Towards an Open and Easily Extendible Home Care System Infrastructure

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***Abstract*— Pervasive home care systems are needed to overcome the problems of an aging population in the western world. An overview of ongoing research at the Pervasive Healthcare Lab, Engineering College of Aarhus on this subject is given, presenting an infrastructure design connecting the various software and hardware projects currently being researched. The primary goal is the design of an open and easily extendible platform for existing and new home care products from multiple vendors. This includes physiological sensors as well as end-user applications, preferably free of vendor lock-in issues. The support of non-professional users, including relatives and neighbors is also a discussed.**

***Index Terms*— pervasive healthcare, home care, infrastructure, sensor networks, vital signs**

I. INTRODUCTION

The western world is aging at an ever increasing rate, mounting a constantly growing pressure on the national healthcare systems. According to estimates [1] and [2] made in recent years, the number of people in Germany older than 60 years, is expected to double before 2030, the group older than 70 years will increase from 10 % in 2003 to 18 % by 2040, and the group of over 90 years old will triple by 2030. Italy is the western country with the largest proportion of individuals over the age of 65 today, currently at a total of 18 % of the population. In Denmark, the population over 65 years will have almost doubled in 2040, an increase of 79 % [3]. Accordingly, the number of people with illnesses and restricted capabilities is also expected to increase. Statistics reveal that the number of persons requiring some kind of home health care in the year 2040 will make up nearly 3.5 % of the population, while the figures for today it is 2.1%. [2].

Keeping weakened elderly at nursing homes or hospitalized for prolonged periods of time is a very expensive operation. A natural, and more cost-efficient, alternative is care provided at the elderly's home, supervised by professional caretaking staff and the associated general practitioners. Often many hospitalizations might have been avoided altogether, if only it was ensured, that the elderly would take his prescription drugs in the prescribed amounts and time. Also, being able to monitor the elderly's physiological parameters (vital signs), and detecting early warning symptoms, might help avoid the patients health deteriorate even further. This might occur if patients are left unsupervised for prolonged periods of time and do not themselves react to changes in their general health condition, e.g. not feeling the initial symptoms of increased blood pressure or a progressing pneumonia or influenza. Supervising patients at their homes has a strong prophylactic effect on avoiding serious health conditions and thus keeping them out of hospitals and nursing homes.

This approach is not free either, however, as wages for caretaking personnel is rising and their numbers diminishing compared to the number of elderly in need of care. At the same time, many western countries are having difficulties in attracting and training new staff at the same rate as experienced care personnel retires.

Having home-nurses and other caretaking staff provide the optimal care, e.g. by measuring blood pressure, ECG and other parameters, while also ensuring that the elderly gets their medication up to four times per day, requires far more personnel than is currently available today, while this might be expected to get worse in the near future, as argued earlier.

II. SOLUTION

One viable solution might be to increase the efficiency of professional caretakers. As caretakers can not be expected to work significantly more hours than today, we may instead seek to support their daily tasks using technology. Of course, today, most western countries are already utilizing a number of technologies [4] to ensure this. For example, a digital blood pressure measuring device, which is able to self inflate, and send the data directly to the general practitioners email clients, saves the caretaker much of the work with writing down the values and reporting them in manually. Although many such systems have been implemented, and are in fact in use today [5] and [6], the caretaker still needs some level of technical understanding in order to use the products, and there is some manual handling required. If we are able to further automate these tasks, and maybe even make some of the tasks completely autonomic and independent of the caretakers training and handling, then we would be able to perform the same caretaking tasks that we handle today with fewer staff, and maybe even broaden the overall level and quality of monitoring. By making the equipment extremely user-friendly, intuitive and failsafe to use, we might also make it possible for relatives, neighbours, cleaning staff and even the elderly themselves, to perform many of the tasks.

A large number of related research projects have already addressed some of these issues, some on a visionary and experimental level, others at the applied domain [1], [2], [4], [7], [8]. Also, several commercial companies have completed home care support products addressing some of these issues.

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Some of these are already available for implementation today at the homes of the elderly [5] and [6].

The research projects at the Engineering College of Aarhus, Pervasive Healthcare Lab, have chosen a novel approach to the home care system genre, trying to rethink some of the classic proposed solutions and technologies, while also allowing for differences in use and preferences on sensor technology and choice of IT-systems.

III. THE VISION

Our vision for a Home Care System design is to develop a completely open and easily extendible infrastructure for home care systems. The goal is to allow easy adaptation of different vendors' hardware sensors, e.g. physiological sensors, heart rate, ECG, blood pressure, oximeter, temperature, as well as software components, including caretaking personnel's note-taking and info applications, log-books, hospital and general practitioner systems, electronic patient records applications and research databases. All with a minimum of development and integration effort. One major goal is to keep all source code freely available, e.g. under an open source license, and keeping the system open for 3rd party vendors to extend and enhance.

Most existing products on the marked (e.g. Telcomed and RTX, [5] and [6]) uses closed proprietary hardware solutions, not allowing individual integrators to add 3rd party sensors, and only to some degree do such products provide 3rd party software access, e.g. with limited Web Service support to some of the data collected. The proposed technology base and infrastructure of this paper will allow caretaking professional institutions, companies or individuals, to freely choose among the best suited sensor types and software components suiting exactly their needs, thus avoiding the inherent risk of vendor lock-in[1] and basing a pervasive healthcare infrastructure for home care systems on a non-extendable and inflexible platform.

IV. CURRENT STATE OF ONGOING RESEARCH

This paper will present the current and ongoing research program on the subject at the Pervasive Healthcare Lab, Engineering College of Aarhus, consisting of a range of both software and hardware research projects. The software projects includes: a basic software component framework, a distribution framework, an information and warning framework, as well as a zero-configuration-sensor data collection and presentation framework. To illustrate the usage of these frameworks, we are developing a range of usage applications, which may be easily replaced with alternative application-level programs, due to the open nature of the software architecture. These includes a data monitoring application, a caretaker's note-taking application (PC, Web and Mobile), a relatives information access module (using SMS, Web and Mobile), and a general practitioners patient monitoring module.

The hardware research projects include the Automatic Medicine Dispenser, the General Purpose Open Base station, the Entry Hall Detection System, the Fall Detection and Communication Device. The above hardware and software systems are divided into two main logical elements, the HealthCare@Home and the HealthCare@Central systems.

While other research projects and commercial companies have worked on several of these ideas before, we aim at providing novel features, but most important, on ensuring maximum openness and flexibility.

In the following, each projects goals and design foci are described in overall terms. A more thorough description might be found in later papers reporting on each of the respective projects.

V. USERS AND STAKEHOLDERS

The primary users of this system are the caretaking staff, including onsite staff providing the daily care at the elderly's homes, using the applications on a regular basis. This includes nurses and other trained professionals. Though most caretaking staff may be highly educated, like e.g. home nurses, it must be expected, that staff are not necessarily IT-professionals, and that systems must be extremely user friendly in order to get accepted and to actually ease the work load.

Other users are the elderly people themselves, who might be able to interact with the caretaking systems to some degree, e.g. strapping on a blood pressure or ECG sensor, using the Automatic Medicine Dispenser, but must be expected to have very limited technical skills.

An interest group, not constituting "users", which might rather be categorized as Stakeholders, includes hospital staff and general practitioners who might access data from Electronic Patient Record systems, obtaining some of these data from the sensor networks at the homes of the elderly.

Stakeholders to this system also include relatives and neighbours, who might be willing to take co-responsibility for surveillance of the elderly's well-being, including reacting to alarms (e.g. a SMS in case of a detected fall or missed prescribed medicine intake). But also adding notes (e.g. using a note-taking application), about current state, and even helping with mounting sensors to perform measurements of physiological data. In this perspective, relatives and neighbours might be regarded as users, putting an extra strain on the usability requirements. As the number of available caretaking staff is diminishing, this might be a natural development, so this should not be left out of the design considerations.

[1] "*Vendor lock-in*, or just *lock-in*, is the situation in which customers are dependent on a single manufacturer or supplier for some product, or products, and cannot move to another vendor without substantial costs and/or inconvenience." [9]

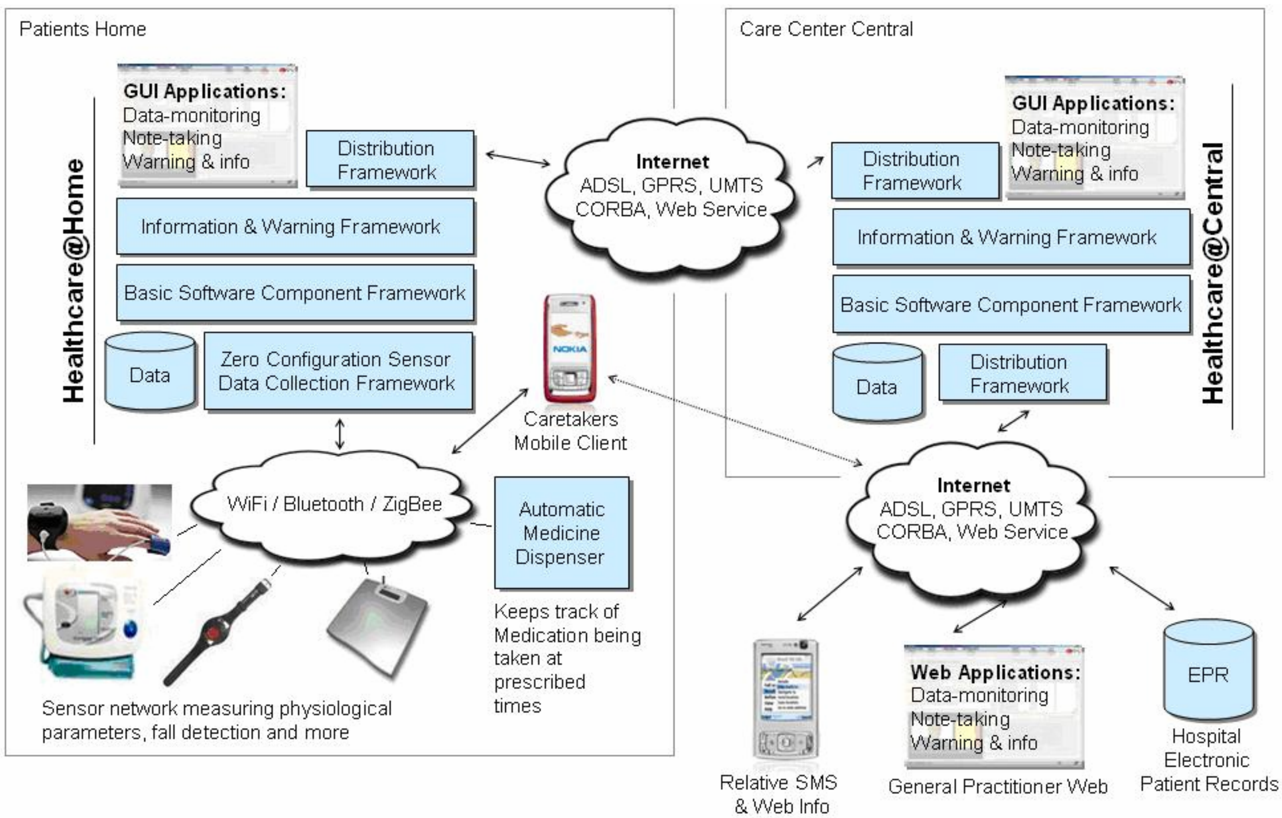

Fig. 1. The HealthCare@Home system (left box) represents all software and hardware components installed at the elderly's home. This includes sensor equipment, the Automatic Medicine Dispenser, as well as the touch-screen PC base station (GPOB). Data is transparently relayed to the HealthCare@Central system (right box), physically placed at e.g. the municipal caretaking center on a server. Here data is relayed to different stakeholders, including relatives, general practioners and hospital EPRs.

VI. Architecture and Components

The system is designed with primary focus on openness and flexibility. This means a highly component-oriented architecture. Every component should be easily replaceable, including the main elements of the system. This includes not only the different sensors, but also the base station software, user interface elements, distribution elements, as well as external access to the application.

The system, consisting of the above mentioned range of hardware and software components, is divided into two main logical elements, the **HealthCare@Central** and **HealthCare@Home** which appears to users as a single unified system entity. The flow of data is designed to be transparent to the users. Once the technician has installed the base station (the General Open Purpose Base station), all configuration and detection of system resources occurs automatically, and without user involvement. The base station software is running at the home of the elderly, and the central handling software, is running at a care center, hospital or emergency central. Either of these may be replaced by other vendors' products, or supplemented by new applications. Internally the programs consists of component-based frameworks, and externally open communication standards and configuration-file approach allows for easy system access.

The **HealthCare@Central** (H@C) system may be placed at a municipal care center, or at a regional or national level emergency center. The system's primary purpose is the hosting of data collected from the patient homes (H@H), and distributing these data to various systems, users and stakeholders, including hospital EPR systems, General Practitioner systems, caretaker mobile devices and other stakeholders. Distribution is allowed to other applications using open standard middleware, but also providing a Web front-end, as well as a SMS gateway servicing relatives and/or staff subscribing for warnings from the warning and information framework.

The **Healthcare@Home (H@H)** system acts as the base station for sensor equipment and other home care equipment, including the Automatic Medicine Dispenser. One base station is placed in each patient's home, for physiological sensor network data collection, user interface access to data and caretaking applications, the hosting of data, as well as synchronizing data seamlessly with H@C system.

Sensor networks are collecting various information, including physiological data, such as blood pressure, temperature, pulse, blood gases and ECG. To meet the usability goals of allowing many different user types, with little or no training, to operate the equipment, a **Zero-Configuration Sensor Data Collection Framework** is also being developed, allowing continuous and automatic discovery of wireless sensors and other equipment. Among the experimental devices currently being sampled for data is an ECG sensor and the 3rd party Bluetooth-based Nonin Pulse/Oximeter device. The framework also automatically detects the Automatic Medicine Dispenser unit (see below), including the information and warning data that it provides for interested servers (base stations) via Bluetooth. See [10] for further details on the Distributed Data Collector.

The **General Purpose Open Base station** (GPOB) is the main hardware platform for all software running in the H@H domain. It is simply a touch-screen based computer, which is equipped with wireless communication facilities, and a broadband internet connection, either using ADSL, cable or UMTS/GPRS. The General Purpose Open Base station might be an embedded touch-screen based personal computer running Windows Vista or XP (which is used in the current research projects), but any PC or laptop might be used, in order to cut cost or for user groups who would like such a platform. The Windows PC platform was chosen out of flexibility and openness requirements, while the low pricing of the PC platform was secondary. The idea not to use a standard PC with qwerty keyboard and mouse, is one of usability, where some user groups might find a PC application more intimidating than an embedded touch-screen solution. Also, most standard PC configurations are more space consuming than most touch-screen based PC's, as these might be mounted on a wall, e.g. in the hallway.

The **Automatic Medicine Dispenser** (AMD) is one of the projects under development. The main design goal is to allow the user to take exactly the prescribed medication within the prescribed time or interval, while not allowing the user to take the medication at the wrong time and in the wrong amounts. Typical users include elderly people at their own home or in a nursing home, as well as caretaking staff acting as proxies to retrieve the medicine. It might also be operated by relatives and neighbours to ease the burden of caretaking staff, as discussed earlier. Also, it is capable of reminding the elderly, relatives or onsite caretaking staff, that it is time to take the medication. Another major design feature is that the device will inform the base station (e.g. the H@H system) of all use, allowing for a log-book of how medication has been delivered to the elderly. In case of warnings, the base station might inform caretaking staff or relatives of this. For this purpose, it may employ features of the H@H and H@C systems, which will send an SMS to a relative or caretaking staff (depending on configuration choices made), while also allowing the home nurse and the general practitioner to get a comprehensive usage log, enabling them to monitor for incorrect medication usage. The Automatic Medicine Dispenser will be presented in detail in a later paper.

Also, researchers will be able to draw on physiological data collected from the patients, comparing on-duty personnel data to the actual usage (or misuse) of the prescribed drugs. Thus a very comprehensive platform for the study of drug effects is a secondary objective of this project.

The **Fall Detection and Communication Device** (FDCD) is a fall detection device, equipped with accelerometers and other sensors to detect fall-accidents. It communicates with the base station using Bluetooth. In case of a fall, the device will inform the alarm central, and enable these to establish a voice connection via the base station or GSM, enabling the emergency staff to verbally contact the patient. Also, the device might serve as an extended user interface of the GPOB, and even take over the sensor data collection tasks when the user is out of range of the GPOB and the Distributed Data Collector running on it.

The **Entry Hall Detection System** (EHDS) is a hardware and software component, which might be used to equip the base station with entry hall sensing capabilities. This includes registering the arrival of a visitor, and identifying him as a well-known user (e.g. a caretaking staff member or a relative) through different means: Bluetooth signature of the users cell phone, or RFID card detection. This will allow the information and warning framework to inform a visitor with information on any pending problems. This might be if the users blood pressure is too high (or has been since last visit), or if the elderly has not taken his prescribed medicine (a warning from the AMD). In fact, the information and warning framework is open for any 3rd party application running on the base station, wanting to convey its information to users. Again, the information and warning framework is running across the H@H and the H@C, so that information and alerts may be presented both locally in the elderly's home, and remotely at the caretaking centre, or as an SMS to relatives.

VII. Conclusion and Future Work

This paper has discussed the design challenges and principles for an open and flexible infrastructure for pervasive health care products, as well as the projects currently being researched. Many of the projects are still under development, and much work remains before they can be used to demonstrate the principles presented in this paper, and be used to gather experiences on their potential efficiency and usability. The ensuing results will be used for a revised infrastructure design.

VIII. Refeerences

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