

A DVB-T Framework for the Remote Monitoring of Cardiopathic and Diabetic Patients

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Abstract

Tele-home care systems enable patients with chronic diseases to be remotely and constantly monitored by the healthcare staff reducing the need for frequent visits to the hospital. Besides the advantages for patients, this solution could also provide significant cost savings through the exploitation of low-cost equipment for simple physiological measurements to be performed at home, sending the recorded data to the healthcare staff placed elsewhere.

The aim of this work is the development of a low-cost tele-home care system based on the Digital Video Broadcasting Terrestrial (DVB-T) technology for the remote monitoring of cardiopathic and diabetic patients. Easy to use even by untrained or elderly people, such tele-home care system could represent the best solution in terms of simplicity, quality and costs.

1. Introduction

Diabetes is a serious chronic disease which causes a high rate of morbidity and mortality all over the world. In 2007, more than 246 million people suffered from diabetes worldwide and unfortunately the incidence of diabetes is increasing at alarming rates. The number of people with diabetes is expected to double within the next 25 years due to a combination of population ageing, unhealthy diets, obesity and sedentary lifestyles [1,2].

Diabetes can lead to blindness, heart disease, stroke, kidney failure, amputations and nerve damage. In women, diabetes can cause problems during pregnancy and make it more likely for the baby to be born with birth defects [3]. Moreover, statistical analysis shows that 75% of diabetic patients die prematurely of cardiovascular disease (CVD).

CVD covers a wide array of disorders, including

diseases of the cardiac muscle and of the vascular system supplying the heart, brain, and other vital organs [4,5]. The absolute risk of cardiovascular disease in patients with type 1 (insulin-dependent) diabetes is lower than that in patients with type 2 (non-insulin-dependent) diabetes, in part because of their younger age and the lower prevalence of CVD risk factors, and in part because of the different pathophysiology of the two diseases. Unfortunately, about 9 out of 10 people with diabetes have type 2 diabetes.

For these reasons, cardiopathic and diabetic patients need to be frequently monitored and in some cases they could easily perform at home the requested physiological measurements (i.e. glycemia, heart rate, blood pressure and body weight) sending the measured data to the care staff in the hospital. Several researches have been presented over the last years to address these issues by means of digital communication systems. The largest part of such works uses a PC (e.g. [6]) or complex hardware/software systems (e.g. [7]) for this purpose. Beyond the cost of such systems, it should be noted that they can be quite accessible by relatively young people but the same does not hold for elderly patients more accustomed to traditional equipments for personal entertainment such as TV sets. The aim of this work is the development of a low-cost tele-home care system based on the Digital Video Broadcast Terrestrial (DVB-T) technology for the remote monitoring of patients with diabetes and suffering from cardiovascular diseases, even exploitable by elderly people.

2. Methods

The system presented in this paper was conceived to keep as low as possible the costs of the extra-hardware with respect to a minimum setup composed of a TV and a DVB-T set-top box connected to the telephone line. This way the usability by untrained people not accustomed to

digital equipments but the TV set one is also preserved. A global representation of the entire system is depicted in Figure 1.

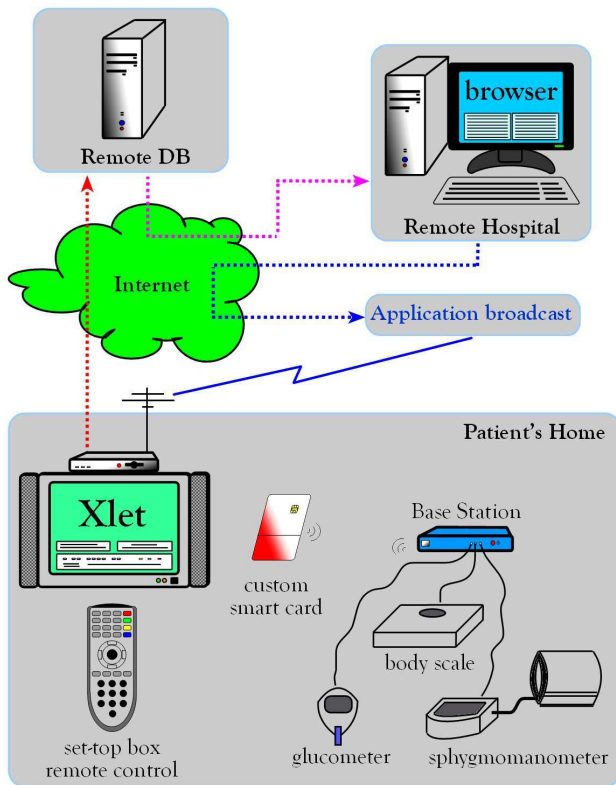


Figure 1. The main parts of the DVB-T based tele-home care realized system.

At the patient's home, the TV set is equipped with a standard interactive set-top box. Standard Multimedia Home Platform (MHP) set-top boxes are simple computers with their Operating System, a Java Virtual Machine and a set of standard ports for I/O interfacing, such as a smart card reader and an internal 56Kbps modem for pay-per-view services. From the patient's point of view, the system exploits the remote control of the set-top box as control input for the user, the TV screen as output for him, and the telephone line to send the data to a Remote Data Base (RDB). For this work, we used a Telesystem TS7.4DT set-top box, with the version 21p1 of the real-time Operating System (i.e. Osmosys) and implementing the MHP 1.02 profile with some enhancements, primarily the addition of java packages for both the smart card and the internal modem management.

The interactive application (Java Xlet) is loaded on the patient's set-top box through an ether broadcast DVB-T transmission, while the user is watching the broadcaster's channels. An Xlet is a JavaTV application model following a well defined lifecycle [8] that can run on the set-top box thanks to the Java Virtual Machine. The Xlet

mainly manages the acquisition and transmission to the Remote Data Base of the patient's data, but also enables the visualization on the TV screen of the physician's feedbacks from the Remote Hospital. To allow a secure one-to-one sensitive data transmission in a one-to-many communication channel, like in DVB-T broadcasting, a double key encrypting technique is implemented. In such a way, patients can view and read just their physician's messages.

A microcontroller-based custom smart card (SC), which is programmed by the Remote Hospital, allows an easy use of the system, providing all the necessary data to the Xlet to configure the framework for a specific patient. The SC stores the patient's name and their personal identification code, the treating physician's name and their identification number, a permission exam code, some information about the Internet Service Provider for the Internet access (user ID, password, telephone number), the Remote Data Base IP address and the private key needed to read the physician's feedback. This way the patient does not have to remember any code, number, password, and different patients can share the same hardware platform simply inserting their personal smart card. According to the international recommendations about the patient's safety, the SC also provides the Xlet with the data exams collected by the acquisition unit (the Base Station) through a wireless link at 2.4GHz in the free ISM band. Figure 2 shows the picture of the first prototype of the realized custom smart card. It is build around a low-cost microcontroller connected through the SPI protocol with a Mi-Wi compliant wireless transceiver.

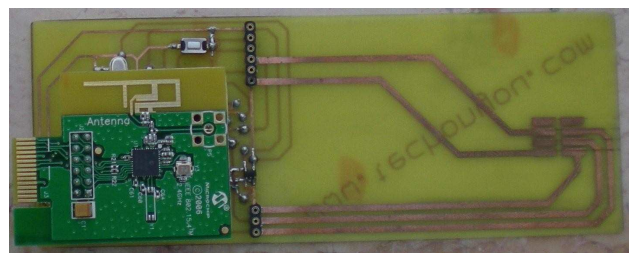


Figure 2. First prototype of the custom smart card.

The Base Station (BS) enables the acquisition of some physiological parameters needed for the monitoring of diabetic and cardiopatic patients (i.e. blood pressure, heart rate, body temperature, body weight and glycemia) through wired serial RS232 compliant connections to three commercial and certificate biomedical devices (i.e. Menarini Glucocard G+ glucometer, OMRON 705IT sphygmomanometer and A&D UC-321P personal precision electronic body scale). It is important to notice that the BS could communicate with others biomedical devices, depending on the application scenario. To improve patient's safety, the BS is battery-powered and

communicates with the Xlet running on the set-top box through a wireless link with the SC. In this way, the DVB-T equipment and the acquisition unit are wireless coupled, improving patient's safety. From the patient's point of view, the BS is only a black box with a very simple user interface: the patient has only to connect the commercial biomedical device to the BS and press a big button. From this point, the Xlet will do all the necessary to send the acquired data to the Remote DB.

We conceived the SC and BS units taking into account the low-cost target, then resorting to a very simple and low-cost microcontroller, i.e. the Microchip PIC18F4620. Based on a 8-bit 10 MIPS RISC CPU, it has 64KB of Flash memory, 4KB of RAM, 1KB of EEPROM, a hardware multiplier, 13 channel 10-bit ADC, an USART module and a SPI/I2C controller. The wireless module used in the SC and in the BS is based on the Microchip MRF24J40 transceiver at 2.4GHz with a built-in ZigBee and Mi-Wi protocol stack.

Exploiting the full potential of the DVB-T technology and of the Java Xlet application loaded on the patient's set-top box, after the acquisition of the physiological parameters of interest, the uplink connection supported by the set-top box is used to send the exam results to a Remote DB for physician analysis. At the Remote Hospital, only a simple PC acting as a TCP/IP client is needed. Through the Internet, the physician can browse into the patient's data for clinical examination and can send feedbacks directly to a specific patient using the DVB-T channel through a secure Internet connection with the broadcasting station.

A DVB-T broadcast system is designed to transmit a compressed digital audio/video/data MPEG-2 stream, using Orthogonal Frequency Divisional Multiplexing and a modulation technique compatible with the traditional 8MHz bandwidth of the analog transmission channel (i.e. QPSK, 16QAM and 64QAM). The compressed video, audio, and data streams of one TV channels are multiplexed together to form a Programme Elementary Stream (PES). The basic digital stream that a set-top box can receive is an MPEG-2 Transport Stream (TS), which is formed joining together one or more PES. From the receiver's point of view, all the TV channel and services are received at once but it only demultiplexes and then decodes the selected content, one at a time, from the received TS. As a matter of fact, we are testing the system on the field in cooperation with a local DVB-T broadcaster (i.e. VIDEOLINA [9]) but for our preliminary tests we also developed the broadcasting part. Our DVB-T broadcast system is based on the CreaTV MiniLab by Media Solution. Through the JustDvb-It 2.0 software, video and audio MPEG-2 encoded contents are multiplexed together with the Xlet application to build the Single Program Transport Stream (SPTS) to broadcast. A PCI card DekTec DTA-110, a multistandard modulator with UHF Upconverter, is coupled with a 20

dBm RF amplifier (RFbay LPA-4-14) for the ether transmission of the SPTS. To establish the bit rate needed to encode audio, video and multimedia contents in the MPEG-2 format, it is necessary to know the coding and modulation parameters used to transmit the SPTS. We have chosen 1/2 for the convolutional rate, 16QAM for the modulation type and 1/4 of the original block length for the guard interval. The resulting bit rate is 9953 Kbps.

Once the Xlet has been loaded on the set-top box, it starts to read the data stored in the SC. Without any valid smart card identification the application cannot proceed. The permission exam code stored in the SC is used to allow the patient to perform only some specific exams among those available, hence disabling all the other ones. For example, Figure 3 shows a screenshot of the Xlet sending two acquired glucometer measurements to the Remote DB. A small area on the top-right corner of the Xlet is devoted to the background TV program streaming. A pop-up window alerts the patient if he/she is exiting the Xlet without sending the results to the RDB (in this case the exam results will be lost).

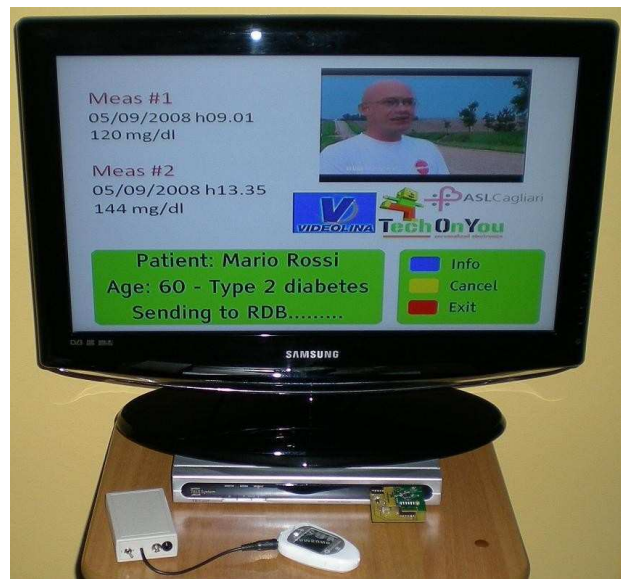


Figure 3. Picture of the Xlet sending two acquired glucometer measurements to the Remote DB.

3. Results

The overall system has been implemented, tested and is currently used for some trials on the field by twenty 65 years old in average selected diabetic and cardiopathic patients. At the end of the trial period, each patient will fill a standard questionnaire (i.e. QUEST, Quebec User Evaluation of Satisfaction with assistive Technology) in order to evaluate patient's satisfaction and the related services he/she experienced.

Thanks to the DVB-T technology, the user interface accessible on the patient's set-top box is uploaded by a DVB-T broadcaster without any intervention in the patient's home. The user can explore the application moving through the different full-screen frames, choosing among the possible options and functions by means of the set-top box remote control keys.

Simply programmable by the hospital, the custom smart-card used for patient's identification, internet connection and for data acquisition, avoids the need to remember any code or password for using the system.

Compared to traditional dedicated systems, the presence of a visual environment on the TV screen allows a more friendly approach also guiding the user through all the exam procedure without any required printed manual.

Even untrained or elderly people, accustomed to use TV sets for personal entertainment, have easily utilized the system, breaking the typical gap that prevents elderly people from using the most advanced high-tech telemedicine systems.

4. Discussion and conclusions

The presented tele-home care system, based on a framework built around the well established DVB-T platform, allows remote monitoring of the patients conditions directly from their home, without any installation procedure. After 2012, DVB-T will be the only terrestrial television system in Europe, so its diffusion will be capillary, at a very low cost for the final user. Exploiting low-cost technologies for the acquisition unit will then lead to the development of a user-friendly cheap solution for tele-home care.

Some strong points of the proposed system are:

- low-cost, since beyond the TV set only a low cost microcontroller-based acquisition unit and a custom wireless smart card are required;
- user-friendly interface, also for elderly people accustomed to TV but not to computers;
- flexibility, since the functionality of the system can change exploiting the same platform;
- easy maintainability, since Xlet broadcasting enables upgrade, and the smart card improves usability and completely avoids any installation activity at the patient's home.

Moreover, our approach is so general that simply modifying the Xlet and the acquisition unit it is possible to extend the functionality of the system to serve application scenarios different from the one proposed in the current implementation.

At present the complete system described above is fully functional and under experimentation. The trials on the field with outpatient clinics (cardiology and

diabetology) will show the appeal of the proposed solution for the patients and their perceived advantages compared to more sophisticated technologies providing the same service. The outcome of such trials will be published soon.

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