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MobiHealth - innovative 2.5 / 3G mobile services and applications for healthcare

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ABSTRACT

MobiHealth aims at introducing new mobile value-added services in the area of healthcare, based on 2.5 (GPRS) and 3G (UMTS) technologies, thus promoting the use and deployment of GPRS and UMTS. This will be achieved by the integration of sensors and actuators to a Wireless Body Area Network (BAN). These sensors and actuators will continuously measure and transmit vital constants along with audio and 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 will support 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.

I. INTRODUCTION

A. Overall Objective

The MobiHealth project addresses the problem of testing the 2.5 and 3G markets by developing and trialing new value-added services and applications in the area of mobile healthcare. On the one hand, 2.5 G networks are today under-used due to the lack of innovative services [1]. As a result, the deployment of 3G technologies risks being delayed and the advances and momentum gained in Europe in mobile services during the last few years is in danger of being lost. On the other hand, 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 [2]. In contrast, the market for para-health services and applications, such as physical state monitoring during sports training and the use of health call centers, is becoming increasingly common and available to every citizen. 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. Thus, 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.

MobiHealth is opening up new application areas for 2.5 and 3G communication technologies, providing the possibility for key-actors (ranging from operators and Small/Medium Size Enterprises (SMEs) to service providers and hospitals) to gain experience with new mobile value-added services. MobiHealth aspires to create market demand for the new mobile health value-added services and applications, thus boosting the development, deployment and use of 2.5 and 3G communications.

B. Related Projects

MobiHealth builds on the results of past and current projects by applying the novel concept of the Body Area Network (BAN) as a generic organising concept for the disparate elements of m-health systems for patients and healthcare professionals. This is a key distinguishing feature of MobiHealth. The MobiHealth BAN enables not only homecare for patients, but also continuity of care in the context of global roaming for the patient /

citizen. Most important, the MobiHealth BAN concept provides a generic platform for implementation and bringing to market of a multitude of services, thus acting as a service integration technology.

Notable IST e-health projects related to MobiHealth include AMON and HEALTHMATE. AMON (Advanced care and alert portable telemedical monitor) [3] targets research, development and validation of a wearable personal health system to monitor and evaluate human vital signs using advanced bio-sensors, plus analysis and transmission of vital signs to a remote telemedicine center via GSM/UMTS. HEALTHMATE (Personal intelligent health mobile systems for telecare and tele-consultation) [4] targets the development of portable personal systems for health telecare and tele-consultation based on GPRS/UMTS.

MobiHealth complements these two projects since it targets not the development of the monitoring devices, but the introduction of a complete m-health service and a set of large scale trials.

Other related IST projects include @HOME (Remote home monitoring of patients) [5], which targets next generation health services using UMTS, Bluetooth and ubiquitous medical sensors for patient monitoring in the recovery phase and for chronically ill patients, also addressing patient compliance.

Relevant projects in this context also are: TELEMEDICARE (Telematic support for patient focused distant care) [6], CHRONIC (An information capture and processing environment for chronic patients in the information society) [7], MOBI-DEV (Mobile devices for healthcare applications), MOEBIUS (Mobile extranet based integrated user services) [8] and M2DM (Multi-access services for telematic management of Diabetes Mellitus) [9].

MobiHealth will build upon the results of these projects, extending their concepts and offering direct links to health centers, transforming them into real services and offering a platform that will act as the integrator for new business applications.

II. 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. These services will be 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 will be tested via a set of trials that will be conducted in different European countries.

The main thrust of the MobiHealth project is to conduct trials that introduce new services by providing continuous medical care (in-home and out-of-home), preferably based on wireless sensors and actuators (ranging from vital constants sensors to audio/video streams), integrated into Body Area Networks comunicating with different health brokers via GPRS and UMTS connections. The MobiHealth BAN will be sufficiently generic to enable the seamless integration (wear and use) of different sensors and actuators. This way, different kinds of services relating to continuous health monitroing can be introduced, including various forms of home care, physical status monitoring during sports, patient follow-up, medical testing, etc.

The MobiHealth project will first concentrate on the integration of existing and experimental prototype hardware components in the generic BAN platform. For this, existing and experimental 2.5 – 3G capable hardware components and prototypes (such as the Compaq iPAQ, or the forthcoming, fully programmable Ericsson mobile phone) will be used, to which a specific set of commercially available sensors and actuators will be integrated by adapting and extending them with wireless connectivity. Next, a series of test scenarios and evaluation methodologies will be developed, introducing the new, mobile health services.

The result of the project will be a set of large scale trials, providing the context in which the business perspectives of the new mobile health services can be evaluated, demonstrating the feasibility of the applications, its usefulness and testing the interoperability of the 2.5/3G network infrastructures in different countries. The aim is in the design of new value-added services for the well-being of the citizens and the creation of a standard that is acceptable by the major players.

Since health related data and information is highly protected by law and by professional ethics, the MobiHealth project will take all reasonable measures to protect information relating to patients and users. To this end, security and encryption technologies will be used in data transmission. At the receiving site, only authorized personnel working for the project will be able to access the data. If needed, confidentiality and responsibility discharge documents will be signed with the users. In this context, MobiHealth aims at defining a harmonized protection framework, based on EU reference directives [10].

Upon completion of the project, several technological, econmoic and methodological results are expected. A first result will be the integration of a generic m-health BAN, equipped with a basic set of sensors/actuators. A first version of a BAN will be implemented by integarating existing technologies. The BAN will have a central unit (MBU) that will serve as the communications gateway to the public GPRS and experimental UMTS networks and it will implement a part of the application functionalities. The generic BAN will allow the simple introduction of new sensors, allowing a high degree of personalization and customization.

A second result will be the development of new m-health services and methodolgies for their trial and evaluation. The new services will allow patients to be continuously monitored by a remote health center.

A third result will be the verification of the suitability of GPRS and UMTS networks for m-health applications.

Different issues will be tested and validated, ranging from security aspects to ease of usage and to quality of service.

Of major importance to the project is the dissemination of the results to a large public. The project results will be presented in expositions, announced in the public media and introduced to consortium customers. It is expected that by the end of the project, the new possibilities offered by the MobiHealth technologies, will be well understood and appreciated by both, the public and commercial companies.

III. PROJECT IMPLEMENTATION

A. Functional Description

The MobiHealth trials will implement simple, but complete services that can be immediately deployed over the UMTS and GPRS networks. The MobiHealth patient/user will be equipped with different interoperating or independent vital constant sensors, ranging from blood pressure and pulse rate to blood glucose and cholesterol sensors, to electrocardiograms and even brain activity sensors, and from different actuators, such as insulin or morphine pumps to pace maker controllers and even electrical muscle stimulation. Audio and video I/O devices may also be incorporated in the BAN, depending on the needs of the application. The vital constant measurements will then be sent to a health broker (which may be a hospital or a medical call center), where specialists will be able to observe the evolution of the patient and intervene when needed. The communication will be based on 2.5 – 3G wirelesss technologies so that the patient/user has complete freedom of movement and can pursue a normal life despite of the need for continuous monitoring. Depending on the patient and the treatment, feeedback might be sent to the sensors/actuators (e.g. instructions to increase the sampling frequency, insulin pump control, pace maker tuning, etc.), or directly to the patient in the form of audible or visual signals. The MobiHealth BAN will handle transmission details and problems such as network disconnection (e.g. when entering a tunnel) and quality of service adaptation due to hand-over situations.

The MobiHealth BAN can also be deployed at the scene of an accident or disaster. The paramedic on the scene of the accident will be equipped with a BAN, with video and audio equipment and will be able to attach and connect BAN sensors to the victim and thus transmit vital constants to the hospital along with visual and audio information. This way, the accident site is transformed into an emergency room where the (telepresent) specialists can intervene from the hospital. The BAN technology, together with the 2.5 – 3G technology, will thus enable virtual trauma teams to be rapidly assembled in response to an emergency situation.

The use of GPRS and UMTS as communication technology is essential due to the need to support a continuous connection to the healthcare center, the high bandwidth required for the transmission of the data (which can easily reach the level of 100 Kbps), the communication costs involved (in GPRS and UMTS, the cost is calculated per Kb, instead of per minute of connection) and the high quality of service required for all health related applications. These are requirements which cannot be met with current GSM technology.
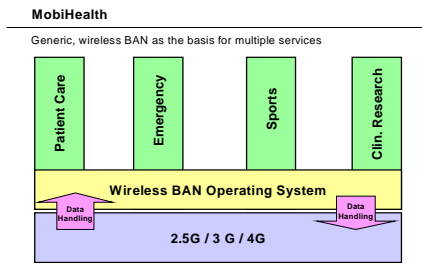
B. Implementation Plan

The MobiHealth Body Area Network (BAN) will be connected to the public GPRS and experimental UMTS networks. The BAN will be based on existing technology, which will be adapted according to the MobiHealth application needs. In a first step, a set of sensors will be extended with wireless intra-BAN communication capabilities. Different options will be evaluated, ranging from Bluetooth [12] to ZigBee [11]. Each sensor sends its signals to the MBU, and actuators receive control signals from the MBU. The MBU operates in different modes. The first mode is a "store mode" (store data for certain periods and send them in regular intervals to the hospital). The second mode is the "process mode" (process the data and provide the patient with some first level information). The third mode is the "stream mode" (establish a permanent connection to the hospital and send the data in a continuous stream).

Mobile Health BAN structure
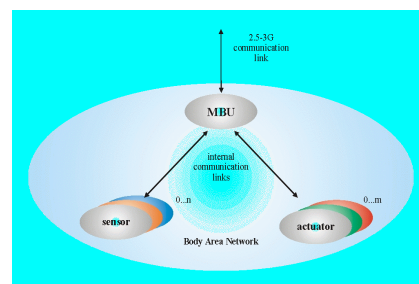
In parallel, depending on the conceptual and functional definitions of services at the beginning of the project, the generic BAN will start to be developed. This will include the programming of the MBU, which will be equipped with GPRS and/or UMTS communication capabilities. Candidate platforms are the Compaq iPAQ and the next generation, fully programmable 3G wireless mobile phone from Ericsson. Depending on the services and applications that will be trialed, either one or both devices will be used in the project. The generic BAN will provide functionality for *plug and play* sensor connectivity, will handle all issues related to security, quality of service control, hand-over, etc.

MobiHealth

Generic, wireless BAN as the basis for multiple services

Patient Care · Emergency · Sports · Clin. Research

Wireless BAN Operating System

Data Handling

2.5G / 3 G / 4G

C. Project Trial Scenarios

As mentioned before, the MobiHealth project will realize and trial a small set of applications, built on top of the generic BAN platform. The choice of the trial applications will be done in the first months of the project, depending on market interest and business potential. The project will set up two general trials, one over GPRS and one over UMTS. Different scenarios with different requirements will be trialed for each communication infrastructure. The trials will involve a sufficiently large number of users, so that credible results can be drawn. For the GPRS trials, the existing publicly available infrastructures will be used for UMTS experimental testbeds.

The trial scenarios will be based on rigorous scientific criteria, so that both, medical and technical results are reliable. A total of four trial sites will be set up in different countries, involving different health centers (The Netherlands, Sweden, Germany, Spain).

There are a few potential trial scenarios. A first scenario concerns "Prevention of exacerbation in chronic patients": here, the main purpose is to evaluate the benefits of distant patient monitoring in a context of a distributed model of care (interaction of hospital and external teams), where it is applied to prevent hospitalisation of chronic disease patients. Potential benefits of distant monitoring must also derive from a global approach, where different conditions are not treated in isolation, but on a holistic basis.

The trial shall be randomised. Candidates to be included are patients admitted to the hospital due to an exacerbation of their chronic condition. They will be stratified according to fragility criteria (e.g. severity of disease, social support). Sample size will be 40 patients (20 in the intervention group, 20 in the control group. The follow-up period will be 6 months. Coordination of interventions across the healthcare system will always be done through the hospital control center. Primary endpoints are: relapses requiring hospital admissions during the follow-up period, relapses requiring new visits to the emergency room during the follow-up and mortality. Secondary endpoints are: improvement in patients' quality-of-life, patients' satisfaction with the program, patients' functional performance, patients' adherence to the treatment, cost analysis and usability and user satisfaction.

A second scenario deals with "Support after early discharge": here, those chronically ill patients are looked at, where there are potential clinical benefits derived from short-lasting, intensive monitoring of vital signs. Those patients leave the hospital under the so-called "early discharge and home hospitalistation programs". These programs were created to partly mitigate the impact of high admission rates in exacerbated chronic patients during the winter season. At the same time, they provide a better recovery environment for the patient. To move a patient from conventional hospitalisation to early discharge and home hospitalisation programs, requires first ensuring clinical safety. Health professionals must be confident that the patients' condition is under control. Though mobile teams can perform regular daily follow-ups, reliable and easy-to-use home monitoring will mean an added value. Study design, intervention structure and endpoints shall be the same as in the first scenario described above, only the follow-up period will be shorter here and only last 6 weeks.

A third scenario is the "Monitoring of home ventilation": end-stage chronic respiratory patients may require non-invasive home ventilation support, because of the existence of hypercapnic respiratory failure. These patients are more fragile and thus more demanding in terms of supervision by health professionals. The risk of exacerbation is further aggravated because of the existence of co-morbid conditions. Home monitoring should be a tool to assess the efficacy of non-invasive home ventilation, to allow detection of abnormal patient-ventilator interactions and allow a remote adjustment of the ventilator setting and to prevent exacerbation in these fragile patients. The trial shall be randomised. Candidates to be included are chronic respiratory patients admitted to hospital for exacerbation of their chronic respiratory condition. Sample size will be 10 patients (5 in the intervention group and 5 in the control group). The follow-up period will be 6 weeks. Study endpoints shall be the same as in the first and second scenarios described above.

A further central point of the MobiHealth project is the assessment and evaluation of the trials. The trial results will be validated 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. This will allow to draw up a business case regarding the potential and profits that a

company can expect from this type of services. 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. The different experiences of using new techniques, feelings of dependence or independence, the empowerment to influence disease-related decisions, all these issues will be explored across all types of trials by means of qualitative interviews and research.

IV. CONCLUSION

MobiHealth represents the convergence of different technologies to enable personalized, mobile health services. On the one hand, wearable devices for communication, vital constants measurement and even fitness applications are today commercially available at low prices. We can find in the market watches and belts to measure pulse, blood pressure and temperature, wearable devices for non-intrusive measurement of blood glucose and even wearable muscle triggering devices for passive fitness exercise. On the other hand, the notion and concepts of Body Area Networks are under development, targeting the problem of relaying signals from the multitude of wearable devices. 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. Furthermore, GPRS networks are available today in most European countries and provide a globally accessible and easy-to-use communication platform. The innovation of MobiHealth lies in one part in the integration of these three 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, and in the other part, in the introduction of a complete and integrated service platform that can be taken up by any Small/Medium Size Enterprise (SME) or service provider wishing to start up a new m-health related service.

The second part of the MobiHealth innovation lies in the actual services that are proposed. Today, 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 [13]. 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. With continuous monitoring, the treating doctor will have more (and more timely) information on the patients' condition and will be able to provide better advice and suggest better treatment.

Finally, MobiHealth innovates by proposing and trialing other new services that can be implemented by SME's based on existing technologies. 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.).

GPRS networks are available in most European countries and different operators are setting up UMTS test sites. A study made by Ericsson Consulting indicates enormous market and business potential for new health services based on wireless communications. Studies for Germany, United Kingdom and France show that the number of individuals suffering from common chronic diseases (diabetes, asthma, stroke, hypertension and coronary artery disease) exceeds 50 million.

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.

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