@HOME: A modular telemedicine system

Sachpazidis I
isachpaz@igd.fhg.de
Germany

Abstract: In that paper we will describe a system for remotely monitoring of patients at home from the doctors at the hospital. In general, the @Home [AtH02] system can measure, collect, analyze and record health care data at a patient's home and then subsequently send these data to the hospital using the global system for mobile communications (GSM) or PSTN telephone line. The paper is organized as follows: In section 1, a brief introduction of the @home project is exposed. In section 2, the overall architecture of the system is shown. Finally, the paper concludes in section 3, stating the clinical trials and the benefits of the project.

Keywords: Home Care, Telemedicine, ECG, Blood Pressure, Oxygen Saturation, Ambulatory Sensors, Medication Dispenser, GSM, Bluetooth, DECT.

1 Introduction

The @Home system is able remotely to surveillance patient's vital parameters, like ECG, blood pressure and oxygen saturation level. The patient is equipped with ambulatory sensors, which acquire health care data. Moreover, the data is transmitted to a local PC station located at patient's home via Bluetooth [Blu02] or DECT [DEC02] communication link. On patient's local PC station, particular software for analysis of the acquired data is used. The doctor is able to set the thresholds values, related to ECG, blood pressure and oxygen saturation, on the patient's PC. The analysis software produces alerts, according to the doctors' thresholds table. Moreover, in case of any abnormality the findings and the collected vital data are immediately transmitted to the clinic through GSM [GSM02] (wireless communication) for further analysis. The whole system works independently and the patient doesn't react with the system. For instance, the patient doesn't connect any ambulatory sensor to the local PC at the end of the day for uploading the recorded data to the clinic's server as described in [YZ00, CJH00, VC01]. Additionally, the patient's PC is programmed to identify the sensors and to retrieve the readings immediately, when they are accessible.

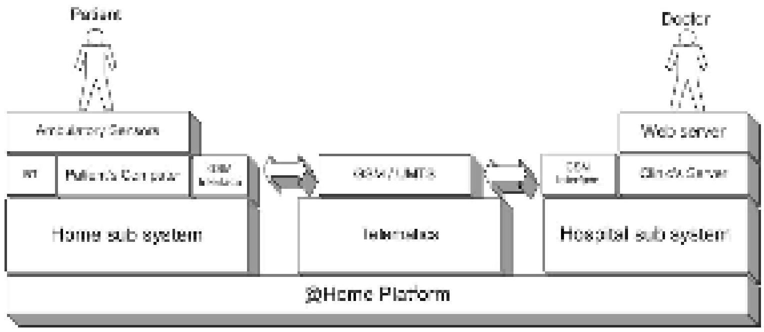

Figure 1: System Architecture

2 System Architecture

In that section we will describe the system architecture of @Home. In general, a telemonitoring system makes use of information technologies to monitor a patient in a remote location [PRF01, LMC01].

The @Home system can be roughly cut into three main parts:

Home sub system, which is responsible for the acquisition, collection, analysis and transmission of the patient's vital signs, like SpO2, BP, ECG.

Hospital sub system, which is responsible for further data analysis, data evaluation, archiving and data representation.

Telematics sub system. It's the communication system, which transmits the recorded data from the sensors to the clinic's server.

2.1 Home sub system

The home sub system is physically located at patients' home, and it's responsible for the acquisition, collection, analysis and transmission of the patient's vital signs.

The home sub system is composed of two modules:

Ambulatory sensors, which are attached on patient's body.

Patient's PC is a common personal computer (running Windows platform), which communicates with the sensor over a Bluetooth connection.

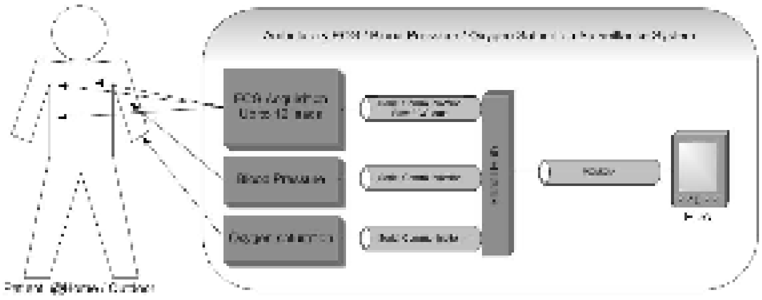

Figure 2: Sensors' communication schema

2.1.1 Ambulatory sensors

For the needs of the @home's clinical trials, four types of sensors [CB01] are going to be used:

- Oxygen saturation
- Blood pressure
- ECG up to 12 leads
- Medication Dispenser

The sensors are wearable and capable of transmitting continuous information to the patient's computer. Furthermore, all the sensors are portable, meaning that the patient is able to use them outdoors as well. Nowadays, none of the sensors, which are available in the market, come with an embedded wireless connection like Bluetooth or DECT. Therefore, we have interfaced the sensors to a Pocket PC, iPAQ, which is equipped with a Bluetooth card. In the following figure 2, the communication schema is shown. As we mentioned above, the communication between the medical sensors and the patient's computer is established via a short-range wireless communication technology. The use of Bluetooth technology is the most appropriate approach. Bluetooth provides short-range RF transmission standard for small, low-cost, short-range radio links between portable or desktop devices. The technology eliminates the confusion of cables, connectors and protocols confounding communications between today's high tech products. The Bluetooth technology has been designed for ease of use, simultaneous voice and data and multi-point communications. It supports a range of 10 meters, which can be increased up to 100 meters with the use of an amplifier. Under this perspective the Bluetooth technology is the answer to the wireless data link between the medical sensors and the patient's computer.

Medication dispenser Electronic monitoring systems present a new approach to the assessment of compliance. Evidence from its application to medical disorders suggests that it is the best available measure of compliance. Electronic medication dispensers record

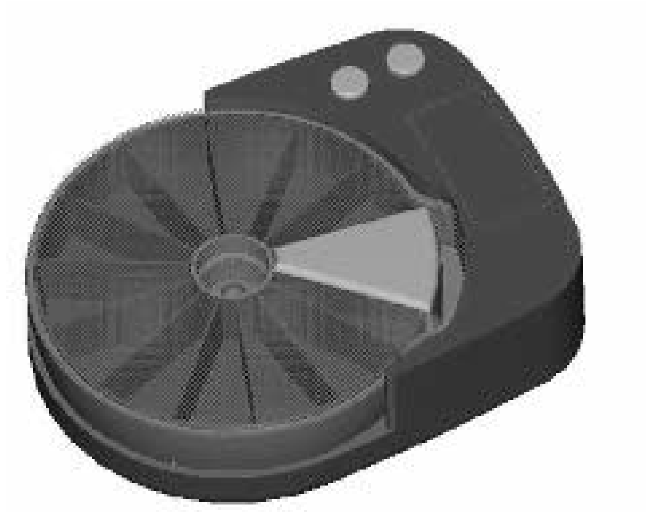

Figure 3: GSM enabled Medication Dispenser

the date and time the patient accessed the dispenser. As previous studies have shown that compliance is enhanced by regular reinforcement, the recording can be used either to trigger early contact with the patient or to be reviewed with the patient at their pre-arranged appointments where dosing irregularities can be discussed. In figure 4, the communication diagram between the medication dispenser and the clinic's central server is depicted. The medication dispenser is programmed periodically to communicate with the central server and upload the readings. The uploaded data, which is the time of the dispensed pills and the type of pills, are been evaluated by the monitoring module, which runs on the central server on the clinic's side. The monitoring module produces alerts according to the doctor's patterns alert table. Finally, the alerts are sent to the doctor via SMS/Email in case of emergency or the doctor will be aware of the non-compliance of the patient when he/she logs into the @home system and searches out the reports.

2.1.2 Patient's personal computer

This component is an intermediate station before the data are transmitted to the Central Server in the hospital. The Patients personal computer or remote controller (RC) is a desktop PC or a laptop, which is positioned at some point in the patient's home. It provides the home end of the communication link between the clinic and the patient's home. Its functionalities are the following:

- It receives all recordings transmitted from the medical sensors and transmits them to the clinic's Central System Server. The transmission will be realized via wireless infrastructure. The Remote Controller establishes a TCP/IP connection over GSM/GRPS and conveys the data to the Clinic's Central Server (CCS).

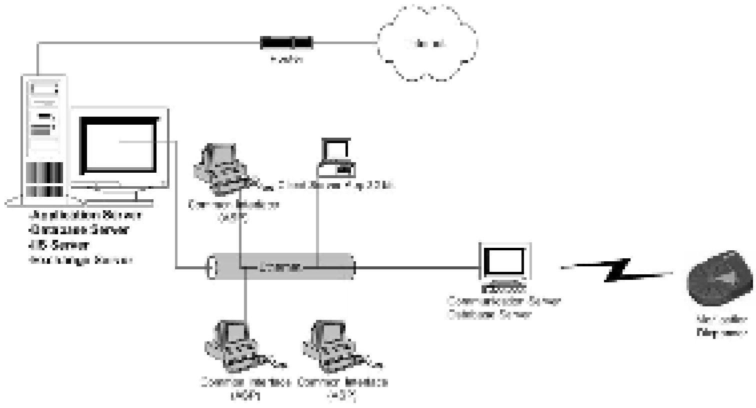

Figure 4: Medication Dispenser Communication

- It controls all remote sensors connected to it. It's responsible for the proper functionality and checks the status of each sensor, identifies communicating sensors, downloading the readings, uploading schedules to the sensors.
- Additionally, the Remote Controller enables the patient and his family members to monitor his progress using an appropriate user interface. That interface offers limited functionality compared to the Clinic User Interface.

2.2 Hospital sub system

That sub system consists of the succeeding sub parts:

- Clinic's Central Server (CCS)
- Health record system / Database
- Clinic user interface (CUI)

2.2.1 Clinic's Central Server

That component has a twofold purpose:

- to intervene between the presentation and data layers of the clinic architecture
- to be the communication channel between the clinic and the patient's home

At the clinic, the Monitoring module is responsible for monitoring the patient's progress. It encapsulates the rules for manipulating the @HOME database. Access to the database is achieved either by using a LAN connection (if the database and the Central server are physically located inside the same hospital) or the Internet (if the database and the Central server are physically located in different premises). Other rules incorporated into the Monitoring module are related to the monitoring of the patient's progress. For each disease, there is a parametric model of the typical patient. These parameters have values specific to each patient's case and are provided by the sensors on the patient. For each measurement the doctor has the option of setting thresholds for actions. For instance, if the oxygen saturation is less than 85% then an alarm is produced.

The Central System Server is also part of the telematics infrastructure of the whole system. The infrastructure allows the communication of information between the patient's home and the clinic and vice versa. For the clinic-to-home flow of information, the central server communicates with the patient's personal computer, known as @Home Remote Controller.

2.2.2 Health Record system / Database

Each clinic has its own electronic patient health records. However, the health records vary from clinic to clinic. Each hospital has its own database in terms of information stored and design. To view these databases in a uniform way, intermediate software is included in the @Home architecture. That software component encapsulates @HOME rules for manipulating the heterogeneous databases and is included in the Business layer corresponding to the Central System Server module.

Existing hospital databases are only used for importing information to the @HOME database. That database includes the following data:

- List of personal details fields. Most of this information is included in the hospital database.
- Current patient status, thresholds and alerts. The doctor responsible for the patient sets thresholds that will trigger alerts when exceeded. These thresholds correspond to limits on indices, such as blood pressure, measured by the patient sensors and transmitted electronically to the clinic where they are stored.
- Medication prescription details for each patient.
- For each patient, name of responsible medical officer and the primary and back-up nurse. Also, their address and contact numbers. This association is important especially when an alert is raised and the system has to contact any of these professionals.

2.2.3 Clinic User Interface

Each member of staff in the clinic has access to the @HOME system through the clinic user interface. The user interface is a web-based application; a web browser can provide the front end. The assumption is that the users (doctors & nurses) must have basic computer skills, similar to those of any untrained home user. The user interface is independent

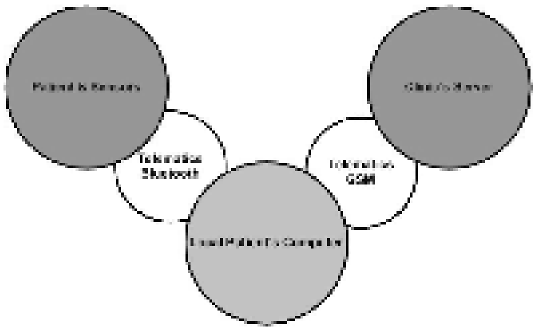

Figure 5: Connectivity among modules

by any operating system. It can be loaded under any operating system (Windows, Unix, MacOS) with the help of a web browser.

The user interface accesses the Central System Server module and provides the following functionality:

- Login to the system. The user is authenticated, authorized and matched to pre-defined user rights. The user interface is adjusted to these rights to offer respective functionalities. For instance, only the doctors and nurses responsible for a particular patient have the authority to de-activate any pending alert.
- Login to the @HOME database to find which patient corresponds to a transmitted alert. Then the user will de-activate the alert.
- Presentation of various reports. The doctor has the option of selecting what kind of document to see, such as per patient, per category of patients and so forth.
- Front-end to the monitoring module of the Central System Server component. This provides functions for continuous and automatic monitoring of the patient's progress. For example, an authorized user can define or modify the parametric models for each disease adjusted to each patient case.

2.3 Telematics Infrastructure

The *Telematics infrastructure* (GSM and Bluetooth interface in figure 1), provides the communication layer among sensors, patient's PC and the clinic's server, as shown in figure 5.

3 Clinical Trials & Benefits

@Home is going to be addressed to patient groups, which need:

Vital Parameters Monitoring. An example is that of patients who have been subjected to surgery. Doctors argue that good psychological spirits can account for dramatic improvements in the patient's health, after serious illness and traumatic treatment. For this reason, moving the patient at home during the final, less critical stages of the recovery, where the patient stays in-house only for monitoring purposes, is expected to speed up healing, more so, considering that by this time the patient has fully regained his consciousness and wishes "to return home" and normal life.

Medication Compliance. This category includes all chronically ill patients, who, as part of their daily routine, have to conform to their prescribed therapy, which typically only involves the intake of medication. Chronic disorders may be physical (such as diabetes) to psychological (such as schizophrenia). In either case, low rates of compliance with prescribe medication regimes pose a major challenge to the effective management of most chronic disorders.

Summarizing the benefits of @home, we could highlight the followings:

Lower relapse rate for chronically ill patients. With the @Home system, doctors will be capable to intervene when chronically ill patients do not conform. Of course, patients cannot be obliged to follow prescribed treatment at home. Nevertheless, the doctors will initiate interviews with the patients non-conforming to their treatment and this is expected to bring the majority of patients back on course. Establishing long-term continuation of treatment is expected to considerably reduce the crisis relapse rate for chronically ill people.

Shorter hospitalisation period for patients. Physically ill patients treated in a hospital will be able to return home sooner. Their doctors will be able to monitor their progress remotely in real time by using the @HOME infrastructure.

Lower cost for patient treatment. Lower treatment costs will result from shorter hospitalisation periods as well as the reduction of the corresponding cost.

Quality of life for the patient. The use of the @Home system will result to less frequent / shorter hospitalisations of patients. This is certainly a direct measurement of quality of life improvement.

Health information for the patient. @HOME will feature an Internet-based service where patients and their carers will be able to monitor their progress and obtain useful advice and information for their recovery.

Increased capacity for hospitals. A hospital that makes good use of @HOME has the potential to treat more patients. A patient dispatched earlier leaves an empty bed, which can be occupied by another patient. This assumes a very busy clinic, which is often the case with incidents, which require a long recovery period, where @HOME would be needed the most.

Increased income for hospitals. The potential of increased income is evident from the potential of increased capacity.

Bibliography

[AtH02] @Home web page. http://www.at-home-medic.net, 2002.

[Blu02] Bluetooth SIG. http://www.bluetooth.org, 2002.

[CB01] J Carr and J Brown. *Introduction to Biomedical Equipment Technology*. Prentice-Hall Pearson, 4. edition, 2001.

[DEC02] DECT. http://www.dectweb.com/dectforum//publicdocs/TechnicalDocument.PDF, 2002.

[CJH00] M del Carmen Raola, D Jimenez, I Hernandez, A Bas, R Montero, and R Gonzalez. Design and Evaluation of a Long Term ECG Monitoring System. In *Proceedings of the 22nd Annual International Conference of the IEEE*, volume 2, pages 934–937. Engineering in Medicine and Biology Society, 2000.

[GSM02] GSM. http://www.gsmworld.com/index.shtml, 2002.

[LMC01] NH Lovell, F Magrabi, BG Celler, and H Huynh, K.and Garsden. Web-based acquisition, storage, and retrieval of biomedical signals. *IEEE Engineering in Medicine and Biology Magazine*, 20(3):38–44, May-June 2001.

[PRF01] JK Pollard, S Rohman, and ME Fry. A Web-based mobile medical monitoring system. In *International Workshop on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications*, pages 32–35, 2001.

[VC01] S Vasudevan and KJ Cleetus. Low Cost Telemedicine for Home Health Care. In *Tenth IEEE International Workshops on Enabling Technologies: Infrastructure for Collaborative Enterprises (WET ICE 2001)*, pages 39–40, 2001.

[YZ00] Zou Yongning and Guo Zhenyu. A palm pilot based Pocket ECG Recorder. In *IEEE EMBS International Conference on Information Technology Applications in Biomedicine*, pages 110–112, 2000.