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# Experiences from Development of Home Health Care Applications based on Emerging Java Technology

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**Abstract**

*Home health care is an expanding area within the health care system. The idea of moving parts of the health care process from expensive specialised hospital care to primary health care and home health care might be attractive in a cost perspective. The introduction of home health care applications must be based on a rigorous analysis of necessary requirements to secure a safe and reliable health care. This article reports early experiences from the development of a home health care application based on emerging Java technologies such as the OSGi platform. A pilot application for follow-up of diabetes patients is presented and discussed in relation to a list of general requirements on home health care applications.*

***Keywords:***

Home health care, diabetes patients, requirements, monitoring, Java technology

## Introduction

Support for advanced home health care is on the agenda of the health care system. Home health care is although a somewhat unclear concept. Depending on the context, home health care can mean everything from a few visits by health care professionals in the home (basic home health care), to care which intends to fully replace hospital care (advanced home health care) [1]. In this article, we broaden the perspective of home health care to ambulatory (non-institutional) health care, where parts of the care process take place in the home with support from a hospital or a primary health care centre. A basic assumption in the concept of home health care in this paper, is the existence of a minimal level of infrastructure in terms of e.g. electricity and telephone networks.

Quality, trust and economy are key issues in the development of home-based health care [2]. The Swedish Council on Technology Assessment in Health Care has performed a broad overview of advanced home health care. Evidence regarding outcome measures performed in accordance with the Cochrane methodology was based on detailed analysis of 95 scientific highly relevant articles. It was found that patients and relatives are more satisfied with home-based, compared with hospital-based, health care in the domains of palliative care and care of children. For other domains within advanced home health care and home rehabilitation, no differences in terms of satisfaction or cost can yet be stated.

In a regional analysis of the care process for elderly [3], it was found that elderly are sometimes hospitalised without medical reason, that elderly generally experience transfer between wards negatively, and that health care units outside the hospital, e.g. responsible for caring and rehabilitation, are diverse and without clear responsibilities. In the same report [3], the stated goals for the care process for elderly are: reduction of unnecessary hospital episodes (e.g. due to social needs instead of medical needs), increased co-operation between organisational levels and units responsible for care planing, and an increased involvement of patients in the planing and decision making.

The development of safe and easy to use methods and techniques supporting advanced home health care is a major challenge for the medical informatics community. The objective of this article is to report our early experiences from development of a home health care application based on emerging Java technologies such as the Open Services Gateway initiative (OSGi) and Java 2 Micro edition [4-5]. A pilot application for follow-up of diabetes patients will be presented and discussed in relation to a list of general and application specific requirements for home health care applications.

## Requirements

In our work we have focused on the monitoring of patients in the home. Different technologies can be used to monitor the patient's status. We define "patient monitoring in the home" in the following way: from patients and caregivers having remote contact via e.g. ordinary or video telephony, to patients carrying body sensors measuring physiological parameters, which are sent continuously or intermittently to a clinic. These situations and technologies have been discussed with professional caregivers and IT organisations in Östergötland county council in Sweden.

There are certain differences between monitoring an in-hospital patient and a patient in the home. One such difference concerns the infrastructure (measuring instruments, computer networks, servers, etc.). In a hospital, secure Intranets, and firmly tested and reliable instruments are used. The hospital has also taken some measures against different devices interfering with, and disturbing each other. In the home, on the contrary, insecure computer networks (mostly Internet) have to be used. Moreover, equipment, firmly tested at the hospital, has to be re-tested and adapted in the home. Also, in the home environment, disturbing and interfering equipment cannot be controlled as in the hospital.

Monitoring medical or physiological parameters in the home and sending data to remote information systems put requirements on security, responsibility, integrity, mobility, and ease of use. There is also a need for event monitoring including data reduction and data-driven alarms. Besides these requirements there are also the aspects of cost and quality of care, which are both very important, these issues are however not discussed in this paper.

**Security**

The Swedish project SITHS (Secure IT within Health Care) [6] was a collaboration between four county councils with Spri [7] as co-ordinator. The objective of the project was to develop models and methods for basic security functions required when using IT-support for the health care. These basic functions can be summarised as:

- Control of given identity; *authentication*
- Establishment of access rights; *authority allocation*
- Protection of information against inappropriate insight; *secrecy or confidentiality*
- Protection of information against undesired change, influence or insight; *integrity*
- Protection against afterward denial of sender or receiver of information concerning action or knowledge about action; *non-repudiation*
- Functions for *traceability*: the possibility to trace actions and events to a certain user.

According to SITHS, realising these basic functions will include the use of "smartcards", encryption, and a Public Key Infrastructure (PKI); only solutions with private keys stored in secure hardware tokens, such as smartcards, fulfil the requirements given by the Swedish health care organisation.

Besides the necessity to meet all the general requirements in the home situation there are also requirements on the patient's home, the patient himself, and the other members of the household. Aspects to consider are e.g. if the patient, or family caregiver, can handle the measuring instruments in a safe way. If not, education might be considered.

**Responsibility and integrity**

Bringing in new technologies in the health care may change the responsibility areas for certain groups of professionals, and before a new technology is introduced, it is of outmost importance to decide the roles and responsibilities within all organisational levels. This is also necessary in the home health care situation [8].

In home health care, as in all health care, one should strive for a balance between the patient's and the professional caregiver's responsibility and integrity areas [9]. Giving care in the home means that the patient may influence both *where* and *when* the care shall be given (*where* could e.g. be the choice of room in the home, and *when* can e.g. depend on the patient's, and family's, other activities). Sometimes also the family members or friends (primary caregivers) take part in, and influence the patient's care [1, 10-11]. Patients, who become more involved in monitoring their conditions and assume more control over their own care, feel empowered, and their quality of life and outcomes improve [12]. The possibility, though, for a patient to partly control and influence his own care, can in some cases jeopardise the professional caregiver's demands on the working environment [9].

**Mobility**

In the case of monitoring physiological parameters in the home one ought to consider the need for mobility. Decisive of the choice of technology can be the patient's degree of mobility and the kind of monitoring to be performed. Patients may be more or less mobile - from totally immobile/bedridden to fully mobile - and therefore the choice of monitoring equipment has to be flexible enough to fit different situations and patients. Possible wireless techniques can be radio communication, for example Bluetooth, and infrared (IR) techniques. Mobile equipment does not necessarily mean wireless equipment; parts of the measuring instrument can in some cases be carried around, in other cases the measurements are intermittent rather than continuous, meaning that the patient can move around freely between the measuring sessions. It is necessary to secure that the different devices are identified (authentication) and sending to each other and not elsewhere either the choice is wireless or wired communication. Since no technique is absolutely reliable and secure one must consider the risk of disturbances, interference, or, in the worst case, a breakdown in transmission.

**Ease of use regarding technical equipment**

The health care professionals are not primarily technicians, which is a good reason to strive for ease of use regarding technical equipment in home health care. Another reason is that the patient and primary caregivers (with sometimes no or little medical and technical training) often are involved in the care. According to both Strang and Arras [1, 8], the introduction of new technologies in the home of a very ill patient can be scaring for both the patient and family, especially if they are not offered adequate support (or education) for the care, and management of the equipment. If, on the other hand, the care is delivered by e.g. a hospital-based home care team, led by a physician, which can be reached in a short time 24-hours a day, the patient's (and family's) feeling of safety and security increases.

Ease of use regarding technical equipment can mean using "plug and play" devices, and easy to use interfaces, etc.

### Event monitoring

To achieve intelligent monitoring with alarms based on multi-dimensional input parameters (different physiological parameters, conditional parameters such as age, gender, diagnosis, etc.) there is a need for integrated decision support. An example of functionality, which should be handled by the decision support module, is choice of data monitoring profiles such as sampling frequency, set of alarm conditions, and priority of alerts and reminders. There is also a need to implement strategies for effective data reduction. A key characteristic of this kind of decision support is the data-driven mode [13], meaning that parts of the knowledge base is executed due to triggering from incoming events, such as changes in input data or installation of new input parameters.

## Choice of technology

What we need in order to support a constantly changing home health care environment is not a large monolithic application with many functions, but a flexible toolkit that can be configured in many ways.

We have chosen to develop this toolkit using Java technology, ranging from micro- to enterprise editions [5, 14]. This allows us to reuse components in different platforms; Java-enabled telephones, PDAs, home gateways running OSGi [4], clients and servers running Linux, Mac, Windows, Solaris, etc.

## Pilot application

This section describes a pilot application for diabetes patients. The application is still in a laboratory phase [15] and has not yet been evaluated in clinical use, but key characteristics of the application are presented and later discussed in relation to the list of requirements above.

### Purpose and reason for choice

Diabetes patients are usually treated at home and are often themselves responsible for parts of their treatment and documentation. The main purpose of the pilot application is to help the patient to understand his own diabetes [16]. Since the individual variations can be very large it is not possible to just follow a standard procedure, for example with insulin dosage, for everybody. An individual plan needs to be made by the patient and health care professional together. New patients and those who are changing their individual plan need to measure their blood glucose levels several times a day during a few weeks.

### Current devices and systems

There are several inexpensive, small, easy to use, personal glucose meters available on the market, which have capabilities of communicating with computers. Many of these glucose meters can store about 100 time-stamped measurements and later export the data, via standard serial interface, to a computer. These values can then be viewed in diagrams and tables on the computer by the patient and/or health care professional.

Every brand of glucose meter has its own software, incompatible with others, which for example means that a diabetes clinic might have to use more than three different programs for the same task depending on which meter the patient is using.

### Extended solutions

In the system development we use the common standard equipment described above and thereby do not introduce any entirely new medical technology. Some extra equipment is introduced in order to facilitate communication and documentation. We view the data collection, presentation, and communication between the patient and professional caregiver, as a complete system not limited to a glucose meter and a PC-program.

Glucose measurements are time-stamped by the glucose meter and kept in its memory. We extract the data from the meter to any device with serial port and a Java Virtual Machine (a PC in the first implementation). The data extraction component is built in a modular way, so that it can handle meters from several vendors, and is also easy to extend for new meters in the future.

Just a set of glucose measurements does not give a complete picture of the patient's diabetes. Other useful data include meals, insulin intake, extensive physical work, infections, fever, etc. To begin with, we use a combination of PC-applications and a simple WAP-based mobile telephone interface to enter all data into the system. We might also add SMS-based input. In the next development stage, input to the system can also come from PDAs, web interfaces, home gateways using OSGi, standard voice telephone calls, Java-enabled telephones and pagers, and other devices. Networks, especially the Internet, are extensively used.

The intention of the first implementation is to send data to a single health care provider, for example a diabetes clinic. In the next development stage we plan for the possibility to let several health care providers get access to the data and take part in the care of the patient.

Further, we design the system in a way that puts the patient in control of exactly which data he chooses to send to the health care professionals, and which way data should be sent over the network. This way, the patient will be free to choose the most convenient and familiar device for data input combined with the most trusted and convenient ways to send the data.

Our reason for giving the patient control and, for example, for him to have the possibility to keep certain data private, is that this can preserve the personal integrity for the patient. It is also a way of sharing responsibilities between the patient and the health care professionals.

Finally, to meet the security requirements in our pilot application, we intend to use an "iButton" (smartcard) solution [17] to identify the devices where it is useful and possible. In the first phase though, the security will primarily be based on a standard username/password solution.

## Discussion

The presented application for the follow-up of diabetes patients has several interesting characteristics in relation to the list of requirements presented above. The application monitors (not continuously, but intermittently) a physiologic parameter (glucose) in combination with activities and events during daily living (meals, exercise, insulin intake, etc.), and is based on integration of several devices such as glucose meters, a PC or home gateway, mobile telephone, and a server with a database application. It is also possible to get a balance between the patient's and the professional caregiver's responsibility and integrity areas.

Using a component-based and networked system introduces problems regarding security, synchronisation, and network reliability and latency.

### Distributed data and synchronisation

A major issue in distributed systems is how to keep data in all parts updated and synchronised. A system that allows data to be entered and/or changed in many ways, by different methods and clients, might result in conflicting entries/changes that need to be resolved upon synchronisation of the different parts. For example, a diabetes patient makes a telephone call to the system in order to record that he is eating lunch, and later he wants to add extra information about the lunch meal, this time using a PDA that is not permanently connected to the database. When the PDA afterwards is synchronised with the system, the latter has to detect that the event has been reported twice and resolve possible conflicts.

***Standardised synchronisation procedure*** - Each part of the system can have a proprietary way of storing data, but all parts agree on a standardised way to exchange data when anything is added, deleted or updated.

***Distributed database systems*** - By using a distributed database solution we can hand over the synchronisation problem to a commercial database management system. The application's different parts will just see the database as a local database, and issue normal queries and updates to it.

***Strict client/server*** - Collects all data at the server and keeps no information in the clients.

The first two methods keep data transfer to a minimum; only changes are sent over the network, and it is possible to work with, and modify local data, even if we do not have constant network access. The changes are accumulated and sent when we have access to the network. Working with local data is a faster method than waiting for data from the network.

Though the client/server method keeps storage to a minimum it requires network communication, which can be slow, and constant access to the server.

It is important that changes are logged, especially conflict resolutions, so that they can be rolled back (undone) in case we run into problems like security violations and broken clients sending garbage.

### Questions and remaining work

Ease of use is an important feature for user acceptance. Apart from the necessary handling of the glucose meters, we want the rest of the self-monitoring system to be as easy to use as possible. The patient should not have to sit down every evening trying to remember what happened during the day. Instead it should be possible to enter things in an easy way when they happen using portable equipment. This is why we introduce different mobile devices as interface for the daily living activities in the first prototype.

In the first version of the system, no specific decision support will be implemented. Collste et al. has reported on ethical aspects on the use of decision support for diabetes care [18]. Based on these experiences, further work will be done with respect to decision support for both health care givers and patients.

Future plans for the diabetes application include reliability testing and evaluation of the system components in a real setting with a group of patients and caregivers. Functionality could be improved, e.g. with respect to integration of decision support modules. Tests could be performed with portable equipment for communication between the home and the clinic, both for self-documentation of the physical conditions and daily activities, and for feedback from the clinic regarding self-management of the diabetes.

Several questions can be asked in relation to responsibility, integrity and mobility concerning all kinds of monitoring within home health care:

Who is responsible for the equipment or information system to function correct? Is it the doctor, a system engineer, or perhaps the patient himself? How much responsibility should the patient take himself, and to what extent should the patient control the equipment and the information system? For example, in the situation of continuously monitoring physiological parameters it could be possible for the patient himself to control the on/off switch of the measuring instrument. Such a situation can lead to ethical considerations including areas of responsibility and personal integrity.

Not all patient groups, suitable for monitoring physiological parameters, are bedridden or even homebound. If a patient is mobile he may want to leave the house during the monitoring session. If it, in such a case, is indicated to monitor continuously it may be necessary to "hand-over" the biomedical signal from one instrument to another. For example, a patient with congestive heart failure, who is trying a new drug and at the same time is monitored with regard to pulse, blood pressure and arrhythmia, using a small body sensor [19] and an OSGi home gateway. When the patient is leaving the house it is necessary to "hand-over" the biomedical signal from the OSGi home gateway to another equipment, e.g. to a portable web pad or mobile telephone. Could such a "hand-over" be made in a secure way without loss of data?

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