobile telephony and mobile internet access, available today in the most remote points of the European continent (and the globe!). One of the major technological advances of the 21st century will be the implementation and wide availability of public broadband wireless networks, and specifically 3G (UMTS) and 4G networks.

The above described needs of the citizens and patients combined with the evolution and availability of wireless communication networks and the ever-advancing miniaturization of sensor devices and computers, will give rise to new services and applications that will have a major effect in health care. Citizens, being patients or non-patients, will not only be able to get medical advice from a distance but will also be able to send from any location full, detailed and accurate vital signal measurements, as if they had been taken to a medical center, implementing the "ubiquitous medical care" dream.

Towards this direction we have completed a research project and are running a commercial validation project, for the development and deployment of innovative value-added mobile health services, based on 2.5 (GPRS) and 3G (UMTS) networks.

The **MobiHealth** research project (financed by the European Union under the IST programme (IST-2001-36006)), started in May 2002 and completed in February 2004, developed a technically validated and fully functioning mobile platform and solution for ambulant patient monitoring with measurements transmitted over public wireless networks. This was achieved with the integration of sensors in a wireless Body Area Network (BAN). The BAN connected sensors continuously measure and transmit vital constants to health service providers or health brokers. This way the BAN facilitates remote monitoring of patients' vital signs and therefore enables proactive disease prevention and management by continuous monitoring of patients' health condition 'anytime and anywhere'.

With the completion of the research project and the very encouraging results and comments coming from the system users (hospitals and patients) we proceeded towards the first phase of the commercialisation of the system and services. A new 18th months project, **HealthService24**, under the eTen framework was launched in February 2005, with the goal of to validating the existing service in the market in order to have a fully marketable solution at the end of the project. The solution will be validated and fine-tuned to the extent that will enable a sustainable market deployment at the end of the market validation phase.

1.1 Overview of the projects' results and targets

The use of health BANs together with advanced wireless communications enables remote management of chronic conditions and detection of health emergencies whilst maximising patient mobility. MobiHealth has developed a generic BAN for

healthcare and an m-health service platform. The BAN incorporates a set of body-worn devices and handles wireless communication (via Bluetooth) amongst those devices. It also handles external communication (via GPRS/UMTS) with a remote location. The main devices used in the project are medical sensors like 3 to 7 lead ECG/EMG, respiration belts and oxygen saturation sensors. The remote healthcare location is a healthcare provider (a hospital or medical call centre). Biosignals measured by sensors connected to the BAN are transmitted to the remote healthcare location over wireless telephony services.

The results of the project include an architecture for, and a prototype of, a generic service platform for provision of ubiquitous healthcare services based on wireless Body Area Networks. The MobiHealth BAN and service platform were trialled in four European countries with a variety of patient groups. The MobiHealth system can support not only sensors, but potentially any body worn devices, hence the system has potentially very many applications in healthcare which allow healthcare services to delivered in the community. In the last months of the project 9 different trials scenarios were implemented for different patient groups. These trials allowed us to identify problems and issues in the development of m-health services and to identify limitations and shortcomings of the existing and forthcoming public network infrastructures.

The HealthService24 project was started in February 2005 and will be completed in July 2006. The main objective of HealthService24 is to test the feasibility of the deployment of the mobile healthcare services via trials that will validate the precise conditions to be fulfilled for the subsequent deployment of the services.

In HealthService24 three trial scenarios at different sites in Europe are used for the validation of the deployment conditions. It should be noted that an important part of the project is the introduction of the required adaptations in order to correct problems that were identified in the trials of the MobiHealth project.

2. The MobiHealth System and Services

MobiHealth has developed a mobile health BAN and a generic service platform for BAN services for patients and health professionals. Remote patient monitoring is only one of the kinds of services that can be provided.

The healthcare BAN is an innovative health monitoring tool that incorporates a range of devices including sensors and actuators, together with communication and processing capabilities. Communication between entities within a BAN is called *intra-BAN* communication. To use the BAN for remote monitoring, external communication is required which is called *extra-BAN* communication. The gateway that facilitates extra-BAN communication is the *Mobile Base Unit (MBU).*

The MobiHealth system provides a complete end-to-end e-health platform for ambulant patient monitoring, deployed over UMTS and GPRS networks. The MobiHealth patient/user is equipped with different vital constant sensors, like blood pressure, pulse rate and ECG interconnected via the healthcare Body Area Network (BAN). The Mobile Base Unit (MBU) is the central point of the healthcare BAN, acting as a gateway aggregating the vital sensor measurements (intra-BAN communication based on wireless networks like Bluetooth[1] and Zigbee[2]) and

transmitting them to the back-end system (extra-BAN communication based on GPRS and UMTS), which may be located within the health broker premises or may be located at the wireless services provider's site. From there the measurements are dispatched to the health care provider or broker where the medical personnel monitor them life or store them for automatic processing. Figure 1 shows the architecture of a BAN. Sensors and actuators establish an ad-hoc network and use the MBU to communicate outside the BAN. The MBU can be any device with sufficient processing power able to manage the BAN and provide extra-BAN communication services.

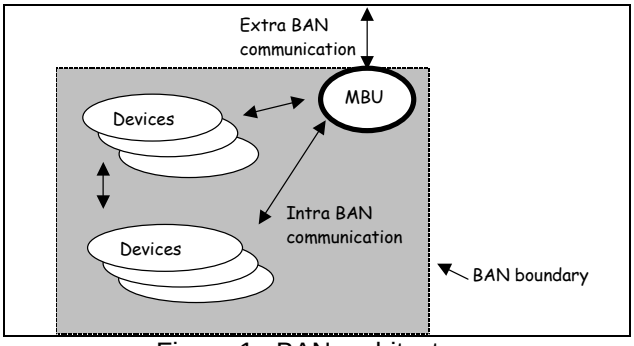

Figure 1 : BAN architecture

2.1 The MobiHealth Body Area Network

The concept of the Body Area Network originally came from IBM[3] and was developed further by many other researchers, for example at Philips [4], at the University of Twente [5], and at Fraunhofer [6]. In the Wireless World Research Forum's *Book of Visions*, we define a BAN as "*a collection of (inter) communicating devices which are worn on the body, providing an integrated set of personalised services to the user*"[11].

In the context of the MobiHealth project the **Healthcare BAN** is a health monitoring tool that consists of sensors, actuators, communication and processing facilities connected via a wireless network which is worn on the body and which moves around with the person (i.e., the BAN is the unit of roaming). A sensor is responsible for the data acquisition process, ensuring that a physical phenomenon, such as patient movement, muscle activity or blood flow, is first converted to an electrical signal, which is then amplified, conditioned, digitised and communicated within the BAN.

The Healthcare BAN sensors can be self-supporting and/or front-end supported. Self-supporting sensors have a power supply and facilities for amplification, conditioning, digitisation and communication. Self-supporting sensors are independent building blocks of a BAN and ensure a highly configurable healthcare BAN. However, each sensor runs at its own internal clock and may have a different sampling frequency. Consequently, mechanisms for the synchronization between sensors may be needed.

Front-end supported sensors share a common power supply and data acquisition facilities. Consequently, front-end supported sensors typically operate on the same front-end clock and jointly provide multiplexed sensor samples as a single data block. This avoids the need for synchronization between sensors.

A sensor is responsible for the data acquisition process, ensuring that a physical phenomenon, such as patient movement, muscle activity or blood flow, is first converted to an electrical signal. This signal is then amplified, conditioned, digitised and communicated inside the BAN.

2.2 Service platform architecture

Collecting and transmitting the vital signal measurements is only part of the healthcare service platform developed in the MobiHealth project and shown in Figure 2. The dotted square boxes indicate the physical location where parts of the service platform are executing. The rounded boxes represent the functional layers of the architecture. The M-health service platform consists of sensor and actuator services, intra-BAN and extra-BAN communication providers and an M-health service layer. The M-health service layer integrates and adds value to the intra-BAN and extra-BAN communication providers masking applications from specific characteristics of the underlying communication providers.

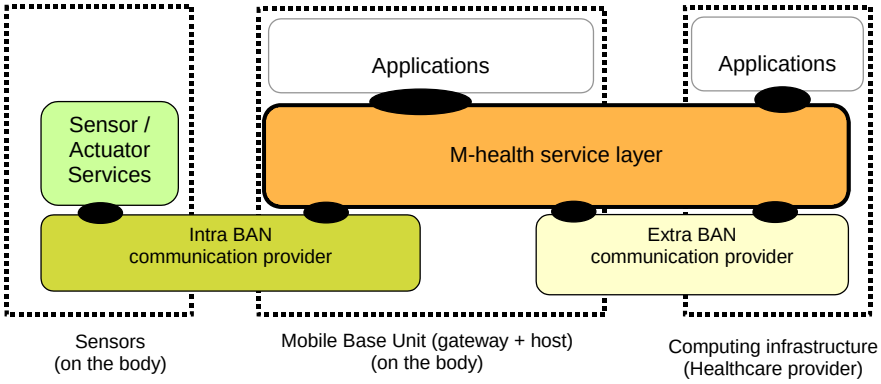

Figure 2 Service platform functional architecture

Applications that run on top of the service platform can either be deployed on the MBU (for on-site use e.g. by a visiting nurse) or on the servers or workstations of the healthcare provider, i.e. the call centre or the co-located secondary care centre in Figure 2. For this the M-health service platform offers a number of services including:

- *BAN registration*: the service platform maintains a list of active BANs and allows applications to retrieve the specific configuration of a BAN.
- *BAN discovery*: applications can subscribe to the platform to receive a notification in case a BAN becomes active (i.e. a patient switches on a BAN).
- *BAN authorization and authentication*: the service platform authenticates BANs and only allows authorized BANs to convey data.

- *BAN data encryption*: the platform encrypts data that is conveyed over unsecured networks
- *BAN configuration*: the service platform allows online configuration and management of the BANs, such as (de)activation of specific sensors or modification of the sample frequency of a sensor.
- *Data acquisition control*: the service platform enables applications to start, stop or temporarily interrupt the data acquisition process of a BAN.
- *Query and modify actuator status*: applications can manipulate actuators from a distance.
- *BAN data storage*: the service platform can act as an intermediate storage provider to applications. Applications determine the minimal duration of the storage.
- *BAN data monitoring*: the service platform can apply filtering algorithms on the BAN data to determine if an interesting event has taken place (e.g. a patient has dropped on the floor) and report this event to the application layer.

2.3 Service platform technical requirements

To leverage the healthcare BAN for use as a *remote* monitoring tool several issues and considerations were taken into account in the design and development of the supporting healthcare service platform. These issues reflect both, commercial and social needs or restrictions, as well as technical limitations of underlying [8]. The most important ones being *scalability*, *security* and *extra-Ban network restrictions*.

Scalability: The healthcare service platform must be able to support services that cover niche healthcare cases that require the simultaneous monitoring of small numbers of patients (e.g., ranging from 10 to 100 BANs) to large-scale chronic disease management processes (e.g., 100.000+ BANs used to monitor COPD patients). In addition geographical scalability, that is global coverage, should be supported.

Security. The healthcare service platform connects the BAN with the Internet. Consequently, the BAN is potentially vulnerable to attacks from malicious Internet users who may either try to break into the system or frustrate its use. Therefore the healthcare service platform should be protected from attacks like Denial of Service (DoS). Mechanisms that ensure data integrity must be included to prevent corruption of BAN data. Each BAN should authenticate itself with the service platform, which should only allow authorized BANs to send BAN data (i.e. preventing masquerading) and access controls are needed to prevent unauthorised access to BAN control signals and/or data.

Mask 'inverted-producer-consumer' problem. Traditionally, providers of data (such as web servers) are deployed on a computing infrastructure with sufficient network and processing capacity. Consumers of data (such as web browsers) assume that providers are available most of the time (except for maintenance) and have sufficient bandwidth to serve a reasonable number of consumers. This model was the one adopted by the public wireless network operators where the data consumer, i.e., the mobile device, initiates a network connection to the producer. Based on this assumption, most network operators of 2.5/3G networks hand out private space IP

addresses to mobile devices. Connection establishment initiated from a fixed host on the public Internet to a mobile device is therefore inhibited.

However in the MobiHealth system each BAN *is a data producer*. For the service platform, the producer and consumer roles are thus inverted because the provider of data is deployed on a mobile device (i.e. the MBU) while the consumer of data is deployed on a fixed host with sufficient processing and communication capacity. The MBU may be temporary unavailable, due to the short life-time of batteries or because it has moved to an area without coverage of the public wireless infrastructure. The service platform therefore masks the inversion of the producer-consumer roles from the BAN and the end-users (e.g., a patient wearing the BAN or a medical specialist analyzing the BAN data).

2.4 The MobiHealth Trials

The MobiHealth system and services were validated with a number of trials that spanned four European countries and covered a range of conditions including pregnancy, trauma, cardiology, rheumatoid arthritis and respiratory insufficiency and made use of patient BANs and health professional BANs (nurse BAN, paramedic BAN). The trials were selected to represent a range of bandwidth requirements: low (less than 12 Kbps), medium (12 – 24 Kbps) and high (greater than 24 Kbps) and to include both non-real time (e.g. routine transmission of tri-weekly ECG) and real time requirements (e.g. alarms, transmission of vital signs in a critical trauma situation). For each application the generic MobiHealth BAN was specialized by addition of the appropriate sensor set and corresponding application software. The nine trials were :

Trial 1 - Germany : Telemonitoring of patients with cardiac arrhythmia
Trial 2 - The Netherlands: Integrated homecare for women with high-risk pregnancies
Trial 3 - The Netherlands : Tele trauma team
Trial 4 - Spain: Support of home-based healthcare services
Trial 5 - Spain : Outdoor patient rehabilitation
Trial 6 - Sweden : Lighthouse alarm and locator trial
Trial 7 - Sweden : Physical activity and impediments to activity for women with RA
Trial 8 - Sweden: Monitoring of vital parameters in patients with respiratory insufficiency
Trial 9 - Sweden : Home care and remote consultation for recently released patients in a rural area

3. Results of the MobiHealth project

The MobiHealth project was completed successfully in February 2004 and a series of important results were obtained. First of all the project developed an architecture for,

and a prototype of, a generic service platform for the provision of ubiquitous healthcare services based on wireless Body Area Networks and 2.5/3G networks. The developed system was used to validate the ability of the commercially available 2.5/3G networks to support advanced mobile health services. The performed trials allowed us to identify the usefulness and the user acceptance of the services in different medical specialties, as well as the problems and issues that need to be resolved for its deployment. Finally the project trials allowed us to identify the market considerations and the different actors that need to be involved in a commercial deployment.

During the trials different types of data were collected by the evaluation team responsible for evaluation of the results. The trials were evaluated using a methodology developed in the project. Specifically we evaluated the trials from the technical point of view (technical evaluation), the medical point of view (end-user and social evaluation) and from the business point of view (market evaluation).

The technical evaluation focused on the evaluation of the performance of the communication infrastructure characterized in terms of: availability, bandwidth characteristics, percentage of data loss/corruption, transmission delay and its variation ("jitter"). In addition to the network performance the technical evaluation also assessed the overall system in terms of validity, accuracy and robustness of the Sensor Service and application, the BAN and the intra-BAN communications, time delays etc.

The system performance related parameters were logged at the BAN side, while the generated traffic was logged by the 2.5/3G network measurement system. Logs at the BAN side record any problems regarding access to the network and the process of transmitting the data to the BEsys. The network log reports were used to verify if any of the logged problems at the BAN side could have been caused by the current status of the network during that time.

The performance characteristics of the MobiHealth communication infrastructure were derived in two ways: objective and subjective evaluation.

The *objective evaluation* of the infrastructure included active and passive measurements. For the active measurements an external data stream was generated (that is, we had no real MobiHealth data) and the performance characteristics of the communication paths were measured. The passive measurements were performed in the up-and-running MobiHealth system so that real MobiHealth data were used. During the passive measurement phase, the participating operators also performed core-network data logging of the MobiHealth traffic characteristics [10].

The *subjective evaluation* of the infrastructure's performance was done by the end-users (healthcare professionals) who expressed their perceptions of functionality and performance characteristics as experienced during the usage of the MobiHealth system.

Part of the technical evaluation was the **2.5/3G Network Evaluation**. The analysis of the network performance evaluation data collected during the trials provides interesting results regarding the performance of the UMTS networks and technical issues related to MobiHealth BAN. Although the current UMTS networks are stable and functional, there are many barriers and technological details that need to be resolved before stable and viable m-health services can be introduced into the

market. Some of the most important problems are the restricted available data bandwidth for uplinks, delay variation, delays in transmission and handovers.

The end user evaluation described the usability/acceptance of the MobiHealth Services seeking the subjective opinion of users regarding the new services, their usability, user interaction, satisfaction, suitability, usefulness, acceptance, independence and experiences. Also questions about *perceived* performance characteristics of the system, like: system accuracy, validity, robustness, its speed or availability of the service were addressed to the professional users. End users in this project were defined as the patients and the health care personnel who were involved in the trials and were using the MobiHealth system.

The end-user evaluation data were collected using diaries, questionnaires, interviews and some objective measurements, e.g. walking distance and step-length for mobility assessment. End-users' evaluation results were compared against the performance measurements of the platform to analyse existence of expected correlations. An example of correlation between user experience and measured technical performance would be the receipt of an unusable poor quality ECG, which cannot be interpreted by the professional, coinciding with large delays and packet drops in the system indicating communication throughput problems.

The goal of ***the market evaluation*** was to provide a set of criteria which would allow valid statements and decisions regarding the market value and potential of the MobiHealth system in the respective trial settings to be made. The factors which were important and decisive in this context included: health political issues, existing market structures and processes, market players, business scenarios, value chains, potential users, users' characterization (behaviour, acceptance requirements), health economic relevance, realization of market potentials (how much and when), barriers of entry, opportunities and threats.

4. Towards commercialization : The HealthService24 project

One of the results of the MobiHealth project was the validation of the fact that today there is no concise mobile monitoring service available in Europe. There are various systems, services and applications available, which allow users to monitor their health status and transmit some type of vital signal information to remotely located medical personnel, e.g. pregnant women can be monitored from home, instead of being admitted to the hospital, Rheumatoid Arthritis patients can be monitored remotely during rehabilitation exercises at home, the glucose level can be registered and the patient can download the data once a day/week to a PC and send it to the hospital. However, the currently available services allow patients to monitor and transmit their state over a wired phone (home services), meaning that the mobility of users is very limited, as they need a telephone line and electricity connection. The medical tools available today are only on the level of administrative information (the doctor has a PDA with which he can access the medical record of the patient and send information

using GSM/GPRS). The mobile solutions that start appearing in the market either are simple technological solutions with no complete integrated service to support them or at best they simply provide the possibility for the patient to store the vital signal measurements and upload them at the evening to the hospital server.

HealthService24 aims to bridge this gap by offering a viable mobile health care service permitting healthcare professionals to remotely assess, diagnose and treat patients whilst the patients are free to continue with daily life activities. The HealthService24 services will allow patients and non-patients to monitor their physical condition and obtain advice and information at any place and moment. Hence the service will enable patients to be fully mobile. The starting point is the system developed and validated during by the MobiHealth project.

Being aware of the fact that many former technological innovations in the field of mobile health applications were not successful in the longer run due to failure to address crucial issues such as social and economic aspects, changes in medical work practices and even standardization of technologies and integration with existing medical information systems, the HealthService24 project will be dealing with the adaptation, customization and localization of the existing service prototype, the related social aspects and working conditions, and the related economic issues stemming from the deployment of the system on a larger scale, including the changes that will be brought to the processes and practices of the healthcare organizations and medical personnel. The HealthService24 will define the needs, expectations and requirements of all members of the value chain and will create added value and benefits for all value chain members, as only such an approach can make a sustainable market deployment possible. We aim to have a commercial product at the end of the project (Fall 2006).

4.1 The HealthService24 operation scenario

A HealthService24 patient/user is equipped with variety of vital constant sensors, like blood pressure, pulse plethismogram and ECG interconnected in a wireless Body Area Network managed by a PDA or mobile telephone and worn on the body, and thus moving around with the person. These way patients can stay mobile but be continuously monitored and receive advice when needed.

The measurements are transmitted wirelessly using UMTS (or GPRS) to a data centre acting as an intermediary between patients/users and health care providers and providing three services: data repository (just collecting of the received data), streaming service (forwarding data to a doctor), and alarming service (interpretation of the received data and sending of an alarm signal to a predefined destination (using SMS)). The data centre may also provide technical support and, if needed, act as the first-level medical support for the HealthService24 users.

From the data centre the data is wirelessly transferred to health care providers. Data sent to a health care provider can be viewed (e.g. on a laptop). Healthcare professionals, to whom the patients' data is transferred, can remotely assess, diagnose and treat patients whilst the patients stay fully mobile and continue with their daily life activities.

4.2 Validation trials

In order to test and verify the system, the service and the network infrastructure for its suitability and the restrictions it imposes on mobile health care applications, nine validation trials will be conducted within the project in three different countries in Europe: Netherlands, Spain and Cyprus. Three different groups of patients will test the service: (high-risk) pregnant women, cardiac patients and COPD-patients (Chronic Obstructive Pulmonary Disease) with respiratory problems. The (high-risk) pregnant women trials will be carried out in Netherlands, the COPD-patients trials in Spain, and the cardiac patients trials in Cyprus.

It is envisaged to conduct three validation trials at each test side. Each trial will last approx. 3 months followed by 1 month results analysis. As the market validation is an interactive process, the results obtained during the first set of trials will be fed into the next phases. Each set of trials will be carried out by a hospital/clinic specialised in the particular disease/health problem to guarantee the highest possible quality level and credibility of the results.

As the number of patients/ users needed per group for a validation trial varies depending on the expected hospital days, different numbers of patients need to be validated within each group. Taking the above into consideration and to assure reliable results from the validation trials, a minimum of 8 pregnant women per trial shall be monitored and 15 COPD- and cardiac patients, which means that in all three trials per patient group at least 25 (high-risk) pregnant women, 45 COPD-patients and 45 cardiac-patients will be monitored.

For the **(high-risk) pregnant women** trials, the trials will use the HealthService24 to support integrated homecare for women with high-risk pregnancies. Women with high-risk pregnancies are often admitted to the hospital for longer periods of time because of possible pregnancy-related complications. Admission is necessary for the intensive monitoring of the patient and the unborn child. Homecare with continuous monitoring is desirable and can postpone hospitalisation and reduce costs, as well as offering more security for the mother and unborn child. In this trial, patients will be monitored using the patient-BAN. The maternal and foetal bio-signals will be remotely transmitted to the hospital. An additional objective of the trial will be to evaluate if such a solution postpones hospitalisation and reduces costs. This trial takes place in Enschede, the Netherlands in the *Medisch Spectrum Twente* Hospital.

For the **COPD-patients trials**, the trials will use the HealthService24 to support remote assistance for elderly and chronically ill patients suffering from co-morbidities including the COPD. The MobiHealth nurse-BAN will be used to perform patient measurements during nurse home visits and the MobiHealth patient-BAN will be used for continuous monitoring during patient rehabilitation at home or outdoors. It is very important to facilitate patients' access to healthcare professionals without saturating the available resources, and this is one of the main expected outcomes of the HealthService24 remote monitoring approach. Parameters to be measured are oxygen saturation, ECG, spirometry, temperature, glucose and blood pressure. The trials take place in the Barcelona, Spain, at the *Hospital Clínic i Provincial de Barcelona.*

For the **cardiac patients trials**, the HealthService24 will be tested by two groups of patients:

Group1: Patients who had an acute episode and have been admitted and stabilised but need continuing monitoring of condition and drug regime for a further few days. With the HealthService24 these patients will be allowed an earlier discharge, with an appropriate follow up (using the HealthService24) in the place of their choice.

Group 2: Patients in a suspected acute episode, brought in for examination; a decision needs to be taken whether to keep the patients at the hospital for observation, or to discharge them home. In case a patient is discharged, and there is a suspicion of an abnormal condition, the patient will be equipped with the MobiHealth patient-BAN enabling constant monitoring of the patient's state.

The cardiac patients' trial takes place in Agia Napa, Cyprus, at the *LITO Polyclinic*.

4.3 Evaluation procedure

Metrics for evaluating the test results will include general indicators such as quality of life (and care) for both patient and doctor, economic benefits for a patient/government of not staying in hospital (and freeing a hospital bed), overall costs of the service and adaptation issues to adjust the service to national requirements as well as reliability, accuracy and sensitivity of the equipment and ease of use for patient and health professional. A number of questionnaires will be prepared, issued and evaluated.

During the trials different types of data will be collected in view of an evaluation of the results. The targets of the evaluation include both technical and socio-economic aspects. From the technical side, the state of the UMTS (and GPRS) infrastructure and its suitability for mobile health applications will be verified, while from the socio-economic side the added value that the HealthService24 can bring to different healthcare domains will be explored and the related issues for its commercial deployment will be evaluated. The technical issues have already been addressed by the MobiHealth project, so the HealthService24 project will mostly just confirm that results and concentrate on the health-economic and socio-economic aspects to make the service ready for the market deployment.

4.4 Status of the HeathService24 project

From the first days of the project we realized that the market is already mature and ready to accept the deployment of m-health services, as proposed by the HS24 project. As a result the project objectives not only remain valid, but there is a need for a faster deployment in order to catch the present market opportunities. For this reason an adaptation of the time frame of the short and long term objectives was made and, furthermore Ericsson adapted its internal structure and processes in order to fulfil in a shorter time the objectives of the project. As a result we were forced to delay the start of the trials for 4 months and adapt the existing system, bringing it closer to a commercial product. Finally in September 2005 the trials were started with an adapted system that was stable with additional functionality and with a simple and ergonomic user interface as requested by the users. The system allows for example the prioritization of the signals to be sent, so in case of low bandwidth the least "important" signals are not sent to the hospital but stored locally, allows for off-line

operation in case of connectivity breakdown or for energy conservation, is able to store and retransmit historical data on request etc. Further secondary functionalities as well as administrative interfaces will be added to the system in the next few months.

Some of the items that were added in the user interface were basic information regarding pulse rate and/or oxygen saturation as well as an easy to read indication (for the pregnancy trial) that labour is highly probable and the woman should come to the hospital at once. In addition and most importantly, simply explained information on the connectivity status. The user knows at any instance if he is connected and if not where is the problem (see Figure 31. Mobile user interface).

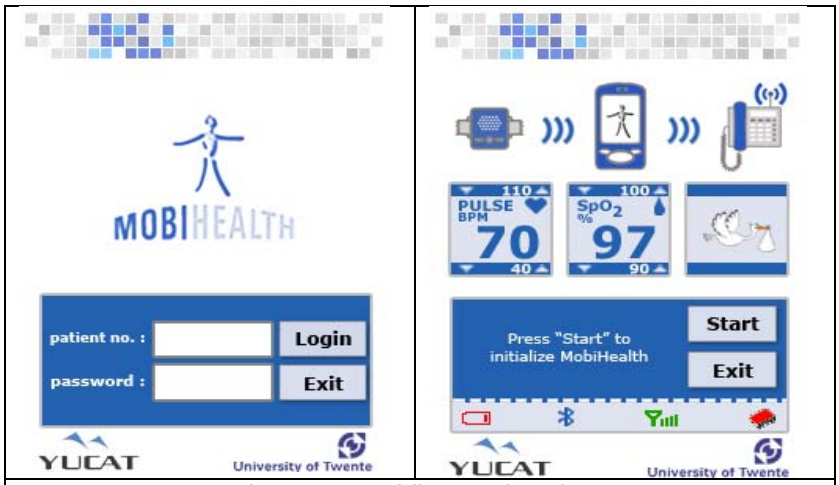

Figure 31. Mobile user interface

5. Conclusions

The results of the project indicate that several issues need to be resolved by both network operators and hardware manufacturers for a better support to mobile health services [9]. Ambulatory monitoring is more successful for some biosignals than others, for example some measurements are severely disrupted by movement artefacts. Some monitoring equipment is still too cumbersome for ambulatory use, because of the nature of the equipment or because of power requirements (Powering always-on devices and continuous transmission will continue to raise technical challenges for the next decade for mobile applications!). Furthermore even with 2.5 and 3G, we still suffer from limited bandwidth for applications that serve many simultaneous users.

Other challenges relate to security, integrity and privacy of data during transmission to both local transmission (e.g. intra-BAN) and long range (e.g. extra-BAN) communications. Legislation differences between European countries do create some problems in the adoption of mobile systems. Some harmonization is expected in the future but it will take time to become reality.

Business models for healthcare and accounting and billing models for network services need to evolve if technical innovations are to be exploited fully. Standardisation at all levels is essential for open solutions to prevail. At the same time specialization, customisation and personalisation are widely considered to be success criteria for innovative services.

The main problems identified relating to the introduction of new mobile health services based on Internet technologies into hospitals relate to the changes required to support these new services, in both technological level and work practices level. From a technology point of view, the introduction of new mobile services requires a modern ICT infrastructure with secure connections to the Internet. However, many hospitals today do not have this kind of ICT infrastructure. Some hospital IT departments didn't even accept the use of standard HTTPS (i.e. HTTP over secure sockets) to retrieve vital sign information. On the other hand other hospitals demanded that the mobile system fully integrates with their existing IT system, using the same data exchange standards and formats.

A second technology related problem concerns the precaution measures taken by the majority of the hospitals in the use of wireless communication devices inside the hospitals. Due to lack of serious studies regarding the interference of wireless communication devices, like telephones, with medical equipment, most hospitals prohibit the use of any such device within their premises. This has as an immediate consequence that any wireless medical system will have difficulties to be officially authorised to function inside the hospital.

Nevertheless, from the reactions and interest of the hospitals and the patients we are very optimistic that the proposed MobiHealth/HS24 system and services will be a commercial success.

6. References

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