MobiHealth[1]: Mobile Healthcare

IST-2001-36006
http://www.mobihealth.org

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Abstract

The use of health BANs together with advanced wireless communications (GPRS/UMTS) enables remote management of chronic conditions and detection of health emergencies whilst maximizing patient mobility. During the MobiHealth project a generic Body Area Network for health monitoring was developed. 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. In addition to serving patients, remote monitoring can also benefit non-patients going about their daily life activities.

Introduction

The EU MobiHealth project (IST-2001-36006) is bringing together a number of technologies including Body Area Networks (BANs), vital signs sensors and wireless communications to provide mobile health services for patients and for health professionals.

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” [WWRF2001]. 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.

The vision of the MobiHealth project is to develop an open extensible BAN platform which allows integration of different health functions by means of a plug-and-play approach. An open BAN platform enables integration of devices from different manufacturers into a single healthcare services platform.

The combination of health BANs and advanced wireless communications enables, amongst other things, remote management of chronic conditions and detection of health emergencies whilst maximising patient mobility. 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

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

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). Each MobiHealth application involves customisation of the generic BAN with a specific sensor set and the application software associated with a particular service.

Development and Integration-technological platform

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. 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 1 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.

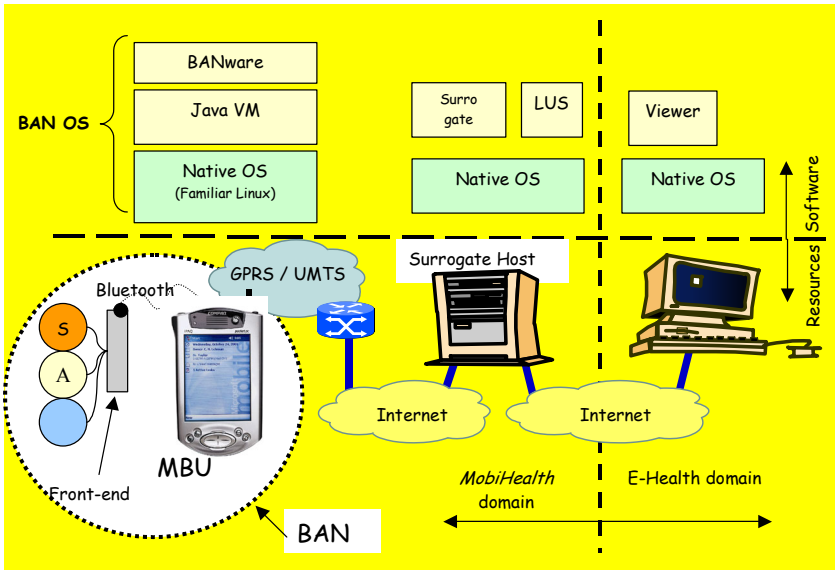

Figure 1. Components of the MobiHealth BAN and its environment

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. The front-end ensures that all sensors attached to it operate at the correct

sampling frequency and that the measured data is synchronized. Different front-ends can be associated with one MBU, enabling customization of the BAN.

MobiHealth BAN Devices. During the MobiHealth project the main BAN devices used are sensors, 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. Pulse oximetry is measurement of oxygen saturation in the blood and is measured by one or two light sensors (red and infrared) detecting light from one or two light sources (red and infrared). The device is a small cuff worn on the finger. Motion sensors used can be simple accelerometers or the more sophisticated and more accurate gyroscopic sensors which measure movement in three dimensions.

MobiHealth Intra-BAN Communications.

The MobiHealth concept allows for wired or wireless communications within the BAN, or a combination of the two. Bluetooth and Zigbee 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. The current BAN uses wired connections between the sensors and the sensor front end with a wireless (Bluetooth) link to the MBU.

MobiHealth Extra-BAN Communications.

For the MobiHealth trials extra-BAN communication is mainly based on GPRS. National GPRS coverage is available in the countries where the trials are conducted (Germany, The Netherlands, Spain and Sweden). 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. Special measures are taken to make the end-to-end communication reliable and secure, these mechanisms are situated above the IP protocol layer.

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.

Validation of the MobiHealth approach: trials and evaluation.

Trials of the MobiHealth services will take place in four European countries. 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. The trials are evaluated according to four perspectives: Technology, Healthcare/Medical, Market and Social. Below we refer mainly to the healthcare/medical part of the evaluation, wherein objective and subjective evaluation data are collected and process and outcome variables are considered over the different trials. It is not expected that definitive clinical outcomes can be established with the numbers and timescales involved. In fact under the context of the Call the primary evaluation focus must be on technology, specifically on the potential for value added services over 2.5 and 3G communications. To illustrate the validation effort we mention here one trial from each participating trial site.

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. Instead of staying in hospital during monitoring, the patient can be at home and can even go freely outside the home. The intention is that through remote monitoring developing clinical trends can be identified and corrected before they become serious. From a health economic point of view the intervention is expected to save time and reduce costs. For the healthcare/medical evaluation blood pressure and ECG readings during the technology intervention are compared to baseline measurements. Main outcome parameters are the number of hospitalizations, drug prescription and the levels of blood pressure and ECG.

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. Admission is necessary for the intensive monitoring of the patient and the unborn child. 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. The objective of the trial is to evaluate if such monitoring services can be supported by 2.5-3G communications such that hospitalisation can be postponed and

costs reduced. 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.

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. It is very important to facilitate patients' access to healthcare professionals without saturating the available resources, and this is one of main expected outcomes of the MobiHealth remote monitoring approach to be explored in this trial. Physical parameters to be measured are Oxygen saturation, ECG, spirometry, temperature, glucose and blood pressure. The healthcare/medical evaluation focuses on acceptability of the technology solution in this health context and compares quality and process of care received under the technology intervention with that received under current practice. Comparison is in terms of numbers of: in-patient hospital stays, ER visits, outpatient visits, primary care physician visits, social support visits, nurse home visits, prescriptions, phone calls (patient-nurse/ nurse-patient) and transports.

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 intention is that the remote health professional receives clinical data which offers a better basis for a good and safe decision on whether the patient can stay at home or needs transfer by ambulance to hospital. The expected benefit is that this intervention will reduce the number of cases where the patient is moved to hospital unnecessarily. 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.

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 trials will be based on GPRS technology while tests and small scale trials will be performed at the sites where UMTS is available. This is the case at the University of Twente where first tests were started using the experimental UMTS network from Vodafone (which delivers 64kbps) and a small number of pre-commercial terminals (Nokia UMTS telephones).

The IntraBan communications of the 60 health BANs are based on Bluetooth. However a small number of test ZigBee chips/board were delivered to the BAN development team and will integrated and tested on later trials.
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.