A WIRELESS WELLNESS MONITOR FOR PERSONAL WEIGHT MANAGEMENT

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***Abstract* - Despite increasing possibilities for the citizen to play a more active role in personal health management, use of Internet-based health applications remains limited. Poor usability, limited personalization, and problems with security and accessibility often frustrate a *continued* use. This paper presents a possible solution by actively using wireless communications and ad-hoc networking techniques to minimize the user's efforts in using the application.**

Overweight is a widespread and increasing problem in western countries. There are indications that self-monitoring combined with guidelines provide a good basis for personal weight management.

The wireless wellness monitor implements a self-monitoring and guidance system using Bluetooth- and Jini-based networking. A scale, heart rate monitor, mobile terminal (personal digital assistant or WAP-enabled digital cellular phone), and home server communicate locally via Bluetooth. Internet-based communications take care of remote use. The set-up allows us to investigate the behavior and use cases based on equipment and protocols that are expected to be in general use in the coming years. Thus, the system provides a useful test-bed for evaluating new techniques that may bring personal health management to a new level.

Keywords - self-monitoring, home health care, wireless communications, Bluetooth, Jini

I. INTRODUCTION

Nowadays, many Internet-based resources exist that help the user with personal management of diseases such as diabetes, hypertension, and asthma and their associated risk factors (e.g., lifestyles such as smoking, overeating and lack of exercise). These systems typically provide basic tools necessary for the management. However, their usage is still quite limited. There are various reasons for this:

- the daily use of the system, e.g., recording and storing personal physiological data, requires significant efforts, such as logging into the system, and entering the values of the recorded variables manually. The system is neither immediately nor effortlessly accessible during daily routines;
- there are limited possibilities to explore the earlier recorded data;
- there is limited personalization of the information and guidelines provided (e.g., a normal weighted hypertensive may be always guided to lose weight to control the blood pressure); and
- there are significant problems with accessibility, usability, security, and authentication of the information.

The rapid convergence of mobile communications, digital broadcasting, rich contents, and network infrastructures opens up new opportunities for citizens, businesses and public organizations. Key technological developments take place in the areas of *Internet connectivity* and *wireless local networking*. Internet connectivity is increasingly provided through a diversity of different devices and related technologies such as XML, WAP, and UMTS. These developments will enable citizens to have affordable online access to any information, at anytime, and anywhere.

New portable devices are equipped with increasing processing power and wireless communications capabilities, such as IrDA or, in the near future, low power high-frequency radio such as Bluetooth. This enables more and more appliances to be networked and interoperate; creating new possibilities for home automation and active-environment based services. The advantages of this technology are the low (or no) networking cost thanks to independence from network operators and the by-default localization of services. Different initiatives, such as Jini, are creating framework solutions for automatic networking. Adaptation of these technologies into personal health monitoring simplifies measurement and data logging, and lies the foundation for obtaining immediate feedback and health information.

This paper concentrates on the use of developments in both Internet connectivity and wireless local networking for application in the domain of personal weight management. Section II of this paper describes the issues that play a role in the personal management of weight, what solutions exist today, and gives a motivation for our approach. Section III describes the wireless wellness monitoring system that has been developed, and Sections IV and V provide discussion and conclusions that can be derived from the results obtained so far.

II. Rationale

Only about half of the population of the European Union is within normal weight range, more than 40% are either over-weight or obese, and more than 10% are under-weight [1]. There is a tendency of more and more people being in a state of weight gain rather than weight loss [2]. The health care system has obvious difficulties to provide treatments and advice to such large number of people.

Many people are trying to lose weight either by dieting, exercise or by a combination of these methods. One of the main problems in weight control is that it is easy to gain back weight after a weight control program. Actually, a majority of people gains back their weight within five years after starting the weight control program [3,4]. Thus, the main problems of weight control are the large number of people being overweight, and difficulties in maintaining the weight after losing it.

A behavioral model of eating may provide some new suggestions to the weight control problem [5]. According to the behavioral view eating and weight may be modified or changed by the individual's own "direct" experience. Accordingly, self-monitoring ("learning by one's own experience") may be necessary for successful weight control [6]. On the other hand, also information in the form of rules, advice, and others' experiences is a widely used resource in weight control programs. However, much of this information does not change behavior because the effects it describes are temporally too far removed from the actual eating behavior or simply because the individual may not remember the information. Thus, information of healthy eating should temporally be as close as possible the actual eating behavior.

In summary, the discussion above points out that the success of weight control may be increased:

1. by self-monitoring and providing (behavioral) feedback to the individual so that he/she can more effectively learn by his/her own experience
2. if the individual has a possibility to receive immediate information and expert advice about weight control.

The goal of our project is to provide an easy-to-use self-monitoring system for weight control. The system must be able to provide behavioral feedback on data recorded over long periods of time. It has the following main functions: 1) a behavioral feedback system for weight and for physical activity / exercise (Figure 1); 2) a database for nutrition and physical activity; 3) a database for behavioral instructions including instructions how to control and regulate eating and physical activity; and 4) an expert service system, which supports the behavioral feedback system. The main emphasis will be on the behavioral feedback system, which includes functions to measure, store and display graphically (feedback) weight and heart rate in long term (months to years).

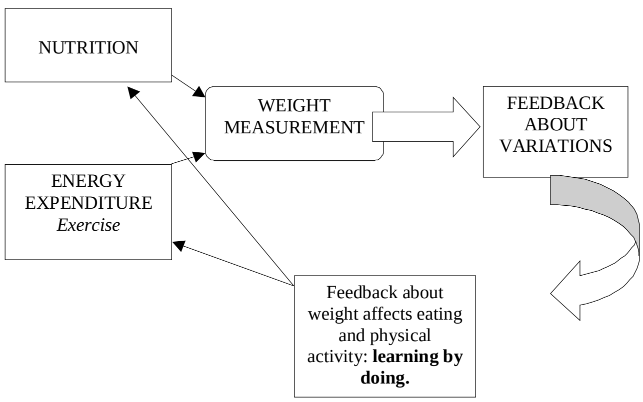

Figure 1: *Behavioral feedback model for weight control.*

Technically, the main challenges for the system are: 1) how to make the measurement, storage and browsing of the wellness data so easy that the user continues the effort, and 2) how to convert the measurement data into informative feedback to the user to motivate him/her and to support his/her management of wellness related lifestyle factors (e.g. eating and physical activity in case of weight control). This brings the main technological focus of our project to 1) dynamical wireless communication of devices, and 2) visualization of wellness data. The emphasis of this paper is on the former.

III. Methods

The main goal is to be able to do measurements, view recorded data (feedback) and have access to guidelines and related information *anywhere* whenever needed. The system contains the following components: a *home server*, *a mobile terminal* and *measurement devices*. Via the Internet, the user can also connect to external *nutrition and exercise databases* as well as to an *expert service system* (Figure 2).

The application software has been built with Java. The core software runs as a collection of RMI (Remote Method Invocation) services on the home server. It is accessed using mobile terminals (typically; a mobile phone or personal digital assistant (PDA) or a laptop computer) The system relies on wireless ad-hoc networking between the devices. Data transfer between measurement devices, home server and mobile terminals occurs over a Bluetooth radio link [7]. In practice, wireless ad-hoc networking means that the services and clients can come and go, they are not bound to a fixed location. New services and clients can be added to the network without configuration and driver installation as well as without cables.

The system uses Bluetooth enabled devices and the Jini software framework [8,9] to allow wireless ad-hoc networking. Jini uses RMI to allow distribution of software onto several devices. RMI works on top of Bluetooth by using TCP/IP protocol. Distribution of software allows developers to place the computationally more demanding tasks in the computationally more powerful server computer instead of mobile terminals.

Bluetooth [7] is an open specification for wireless RF communication and networking. The normal coverage of a Bluetooth transmitter is 10 meters. Peak data rate is 1 Mbps. The idea of Bluetooth is to provide a personal network, which covers the area of one room. The Bluetooth chips are designed to have low power consumption and low price. It is assumed that at least computers, mobile phones, PDAs and computer peripherals will have integrated Bluetooth chips in the near future, but potentially also more simple devices such as measurement devices or sensors might be equipped with Bluetooth. It is possible to use existing protocols like TCP/IP, WAP and RFCOMM on top of Bluetooth. Bluetooth supports point-to-point and point-to-multipoint data and voice communication.

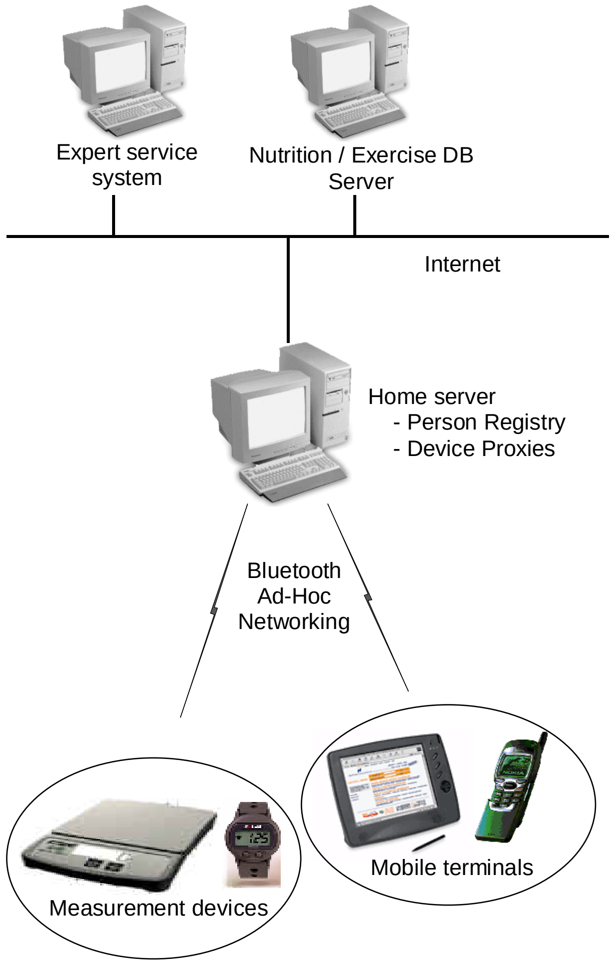

Figure 2: *Setup of the used system. The core software runs on the home server. It is accessed by using mobile terminals.*

Jini [8,9] is a Java-based software framework that allows services and clients join and leave the network at any time (ad-hoc networking). When two Jini enabled devices connect to the same network they can share each other's services. Heart of the Jini architecture is the Jini Lookup Service, which keeps track of available services. The services and clients find the Jini Lookup Service by using the *discovery* protocol. Once the Jini Lookup Service has been found, a service can register itself in the Jini Lookup Service by using the *join* protocol. A client uses the *lookup* protocol to find a specific service from the Jini Lookup Service. Once the client has found the service it was looking for, it uses RMI to call the methods of the service.

The current system uses RMI [10] for connecting the distributed programs. RMI is a Java-based technology that allows distributed computing, i.e., computing in a multiple JVM (Java Virtual Machine) environment. RMI allows transfer of code and objects as well as garbage collecting of remote objects. The software is distributed among the server and client so that the actual implementation classes reside and run on the server, while only the interfaces reside on the client. The interfaces describe the service; they do not include executable code. The client program calls the methods described in the interface. RMI forwards the calls to the implementation classes residing on the server. The client can find a remote service via a naming and directory service. In this prototype, the RMI Registry that comes with RMI is used. The RMI Registry is run on the home server on a well-known port number so that services and clients can use it for registering and querying services.

A. Home server

The home server runs the primary *person registry,* which holds the measurement data and other personal data. The home server also hosts *proxies* for devices, which do not have a JVM. The home server enables local connections via Bluetooth by running the RMI services and Jini Lookup Service.

A web server is installed on the home server to allow any device with an HTML browser to connect to the home server, typically, from outside the house. In local use, the connection is established using the Bluetooth radio link. The web server is equipped with Java servlets that have a connection to the actual RMI services. The servlets dynamically generate HTML pages that the HTML browsers can access and display to the user.

A more efficient way of accessing the server from a larger distance via a mobile connection is achieved by using WAP-enabled (Wireless Application Protocol) devices. In order to use the system also with WAP enabled devices, a WAP gateway (Nokia WAP Server 1.1) was installed on the home server. The Java servlets generate WML pages for the WAP-enabled devices. The WAP gateway converts the WML responses into binary format and sends them back to the WAP device.

In the prototype, the home server hosts nutrition and exercise databases as RMI services. Since the databases are implemented as RMI services, they could reside anywhere in the Internet. Use of external services might be necessary if the databases reside on a another provider's web server.

B. Mobile terminals

The mobile terminals are used to display measurement data and health information and to access the nutrition and exercise databases. They are also used to initiate the measurement, to display the measurement result, and to confirm storage of the measurement result. Since the terminals have different capabilities, some terminals can only show a limited set of functions. Use of two types of mobile terminals was studied: pen computers and WAP phones.

A pen computer with full Windows 98 operating system is used. A pen computer is a portable computer with a touch screen instead of a keyboard. The pen computer used is envisioned to have a similar look-and-feel as the future mobile phones/PDA combinations. The pen computer is capable of running the most recent JVM[1]. In local use, software in the pen computer calls the RMI services directly by using the Bluetooth connection. Alternatively, it is also possible to use the HTML browser available in the pen computer and connect to the web server.

The WAP phone runs a WAP user agent and is capable of browsing WML pages generated dynamically by the Java servlets. Each time the software is used with a WAP phone, the phone connects to the home server to read the dynamically generated WML pages. The tiny monchrome displays and small memory capacity of the current WAP devices set limits to the WML pages.

C. Measurement devices

The scale and heart rate meter are connected to a laptop computer via a serial cable and a wireless interface, respectively. These combinations emulate the future measurement devices, which have integrated Bluetooth chips. Once these devices with integrated Bluetooth chips are available, the laptop, which now contains the Bluetooth card, can be removed from the setup. The communication between the measurement device and the home server occurs using Jini and RMI over Bluetooth. In order to use Jini, each service has to support Jini. A current measurement device such as a scale has no (or very little) processing power and does not currently support Jini. Therefore, it needs a proxy. The proxy is situated in the home server. It creates a

[1] This is the main reason for not using PDAs that are on the market at this moment; they typically contain older versions, if any, of JVMs which do not support the full use of RMI/Jini

standard Jini interface for the measurement device. The clients invoke the methods available on the proxy interface. With help of the proxy, the communication between the interface and measurement device can use any proprietary protocol.

D. Software

The *person registry* keeps track of personal information and measurement data. It runs on the home server and is accessed using the mobile terminals. A *data browsing* tool visualizes the measurement data at selectable time intervals. It also gives immediate feedback to user in connection with each measurement. The complexity of the presentation varies depending on the capabilities of the mobile terminal used. The *health information tool* gives everyday instructions for the user. It is a database of frequently asked questions about weight control. The application running in the pen computer can hold a local copy of this database. The instructions can be viewed also with the WAP phone. The instructions are personalized to the user.

The *planning tool* uses the nutrition and exercise databases to give the user the possibility to view the effects of using different food items or performing different exercises. The planning tool visualizes e.g., how much cycling you have to do to burn the calories you get by eating two hotdogs. A nutrition database, Fineli (National Public Health Institute, Finland), is used with an exercise database. The information for the exercise database was on the results of studies listed in [11] with local addition of some typical Finnish exercises.

An *interface to an expert service system* allows the user to send data to an expert, to send requests for consultation and to post and read messages on discussion boards.

E. Remote use

The mobile terminals also allow remote use of the system, i.e., use from outside the Bluetooth range. It is fairly common that a diet or an exercise program fails during travelling. Remote use makes sense in cases, when the user is not at home, but wants to browse the measurement data, instructions or nutrition/exercise databases. It may also be possible to take the measurement devices along and use the system normally from anywhere.

A mobile terminal that is capable of running JVM can connect to the home server from anywhere via telephone and start using the RMI services. In the system at hand, the pen computer with GSM data card is used to study this type of connection.

The remote device can also use a plain HTML or a WML browser to access the system. It is, e.g., possible to make a remote connection to the system with a WAP phone by making a GSM data call to the dial-in modem attached to the home server.

F. Use Case: Weight Measurement

An example of how the system is used is depicted in Figure 3.

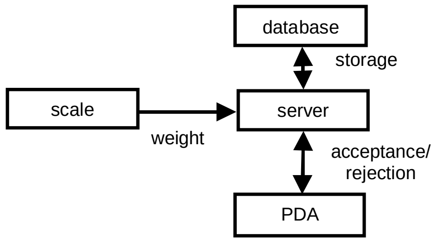

Figure 3: *Use case weight measurement. A scale and the corresponding RMI service is running on the home server. As the user enters the service range of the wireless network with his PDA, the PDA terminal number serving as the user identifier is recognized and the PDA is registered as client in the network. On his PDA the user can see a list of services that are available in his home environment. As he selects one of the services (e.g., the scale) he initiates the measurement process. He steps on the scale and subsequently the result is shown on the PDA screen. He can accept the result by tapping a button on the screen, after which it is stored in the database.*

IV. Discussion

The main emphasis of this project is to apply both high-techology and behavioral psychology in order to solve practical problems in health management and wellbeing. The system allows self-monitoring with minimal effort and provides immediate feedback, which increases possibility for successful self-management. Futher, the individual has a possibility to receive immediate information and advice, the impact of which increases since it is temporally as close as possible to the actual behavior to be changed. This project is an example of how the use of high-techology can also provide to behavioral management solutions, which were not possible earlier.

The technological emphasis of the project is to optimize the use of the system at home: measurement and data storage should be as automatic as possible. The user has a convenient mobile terminal to browse the measurement results, trends and instructions immediately after measurement.

The home server, measurement devices and mobile terminals are all expected to have an integrated Bluetooth chip in the future. The current prototype has to rely on separate Bluetooth cards (e.g., Compact Flash cards), because the devices with integrated Bluetooth chips are not yet available. The hardware selections for the prototype were based on the assumption that the very first Bluetooth cards appearing on the market will only have drivers for the Windows operating system. Bluetooth, however, is not a necessity per se, and indeed other communication protocols, or combinations thereof can be employed instead while keeping the proposed dynamical networking principles intact.

In the current system, the WAP phone accesses the home server via a local Windows NT RAS (Remote Access Server) service. This requires installing the RAS service, WAP gateway and the dial-in connections (including a modem) on the home server. Use of the RAS server can be avoided if the home server has a fixed Internet connection. Fixed connections are now becoming reality also in the home environment. With the fixed connection the user also gets a fixed IP address. Using the given IP address the mobile terminals could access the home server via Internet instead of telephone networks. This would be a more economical solution for the user. However, if the home server is publicly available on the Internet, strong authentication and encryption algorithms must be used. With the RAS server approach, probability of getting unwanted visitors on the home server is slightly smaller, since the home server is not continuously connected to the Internet.

The general goal of the development of the system is the evaluation of its architecture and dynamics. The chosen application, weight control, is just one of the possible application areas, in which this set-up can be used. In principle any type of measurement device could be used instead of the scale and heart rate meter.

V. CONCLUSIONS

The Wireless Wellness Monitor is a prototype that provides information on weight control, nutrition and exercise as well as online access to the measurement data. It also experiments use of ad-hoc networking in everyday use. In its current form it uses communication technologies that are only available in PC-based environments as of yet, but that are expected to be available in embedded form in portable/mobile equipment within the coming 1-2 years. As such it provides a platform and test-bed for exploring and refining the concept further, using usability tests, before actual commercial implementation.

ACKNOWLEDGEMENTS

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