Proceedings of the 25th Annual International Conference of the IEEE EMBS
Cancun, Mexico • September 17-21, 2003

Continuous monitoring of vital constants for mobile users: the MobiHealth[1] approach

Dimitri Konstantas[2], Rainer Herzog[3]
[2]University of Twente, Center for Telematics & Information Technology – APS, NL-7500 AE Enschede, The Netherlands
[3]Ericsson GmbH, Maximilianstr. 36/RG, D-80539 Munich, Germany

ABSTRACT

MobiHealth[1] aims at introducing new mobile value-added services in the area of mobile healthcare, based on 2.5 (GPRS) and 3G (UMTS) technologies. This is achieved by the integration of sensors and actuators to a Wireless Body Area Network (BAN). These sensors and actuators continuously measure and transmit vital constants along with voice and images/video to health service providers and brokers, improving on one side the life of patients and allowing on the other side the introduction of new value-added services in the areas of disease prevention and diagnostic, remote assistance, para-health services, physical state monitoring (sports) and even clinical research. Furthermore, the MobiHealth BAN system supports the fast and reliable application of remote assistance in case of accidents by allowing the paramedics to send reliable vital constants data as well as audio and video directly from the accident site. Trials are underway focusing on home care, trauma care and ambulatory monitoring.

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 [1]., 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. This results in high costs for the hospitals and social insurances and in the loss of work hours and morale of the patient.

The introduction of new pan-European mobile health and para-health personalized services, based on 2.5 and 3G technologies will provide new markets and opportunities allowing both, citizens and the industry to profit.

The EU MobiHealth project (IST-2001-36006) is bringing together expertise and technologies including Body Area Networks (BANs), vital signs sensors and wireless communications to provide mobile health services for patients and for health professionals. MobiHealth proposes new services that will allow the monitoring of vital constants for out of hospital patients. Moreover, MobiHealth improves current practice by allowing continuous monitoring of constants such as pulse rate, temperature, etc, whereas today, these measurements are sampled at intervals only.

The objective of the MobiHealth project is to develop and trial a generic Body Area Network for health monitoring using 2.5/3G for extra-BAN communication. Patients' biosignals are measured by the BAN and transmitted to a remote healthcare location. The MobiHealth trials focus on home care, trauma care and ambulatory monitoring. MobiHealth trials involve BANs for patients (such as the patient trauma BAN) and for health professionals (e.g. nurse or paramedic BAN).

In our definition, a Body Area Network is "a collection of (inter) communicating devices which are worn on the body, providing an integrated set of personalised services to the user" [2]. When the devices of a BAN measure physiological signals or perform other actions for health-related purposes we call this kind Body Area Network a health BAN. Communication within a BAN may be either wired or wireless, or any combination of the two, and is known as intra-BAN communication. Communication between a BAN and another network is known as extra-BAN communication.

2. PROJECT APPROACH

The overall objective of the project is the introduction of new mobile health services, based on the on-line, continuous monitoring of vital signs, via GPRS and UMTS technologies (Figure 1). These services are supported by the MobiHealth Body Area Network (BAN), a wireless system that will allow the simple connection of different vital signal sensors. The BAN, the GPRS/UMTS infrastructures, as well as the new services are tested via a set of trials conducted in different European countries.

[1] The MobiHealth (No IST-2001-36006) project is supported by the Commission of the European Union under the 5th EU research framework.

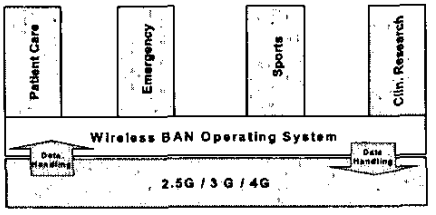

***Figure 1** Generic MobiHealth System*

These trials provide the context in which both the medical advantages and business perspectives of the new mobile health services are demonstrated and evaluated.

Since health related data and information is highly protected by law and by professional ethics the MobiHealth project takes all reasonable measures to protect information relating to patients and users. In this context MobiHealth aims at defining a harmonized protection framework, based on EU reference directives [3].

3. PROJECT IMPLEMENTATION

3.1. Functional Description

The MobiHealth trials implement simple, but complete services that can be immediately deployed over the UMTS and GPRS networks. The MobiHealth patient/user is equipped with different interoperating or independent vital constant sensors, ranging from blood pressure and pulse rate, to oxygen saturation and electrocardiograms (ECG). In addition images and video can be captured and transmitted to the health center.
The vital constant measurements are sent to a health broker (which may be a hospital or a medical call center), where specialists are able to observe the evolution of the patient and intervene when needed. The communication is based on 2.5 – 3G wireless technologies.

The use of GPRS and UMTS as communication technology is essential due to the need for wide coverage and continuous connection to the healthcare center.

3.2 MobiHealth BAN architecture.

The generic MobiHealth BAN architecture consists of a central unit called the *MBU* (*Mobile Base Unit*) plus a set of devices, which may include sensors, actuators, and various multimedia devices. The MBU handles co-ordination, (local) computation functions and communication. (Figure 2).

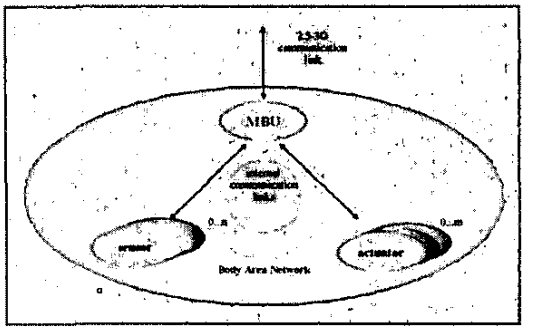

***Figure 2** MobiHealth BAN architecture*

The MBU used currently in the MobiHealth trials is based on the HP iPAQ platform, with plans to port also to other platforms such as the Sony Ericsson P800 phone in future. The BAN Operating System (BAN OS) provides the local functionality offered by the MBU. The BAN OS consists of a native OS, such as Linux or Windows CE, a Java virtual machine and a set of generic functions implemented in Java, referred to as BANware.

Figure 3 shows the hardware and software components of the MobiHealth BAN and its environment. The surrogate host acts as an intermediary between the applications in the E-health domain and the MobiHealth domain. The surrogate host executes a surrogate object to represent each BAN. A surrogate object shields applications in the E-health domain from temporary disruptions in the wireless networks, in addition it offers a LookUp Service (LUS) which enables lookup and discovery of active BANs. The surrogate objects are defined according to the Jini Surrogate architecture.

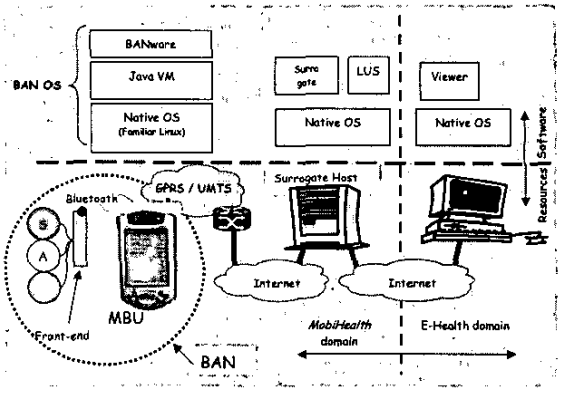

***Figure 3.** Components of the MobiHealth BAN and its environment*

Sensor data is transmitted to the MBU via a sensor front-end. The front-end is a device that digitizes the analogue signals from the sensors and transmits this information to the MBU.

MobiHealth BAN Devices. During the MobiHealth project the BANs are customized for each trial with a different sensor set. For example we can make a BAN for cardiac monitoring by attaching a miniature wearable (3-lead) ECG monitor. The electrodes are sensors which convert chemical concentration differences from ions into an electrical potential. Additional sensors can be attached to measure oxygen saturation and NIBP (non invasive blood pressure). Heart rate can be calculated from the ECG.

For other applications other sensor sets are used incorporating for example pulse oximeters and motion sensors.

3.3 MobiHealth Intra-BAN Communications.

The MobiHealth concept allows for wired or wireless communications within the BAN, or a combination of the two. Bluetooth [4] and Zigbee [5] currently are the wireless technologies of choice for intra-BAN communication. The choice of communication technology partly depends on the application and the sensor sets involved, such as the amount of data that a sensor set produces and the power consumption needed for a certain communication technology.

3.4 MobiHealth Extra-BAN Communications.

For the MobiHealth trials extra-BAN communication is mainly based on GPRS. Transmission speeds in GPRS networks depend on the type of terminal used and settings (controlled by an operator) in the GPRS network, and may be asymmetrical (i.e. uplink and downlink speeds may differ). Terminals can either be GPRS phones (e.g. Nokia 6310 or Sony Ericsson P800) or PC cards. Transmission speeds vary from 14.4/28.8kbps uplink and 28.8/43.2kbps downlink. In the MobiHealth project the GPRS phone acts as a 'wireless modem'. The MBU communicates via Bluetooth to the GPRS phone. The GPRS phone uses an asymmetrical transmission scheme (14.4kpbs uplink and 43.2kbps downlink) and forwards the information to the GPRS network. It is also possible to use a GPRS PC card in combination with the MobiHealth MBU, integrating external communication technology in the BAN. Transmission speeds are symmetrical and are limited to 28.8kbps. In order to abstract from wireless transmission technology, BAN to Internet communication, and vice versa, is based on the IP protocol.

When UMTS becomes available (2003/2004), initial transmission speeds will vary from 64kbps to 144kbps. During the MobiHealth project lifecycle UMTS availability is likely to be limited to test sites only. The availability of a first generation UMTS network will broaden the application suite which can be supported by the BAN.

4. VALIDATION OF MOBIHEALTH APPROACH

A central point of the MobiHealth project is the assessment and evaluation of the trials. The trial results are validated with different medical applications from four points of view. First, the accuracy and validity of the measurements taken by the MobiHealth BAN will be validated. This will be done by comparing MobiHealth measurements with those measurements captured using current methods. Secondly, the usability and suitability of the GPRS/UMTS networks to support the MobiHealth application requirements will be tested. For this, network-related events like change of operator or UMTS-GPRS hand-over will be registered and the effects on the MobiHealth services will be measured (delays, loss of data, bandwidth problems, security issues, etc.). Thirdly, the business and market potential for the new services will be defined. Related costs will be measured and compared with actual traditional methods. Subjective opinions of users and organizations regarding the new services, their usefulness and usability will be collected. The fourth and last issue here concerns emerging ethical questions. Evaluation will include the effects of prevention and the intervention on the person or the family.

Different scenarios with different requirements are trialed involving a sufficiently large number of users, so that credible results can be drawn. A total of four trial sites has been set up in different countries, involving different health centers (The Netherlands, Sweden, Germany, Spain). The trials cover a range of clinical conditions and take place in different settings (the patient's home, outdoors and, for the trauma setting, at the scene of the accident and in the ambulance) and cover use of patient BANs and health professional BANs (nurse BAN, paramedic BAN). The trials are also selected to represent a range of bandwidth requirements and to include both non-realtime and realtime requirements. The overall goal is to test the ability of 2.5 and 3G infrastructures to support value added services.

4.1 Telemonitoring of patients with ventricular arrhythmia.

In Germany the MobiHealth system will be tested and evaluated with a cohort of patients suffering from ventricular arrhythmias who are undergoing drug therapy for this condition. In such patients, ECG measurements have to be taken regularly to monitor efficacy of drug therapy. In this trial the patient BAN transmits ECG and blood pressure via GPRS to a Medical Service Centre, where the vital signs are monitored by physicians and nurses. From a health economic point of view the intervention is expected to save time and reduce costs. Main outcome parameters are the number of hospitalizations, drug prescription and the levels of blood pressure and ECG.

4.2 Integrated Homecare in women with high-risk pregnancies.

This Dutch trial will use the MobiHealth BAN to support Integrated Homecare for women with high-risk pregnancies. Women with high-risk pregnancies are often admitted to hospital because of possible pregnancy-related complications. Homecare with continuous monitoring of women with high-risk pregnancies, when feasible, is desirable and can postpone hospitalisation and reduce costs. In this trial, patients are monitored from home using the MobiHealth BAN and maternal and foetal signs are transmitted to the hospital. For the healthcare/medical evaluation, main outcome parameters are the number of days in hospital, the number of emergency interventions, patient satisfaction with hospital or telemonitoring and the reliability of the system to monitor the patients and to inform the gynaecologist regarding CTG /ECG and EMG data.

4.3 Support of home-based healthcare services.

This Spanish trial involves use of GPRS for supporting home-based care for elderly chronically ill patients including remote assistance if needed. Trial subjects suffer from co-morbidities which include Chronic Obstructive Pulmonary Disease. 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 home monitoring and also outdoors during patient rehabilitation. Physical parameters to be measured are Oxygen saturation, ECG, spirometry, temperature, glucose and blood pressure.

4.4 Home care and remote consultation for recently released patients in a rural area.

In this Swedish trial the trial subjects are patients with multiple chronic diseases including cardiac failure, diabetes and respiratory disability who have been recently discharged from hospital and who are living at home in a low population density rural area. Measurements (including blood pressure, heart rate, oxygen saturation and blood glucose, as appropriate) are transmitted to a remote physician or a registered district nurse (RDN). The healthcare/medical evaluation will focus on qualitative instruments measuring user experiences of the intervention by the involved roles: staff, patients and their next-of-kin.

5. CONCLUSION

MobiHealth represents the convergence of different technologies to enable personalized, mobile health services. The function of a BAN is to integrate all the wearable devices such as PDA's mobile phones and watches that a person carries around during the day.

The innovation of MobiHealth lies on the integration of these technologies in a flexible and generic system – the MobiHealth BAN – with the development of the required software that will provide an open platform for the creation of new, personalized services in the area of mobile health. The MobiHealth BAN, being generic, can be easily customized to provide services to the sports community, the medical research community, to the study of causes and triggers in chronic diseases (e.g. asthma or epilepsy) and to the detection and prevention of serious acute events (e.g. sudden infant death, stroke, etc.).

Finally, it is considered to be important to also point out to the technological and medical risks of MobiHealth. Technological risks include e.g. radio interference or interference with medical equipment. Medical risks may be possible health effects that the new technology might introduce to the patients, e.g. possible electromagnetic hazards associated with cell phone usage. The in-depth study of these risks is out of the scope of the project, nevertheless, risks will be identified and the project will take into consideration possible consequences and integrate existing solutions to cope with the related issues.

5.1 Status of the project

The project started in May 2002 and will be completed in November 2003. At the time of writing (may 2003) the project is about to start the trials at the four sites. 60 health-BAN sets are under implementation based on the HP (previously Compaq) iPAQ and will be delivered to the users in early June 2003.

The IntraBan communications of the 60 health BANs are based on Bluetooth.

The evaluation methodology and the detailed trial scenarios have been defined, while pre-trials are underway at the different sites. The trials will last 6 months and an evaluation on both at the medical and technological results will be performed. More information on the project status and results can be found at the project site (http://www.mobihealth.org).

REFERENCES

[1] Health Statistics 2001, BKK Preussen Elektra, Hannover, Germany

[2] Wireless World Research Forum, 2001, The Book of Visions 2001: Visions of the Wireless World, Version 1.0, December 2001; http://www.wireless-world-research.org/

[3] EU Directive 95/46/EC on the protection of individuals with regard to the processing of personal data and on the free movement of such data

[4] BlueTooth, http://www.bluetooth.com/

[5] ZigBee Alliance, http://www.zigbee.org/