

Key factors for personal health monitoring and diagnosis devices

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Abstract: The current common goal in medical information technology today is the design and implementation of telemedicine solutions, which provide chronically ill patients with mobile services that enhance their quality of life, and support and optimize their treatment in case of emergency.

Several projects being worked on by FZI and its partners will form a basis for a novel, individual and widespread health monitoring system, which can provide patients with 24h monitoring of their relevant physiological parameters, and therefore optimize their medical treatment and could possibly be life-saving thanks to the enhanced emergency management.

In order to be able to build a successful platform for a wide range of medical applications in practice, key factors have been identified which will be introduced in this paper: micro-technological sensors, which are to be used in mobile applications, modularity, a wireless communication network, local intelligence in the form of a powerful mobile information unit, connection to a global network and a conclusive system design for improving the efficiency of health care-related procedures.

Keywords: health monitoring, mobile computers in medicine, online patient record, wireless sensors

1 Introduction

According to a study performed by Roland Berger Business Consultants in 1997 [Ber97], telemedicine is the most important step in cutting costs and increasing service quality in health care. Up till now, health-telematics have mostly been restricted to communication systems between health professionals. Those systems give doctors in remote locations access to specialists' knowledge.

What health-telematics have not yet been able to do is to actually improve the lives of chronically ill patients. Disabled, elderly and chronically ill people still have to visit their practitioner, which eventually could lead to major difficulties, especially for patients such as these. On the other hand, intelligent mobile health systems can save doctors' time normally spent with those routine checks on chronically ill patients.

A mobile-health (m-health) platform addresses the needs of healthcare professionals and patients alike. Partners from healthcare, telecommunication and device manufacturing industries are joining in an effort to bring medical services to patients at any location.

The European Heart Network states that every year 4 Million people in Europe die from cardiac diseases [EHN]. Many of those lives could be saved if people bearing the risk of sudden cardiac failure could be monitored at all times by a mobile system which can automatically initiate emergency calls.

According to the WHO "Diabetes Mellitus [...] threatens the health of 30 million people" in the WHO European region [Eur]. To enhance the quality of treatment for those people, it is vital to enhance the quality of their monitoring first, so that instructions for nutrition and treatment can be optimised and the patient might be informed faster.

Using this as a background, the department of Medical Information Technology (MIT) at the Forschungszentrum Informatik (FZI) (Information Technology Research Center) is developing a generic modular platform for providing mobile medical services for diagnosis, monitoring and emergency rescue. It includes the recording and, to a great extent, automatic analysis of vital patient parameters in the patient's familiar surroundings. The patient's doctor can have efficient access to expert opinions on certain diseases, the patient can get optimized therapy and the certainty of an automatic reaction in case of emergency. Additionally health care and rescue personnel will have access to information about the status and medical history of the patient, which is necessary for optimal treatment.

2 The Current Situation in Health Care

One problem of today's health care is the insufficient availability of data concerning the status and medical history of the patient, both to the medical personnel treating the patient, as well as to the patient himself. For one thing, decisive vital signs can't be measured often enough, since the patient isn't constantly in the doctor's practice, which would involve a great time and financial investment. These parameters, however, could often give indications about the current status of chronic illnesses and are necessary for optimizing the patient's treatment within short intervals of time. Some measurements, such as blood pressure or glucose, can be measured by the patient himself several times a day, but the optimal interpretation of these measurements and the therapy to go with it requires expert knowledge about the current state of medical research.

On the other hand, there's the technical and legal problem of making medical information available on a network. When the patient changes doctors or in case of an emergency, no data is available, which can lead to repeated tests, delays in therapy, or even result in the patient receiving the wrong treatment. Current developments involve networking different hospital wards with each other, networking individual practices, and storing basic data on a chip card that the patient carries around with him. All these approaches for information exchange can be compared to small islands, however, and don't correspond to the global networking of information systems in other areas.

Using partially mobile medical diagnosis and monitoring systems, which access a central data base, which is also partially accessible by doctors and experts, can solve this problem.

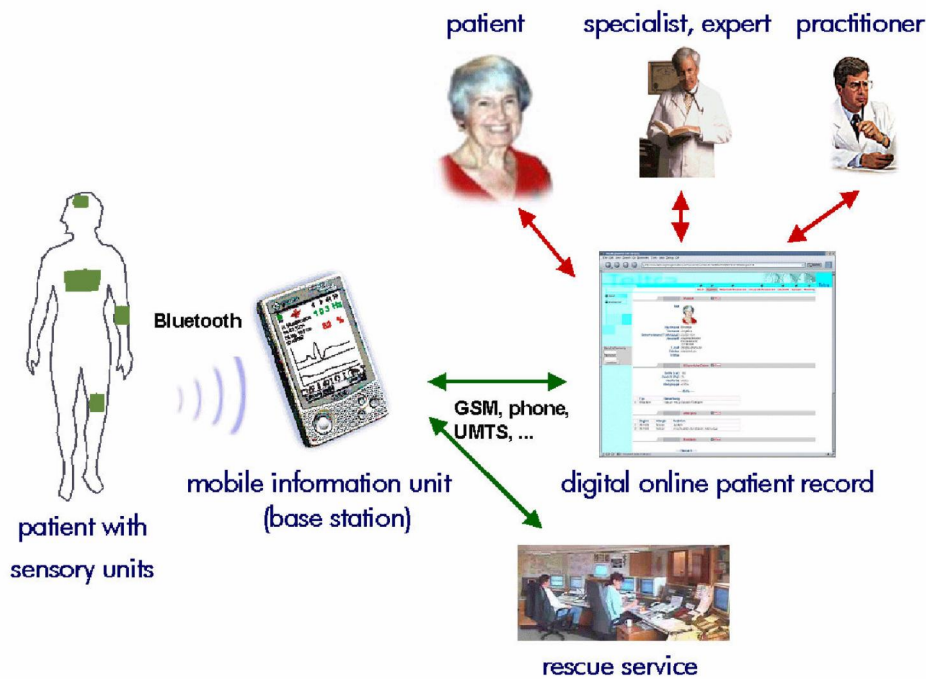


Figure 1: Personal mobile health monitoring platform

3 System Design of a generic personal mobile health monitor

The platform for personal mobile diagnosis and monitoring systems, currently developed at FZI (Fig. 1), consists of two core elements connected to each other according to the client/server principle: a mobile information unit - such as a PDA - which represents the interface to the patient and which measures the vital parameters, and an internet-based patient record, acting as the central information interface. The owner of all stored information is the patient, which can release certain partitions of his chart to his doctors or other persons. One "side effect" of this is that the patient is automatically more intensively informed of his health status, giving him a lot more responsibility in keeping up with his treatment.

The system provides the following possible applications and services:

- Recording of vital parameters measured by sensor units. These have a wireless connection to the mobile information unit.
- Manual input of parameters and patient actions, e.g. to document daily food intake and personnel exercise.
- Standardized storage of data "on the scene" and transmission into the digital online

patient record, either for online monitoring or for documentation.

- Possibility for locating a patient via GPS in an emergency situation.
- Automatic analysis of recorded parameters and a context-sensitive reaction, such as giving patient instructions or initiating an emergency call.
- Access to information about the medical history of a patient from the digital patient chart over the mobile information unit, or any other web terminal after getting patient authorization.
- Patient support in day-to-day living, e.g. through diet advice or helping the patient find the next doctor, pharmacy, etc. in an unfamiliar town.
- Automatic translation of the patient chart for doctors in foreign countries.
- Access to some patient information by experts who support the patient's doctor in the therapy of certain diseases.

4 Sensors and Wireless Connections

A long-term applicable sensor for patient monitoring makes high demands on robustness, reliability and "patient friendliness", which, for example, can't be reached by the classical ECG monitoring devices. The patient's mobility must not be limited. The sensor system must be able to handle movements and other daily influences, and if used over a long period of time, must not cause irritation, infection or other skin damage. It is therefore decisive that the electrodes are not applied with glue, and they should be able to be integrated in normal clothing or in belts that don't limit the patient's movement. The sensor units on the body should be able to communicate without wires, which makes micro-amplifiers, A/D converters, radio modules and processors for communication control necessary.

From the experience gained from previous work, it has been found that a communication protocol oriented toward medical technology can be based on existing wireless network standards [MSS01]. This solution has the big advantage that no cost intensive HF module has to be developed.

Another advantage of Bluetooth is the European-wide, or even worldwide usability of frequencies compared to commercially available modules at 403.55 MHz. Also very important is the already integrated protocol on commercial chips as well as the availability of the respective software for portable computers, which covers the lower 4 layers of the OSI layer model for information networks (see Figure 2). An error-correcting serial interface or a TCP/IP connection is offered with a bandwidth, depending on the disturbance level on the channel, up to 721 kbit/s in asynchronous mode. In addition, features such as authentication of the user, coding, channel selection, roaming and multi-point connections are offered, which can be accessed by higher layers. Bluetooth especially distinguishes itself through its ad-hoc networking capabilities compared to other wireless transmission methods.

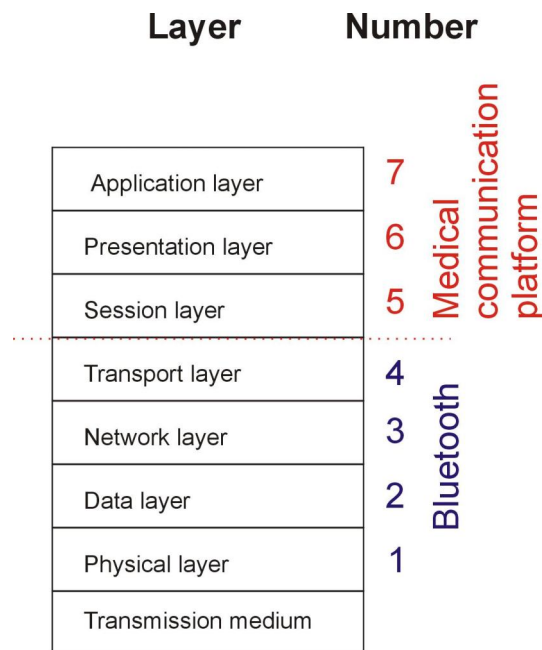


Figure 2: ISO/OSI layers for data networks

The goal of some projects at FZI is the development and management of data connections between sensors and base stations. In these projects layers 5 and 6 will be designed for different medical applications, to make data available to the application layer.

5 Base Station (Mobile Information Unit)

One central element of the mobile diagnosis and monitoring platform is a mobile computer which serves as a local information interface and patient interface. It takes on the tasks of recording and storing vital parameters, and allows data to be entered manually. The application of ECG and oxygen saturation monitoring is shown in Fig. 3. Depending on the application, the data can be analyzed immediately to determine the patient's status and, if needed, certain actions can be initiated. The base station also has an interface to the digital patient chart, which was realized using SOAP [SOA] and can be based on different communication technologies (GSM, UMTS, analog modem, ISDN, ...).

A user-friendly user interface is the prerequisite for the acceptance of this system in practice. Especially considering the short development times, it makes sense to use PDAs, e.g. with the Windows CE operating system. It is now being checked in several projects whether the requirements of the medical application regarding robustness and real-time capability can be complied with.



Figure 3: Design study: mobile information unit

A major focus is also the management of the overall mobile system and the hierarchical possibility for process administration. Four levels influence the system, which the mobile computing unit has to manage:

- The operator on the scene, possibly the patient himself
- Devices near the body (sensors, therapy devices), which change their operating states
- The base station itself, which could possibly have analysis functions in the application layer and which can, e.g. recognize a critical state or request data from additional sensors
- An external level – e.g. the doctor or health care service which monitors the patient and accesses the base station over the network connection

The error-free interplay of all these levels must be guaranteed, as well as the compliance with the corresponding authorization when system states are changed.

6 Central Information Storage

Regarding this, a digital, XML-based online patient chart was developed at FZI (<http://www.avetana.de/>) [GFS01]. The use of XML-Schema for the validation of data will

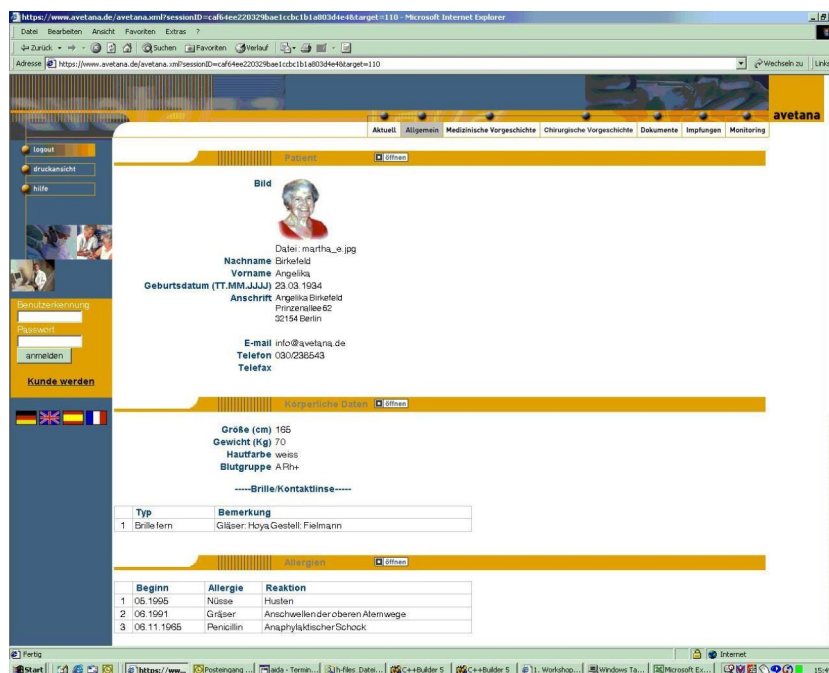


Figure 4: Online patient record with basic data, contact addresses and medical history

make the service expandable for future use and is easily adaptable by third-party module providers. The patient user is able to easily collect his medical data over his lifetime and can use his medical history for documentation. Besides standardized information for special types of illness, any other kinds of documents can also be included in the chart, such as x-rays, lab results, or doctor reports.

In this way, all important information concerning the medical history can be stored. In the case of a medical emergency, the doctor can have direct access to the chart using the access code on the personal card. This way, the parameter values recorded at home, the diagnosis and therapy decision (by specialist on disease/illness in question) and the therapy management (practitioner) can be decoupled, which will allow health care to become a lot more efficient in the future.

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