

Long distance care

As mobile devices pave the way for mobile healthcare services that put long-distance patients at the helm of their own diagnoses and treatment, it's important to evaluate user requirements and expectations

Inevitably the emergence of high bandwidth public wireless networks and miniaturized mobile devices give rise to new mobile healthcare services. The MobiHealth system (the example discussed here) provides highly customizable vital signs, tele-monitoring and tele-feedback system based on a Body Area Network (BAN) and a mobile-health care (m-health) service platform. The BAN allows the incorporation of diverse medical sensors via wireless connections, and the live transmission of the measured vital signs to healthcare providers, as well as real-time feedback to the patient. Since 2002 the system has undergone substantial development in consecutive research projects. Diverse trials for different healthcare scenarios and patient groups have been conducted in all projects in multiple European countries. In these trials we aimed to derive end-user Quality of Service (QoS) requirements and his Quality of Experience (QoE) expectations, and evaluate the service and the network infrastructure for m-health applications' delivery. MobiHealth BV is a spin-off company that builds upon expertise gained from these endeavours and continues challenging research on the QoE/QoS for healthcare domain.

Introduction

The expansion and availability of high capacity mobile networks (i.e., 2.5/3/3.5G) combined with the ever-advancing miniaturization of sensor devices and personalized computers give rise to new applications that affect and change our daily life. An area where these new technological advances will have a major effect is healthcare. The vision we strive for is

that patients are able to send full, detailed and accurate vital signs measurements and receive medical advice from a distance, irrespective of when and where they are. This data is to be of an equivalent standard to that obtained in a medical centre.

The MobiHealth project (supported by the EU Commission in the 5th research Framework under the project number FP5-IST-2001-36006, 2002-2004) has started a development of an innovative value-added mobile health service platform for patients and health professionals. This service platform has been denoted MobiHealth and has been further developed in the European HealthService24 research project (FP6-eTen-517352, 2005-2006), Dutch national Freeband-Awareness project (BSIK-5902390, 2004-2008) and the European MyoTel project (FP7-eTen-046230, 2007-2009). The MobiHealth Service Platform™ in its current development stage is owned by the University of Twente spin-off company named MobiHealth B.V. (created in 2007).

The platform enables remote patient monitoring and treatment through the use of advanced wireless communications and integration of sensors to a wireless Body Area Network (BAN). The platform permits a remote management of chronic conditions and detection of health emergencies while maximizing patient mobility.

From all those years of research on the MobiHealth platform we have learned how important it is for the overall success of the service delivery to derive user Quality of Service (QoS) requirements and his Quality of Experience (QoE) expectations accurately. These, and not

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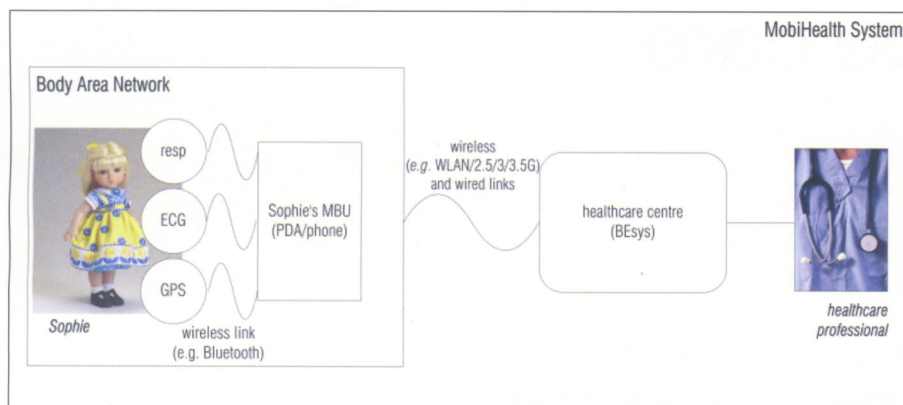


Fig 1. MobiHealth system high-level architecture

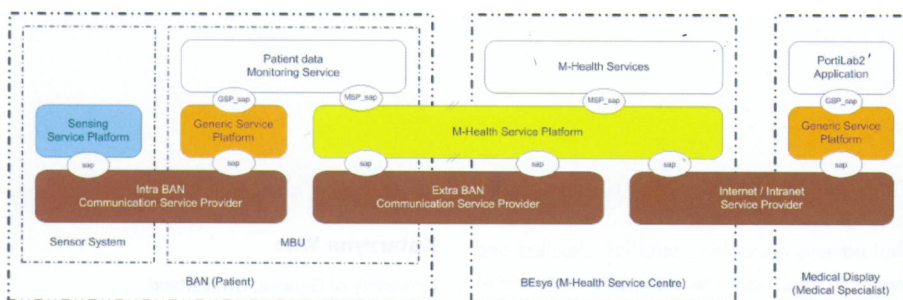


Fig 3. MobiHealth Service Platform™ Functional Architecture



Fig 2. Example of front-end based MobiHealth BAN

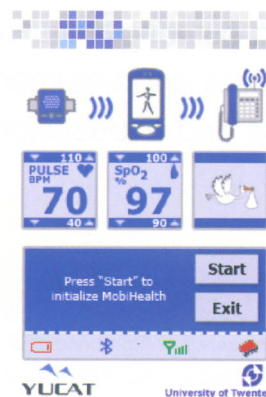


Fig 4. Graphical User Interface for high-risk pregnancy monitoring

the underlying technologies, are the major drivers for the service acceptance. The major challenge is that these requirements and expectations are in most cases implicit, hence easy to be overlooked. MobiHealth is an example of a team that uses lessons learned and succeeds in scientific, as well as commercial areas of m-health services delivery.

MobiHealth system

The MobiHealth system provides a complete end-to-end m-health platform for ambulant patient monitoring and treatment, deployed over next generation wireless networks (Fig 1). The patient wears different sensors continuously monitoring his vital signals, e.g. blood pressure, heart rate or respiration. These are interconnected via a healthcare BAN consisting of sensors, actuators, communication and processing components.

The central point of the healthcare BAN is a Mobile Base Unit (MBU), aggregating the sensor measurements and transmitting them via a wireless network to the application-server (BEsys). The BEsys system can be located within the healthcare provider premises. The BEsys dispatches the measurements to the healthcare provider, where they are examined by personnel or automatically monitored for abnormalities.

Communication between entities within a BAN is referred to as intra-BAN communication and it is based on short-range wireless networks,

e.g., Bluetooth. Extra-BAN communication is performed between the MBU and BEsys and it enables remote monitoring via 2.5/3/3.5G/WLAN technologies.

The sensors used in the BAN monitor and capture a physical phenomenon, such as patient movement, muscle activity or blood flow, convert it to an electrical signal, which is then amplified, conditioned, digitized and communicated within the BAN. Figure 2 presents a TMSI front-end (right) with 4-leads ECG sensors and respiration belt. It uses Bluetooth for intra-BAN communication. ECG electrodes, a movement sensor, a temperature, pulse oximeter and an alarm button are examples of sensing devices that can be attached to this front-end. The MBU was incorporated in an HTC Qtek 9090 device.

Service platform architecture

The MobiHealth service platform integrates the mobile BAN and the BEsys. Figure 3 shows the overall functional architecture of the platform. The dotted square boxes indicate the physical location where parts of the service platform are executed. The rounded boxes represent the functional layers of the architecture. The m-health service platform consists of sensor/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. Applications that run on top of the service platform can either be deployed at the MBU (for on-site use, e.g. by a visiting nurse) or at the BEsys in the healthcare provider domain. Applications that use the m-health service layer can range from simple viewer applications that provide a graphical display of the BAN data, to complicated applications that analyse the data and provide personalized feedback to a patient.

System trails and user QoS requirements

The primary question answered by the MobiHealth project in 2002 was that 2.5G and 3G generation technologies can support the MobiHealth vision with respect to data transfer from a mobile patient to (fixed) healthcare centre. In the HealthService24 project we further proved the technical feasibility and a market potential for remote monitoring systems. Similarly, in the MyoTel project, we showed a market potential for myo-feedback-based remote monitoring and treatment systems for patients suffering from chronic shoulder-back pain. The Freeband-Awareness project resulted in developing a context-aware service platform that adapts service delivery to the user's location, time and activity.

To address these particular questions, in each project we organized and conducted

MobiHealth system—use trials with a number of end-users. They enabled us to elicit detailed end-user QoS requirements and QoE expectations, and to identify issues in the development of the intended services.

The MobiHealth project trials were targeted at the areas of acute trauma care, chronic and high-risk patient monitoring, and home care. A range of medical conditions was covered including high-risk pregnancy, trauma, cardiology (arrhythmias), rheumatoid arthritis and respiratory insufficiency (Chronic Obstructive Pulmonary

user expectations towards the service delivery. Our users required further miniaturization and/or integration of BAN devices and an increase of BAN battery lifetime beyond 24 hours, as it is today. Moreover, the weight/size as well as overall 'wearability' of BAN was an issue; users preferred smaller and less obtrusive devices, rather than big ones, which would be visible.

Another implicit requirement was identified with respect to the user interface - as expected end-users required simple, intuitive interfaces, which at a glance would indicate the state of the

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Disease). HealthService24 trials focused on high-risk pregnancy, cardiac arrhythmia and COPD. Freeband-Awareness trials focused on epileptic and spasticity patients. MyoTel project trials focused on monitoring and treatment trials for patients suffering from chronic shoulder-back pain. The feedback (auditory, tactical or visual) to the patient is dispatched if the system observes that he/she tenses shoulder-back muscles for longer than 15 minutes.

In all projects, the basic end-user QoS requirement included lossless and in-order data delivery. Moreover, the trials represented a range of bandwidth requirements: low (less than 12 kbps), medium (12–24 kbps) and high (greater than 24 kbps), as well as delay requirements, i.e., including both non-realtime (e.g. routine transmission of tri-weekly ECG) and realtime requirements (e.g. alarms or transmission of vital signs in case of an epilepsy seizure). Another QoS requirement always posed by the users is requirement for secure data transfer; this has been established with used of encrypted application protocols. End-users were not able to indicate the monetary costs limits as their requirement for the service; they indicate that the underlying business model must be developed such that these services will be reimbursable.

For each trial application, the generic MobiHealth BAN was customized by addition of the appropriate sensor set and corresponding application software.

Emerging challenges in user experience

From the MobiHealth project trials, we learned that mobile remote monitoring of patient's vital signs is technically and commercially feasible. However, from the trials we have learned that to ensure user acceptance of the proposed healthcare services, it is important to derive (implicit) end-

system (running/not, values out of bounds, etc.). Moreover, in the first release of the system when something is not correct/accurate it is indicated in red, and where it is correct, in green. We have learned that the dominant colour preferred in healthcare domain is blue, and we have changed all interfaces accordingly.

Figure 4 presents an example interface deployed in the trial for high-risk pregnancies in Awareness project; at the top we present a status of the extra-BAN communication, below which we present values for the (selected) vital signs. Below the user interaction component (Start/Exit), we indicate the status of the battery (in red if low), intra-BAN Bluetooth status, extra-BAN network coverage (2.5G/3G/WLAN) and status of the internal memory (red if full).

Conclusions

The results of our research projects and commercial undertaking include architecture for, and implementation of, a generic service platform for provision of ubiquitous healthcare services based on body area networks. The MobiHealth Service Platform™ can support not only health-state sensors, but potentially any body-worn or personal devices. Consequently the MobiHealth system has potentially many monitoring and treatment applications not only in a healthcare domain. However, before the system can be used in routine practice in any application domain, we indicate a need for its technological assessment against its user requirements and expectations, as well as a need for business models, in which costs and benefits will be split amongst the participating actors. ■

The primary aim of these projects was to evaluate technical feasibility and added value of MobiHealth system in a healthcare, and not to validate new medical tools clinically.



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