A DVB-T BASED SYSTEM FOR THE DIFFUSION OF TELE-HOME CARE PRACTICE

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Keywords: Telemedicine, tele-home care, remote monitoring, ECG, DVB-T, MHP.

Abstract: Typical telemedicine systems are usually PC based and in some cases they use expensive custom devices to satisfy the system requirements. For tele-home care uses by elderly or untrained people, these type of solutions are impracticable. As an example of user-friendly tele-home care system, in this paper we present the first tele-home care application of DVB-T technology over standard home entertainment equipments and a prototypal low cost microcontroller-based acquisition unit for 1-lead ECG. The usability and low cost of the system show the potentiality of the approach.

1 INTRODUCTION

In order to reduce the costs for both the patients and the public administration, tele-home care systems are today often used for clinical practice. They permit to avoid the overcrowding of ambulatories for simple routine examinations and, in the case of chronic patients that must be frequently monitored, to avoid the costs and the waste of time of an ambulatory examination for simple physiological measurements that they could easily perform at home, sending the recorded data to the care staff in the appropriate department. However, these telemedicine systems are usually PC based or use complex hardware and software products. Even if such technologies are quite popular today, they are frequently used only by relatively young people, which are not the primary tele-home care target.

The Digital Video Broadcast Terrestrial (DVB-T) technology, under experimentation in Europe, will be the only terrestrial television system after 2012. By the use of a cheap set-top box, it is now possible to adapt the new transmission tecnology to the old TV equipments. The set-top box is actually a simple computer, normally embedding a RS-232 compliant port connector, a smart card reader and a modem for the return channel link. In principle, it is then possible to define tele-home care systems based on such technology where the user interface is represented by the TV screen (output) and the remote control (input). This paper presents an example of a such system based on DVB-T technology with a cheap microcontroller-based acquisition unit and a very user-friendly interface well exploitable even by elderly people.

The remainder of this paper is organized as follows. In Section 2 a brief analysis about related works is presented. In Section 3 the whole proposed system is introduced; Section 4 deals with some details on the prototypal 1-lead ECG Base Station, whereas the application on the set-top box is presented in Section 5. Section 6 concludes this work.

2 OTHER TELE-HOME CARE PROJECTS IN LITERATURE

The primary activity of telemedicine systems was the transmission of diagnostic medical images using television for medical consultation from physician to physician in remote places. Recently, telemedicine systems through the Internet via satellite have become a reality by means of high throughput mixed satellite-web communication channels. This Section presents some home-oriented telemedicine projects making use of DVB and Internet, without the claim to be exhaustive.

The Interactive Satellite Multimedia Information System (ISIS) project (Pierucci and DelRe, 2000), realized a telemedicine system based on satellite com-

Angius G., Pani D., Raffo L., Seruis S. and Randaccio P. (2008).
A DVB-T BASED SYSTEM FOR THE DIFFUSION OF TELE-HOME CARE PRACTICE.
In *Proceedings of the First International Conference on Health Informatics*, pages 31-36

munication for furnishing interactive services for residential users together with the traditional TV distribution, porting tipical applications developed for terrestrial network (Internet) to the satellite digital video broadcasting technology (DVB-S). By a dualband terminal, connected in uplink via Eutelsat satellite and in downlink via the Italsat satellite, the ISIS system provides a small and low-cost transceiver for sites not connected to the Internet or connected only in dial-up low-speed mode. Through his Java application for the DVB-S transceiver, called Medical Environment for Diagnostic Images (MEDI), the project can manage a medical image database for remote expert consultation and so it demonstrated the feasibility of satellite-based interactive multimedia services for telemedicine purposes.

In 2001, a multipurpose health care telemedicine system with a base unit and a mobile unit was developed in Greece too (Kyriacou et al., 2001). At patient's home, the mobile unit allows the transmission of vital bio-signals and static images of the patient to the base unit at the physician site (office or hospital). The mobile unit device is compliant with some of the commercial main vital signs monitor and it is able to transmit ECGs, non-invasive blood pressure (NIBP), body temperature, percentage of arterial oxygen saturation (SpO_2) and heart rate. Based on the TCP/IP protocol, the communication between the two parts ensures safe data transmission and the possibility to use different telecommunication means (GSM or satellite links).

Launched in January 2001, the Universal Remote Signal Acquisition For hEalth (U-R-Safe) tele-home care project (Mailhes et al., 2003), created a mobile telemedicine system for home monitoring to be used by elderly peaple and disabled patients in Europe. Via short range Wireless Personal Area Network (WPAN), wearable ECG and SpO_2 sensors are connected to a portable electronic device, able to send the recorded data to a remote central through the TCP/IP protocol and the wireless public network (GPRS, UMTS and GEO satellites). The portable unit is also capable of sending an alarm when patient fells sick, falls or pushes a button.

The Standard and Interoperable Satellite Solution to Deploy Health Care Services Over Wide Area (HEALTHWARE) project (Loghelongue, 2007), is an integrated project of the Aeronautics and Space thematic priority of the 6th Framework Program (FP6) for satellite telecommunications systems and telemedicine applications. Thanks to the digital video broadcasting - return channel by satellite (DVB-RCS) technology, that offers satellite reception and transmission capabilities from anywhere, the project aims at developing and validating DVB-RCS based telemedicine solutions. It will focus on the areas of chronic respiratory disease, cardiology and oncology, through four main applications: medical training, tele-consultation, second opinions and monitoring and remote assistance at home.

Even if these systems are very interesting, none of them owns the characteristics presented in Section 1, primarily the possibility to be used by untrained people to perform single exams rather then continuous monitoring, with an immediate visual confirmation of the quality of the signal measurement. None of them could be used by the patient to control his/her health state through simple measurements even without sending the exam to a remote care center.

3 THE PROPOSED DVB-T TELE-HOME CARE SYSTEM

Digital Television (DTV) uses digital encoding techniques to broadcast video, audio and data contents to a receiver in the consumer's home (set-top box). In order to add multimedia information to the normal television program, the Multimedia Home Platform (MHP) allows the user to actively interact with the TV (Interactive TV) obtaining useful services and information. Based on the JavaTV platform, an extension and standardization of existing Java APIs in the context of DTV, MHP enables the interaction between the interactive applications and the set-top box by a software interface (middleware). Over a Virtual Machine, JavaTV applications (called Xlets) run in the set-top box with the support of a real-time Operating System (OS), which provides all the functionalities required including hardware resources access.

3.1 System Overview

The proposed system is depicted in Figure 1. The patient must own a TV, a DVB-T set-top box (with its remote control) connected in uplink to the telephone line, a personal smart card and a simple Base Station unit for bio-signals acquisition. The *Remote Care Center* (RCC) instead, has only a simple PC acting as TCP/IP server, since the patient's set-top box can send through the Internet the result of the exams.

The *Base Station* is a simple microcontroller-based acquisition unit to perform the digital biosignals acquisition. It is connected to the set-top box for data visualization and transmission, and it is controlled by it and then indirectly by the user *only* through the set-top box remote control, then simplifying the overall procedure.

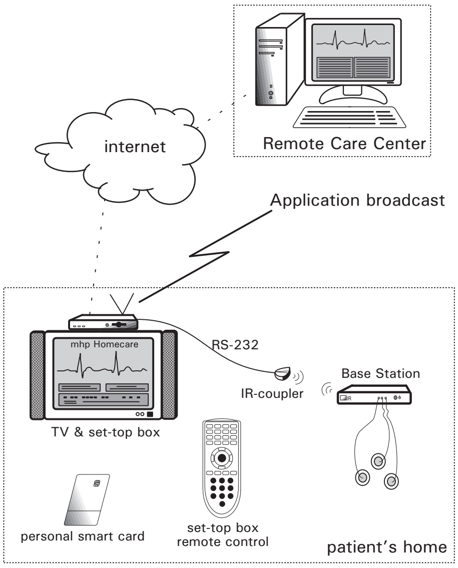

Figure 1: A schematic representation of the proposed DVB-T system for tele-home care.

The *smart card*, which must be programmed by the RCC, is used to identify the patient providing all the information needed to carry out the proper exams sending them to that RCC. The adoption of the smart-card for user authentication and to provide to the Xlet the required information about internet connection and RCC server IP address, avoids the patient to keep in mind or annotated elsewhere such information, improving the system usability. It also enables the personalization of the Xlet for the single user, since the exams that can be performed are only those programmed in the smart-card by the care staff. Since the largest part of DVB-T set-top boxes has a smart card reader (normally used for the pay-per-view services), no hardware on the base station is required to add this functionality.

The DVB-T MHP *set-top box* is like a computer, characterized by an input channel from user (the remote control), an output channel for the user (TV screen) and some ports to allow its interfacing with other devices, namely a serial port (RS-232) and an RJ-11 connector for the telephone line (since the set-top box has an internal modem), beyond the traditional audio/video connectors. The application presented in this paper has been tested on a Telesystem TS7.4DT set-top box, with the version 21p1 of the producer's software, and implementing the MHP 1.02 profile with some enhancements, primarily the addition of java packages for both the smart card and the serial RS-232 port management. The real-time OS is Osmosys. To interact with the base station, the set-top box uses the RS-232, whereas to send data to the RCC the integrated modem is used. In the proposed system the connection is in dial-up, so that it is surely simpler to have this facility in every home compared to broadband connections. The Xlet application is loaded into the set-top box by means of a broadcast transmission provided by a broadcaster, so that successive releases of it can be updated without the user's intervention.

3.2 Patient's User Interface

The graphic user interface (GUI) of the Xlet (hereafter called MHPHomecare) is user-friendly and intuitive, so that the patient can easily control the application by means of the remote control. The user can explore the application moving through the different full-screen frames (hereafter called FSFs), choosing among the possible options and functions by means of the remote control keys, as if it would be a PC keyboard. Three of the full-screen frames are generic whilst there is another FSF for each exam. The three generic FSFs are:

- the *primary* FSF, the first FSF shown when the application is started. It waits for the smart card insertion in the set-top box for user authentication and then it shows the patient's name (storing the other authentication data only for the transmission purposes), waiting for patient's commands. It is possible to close the application only from the primary FSF.
- the *about* FSF, that shows the application credits and can be launched only from the *primary* one;
- the *reduced* FSF, that corresponds to the window minimization to allow the patient to watch a TV program while the application is running in background. It can be launched from every FSF.

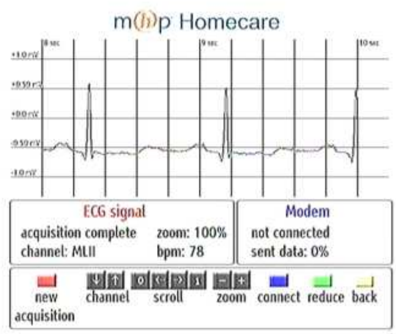

Figure 2: The ECG exam screen of the MHPHomecare application (ECG Exam FSF). The image has been acquired by means of a frame grabber from the set-top box video output, resulting in a poor quality and in altered colors.

In this application we used a simple 1-lead ECG to test the whole system, so there is only another FSF (a screenshot of this FSF is shown in Fig. 2), *ECG exam*. It enables the ECG acquisition and shows in real-time the samples acquired from the Base Station and all the other information sent by it about the current exam, such as the hearth rate (in bpm) and a warning message in case of poor quality signal. Once the exam has been saved, from the same FSF it is possible to send it to the server of the RCC, to review it on the TV (with zoom and scroll functions), to save a new exam or to return to the *primary* FSF. The patient can interact with the application moving through the different FSFs as depicted in Fig. 3.

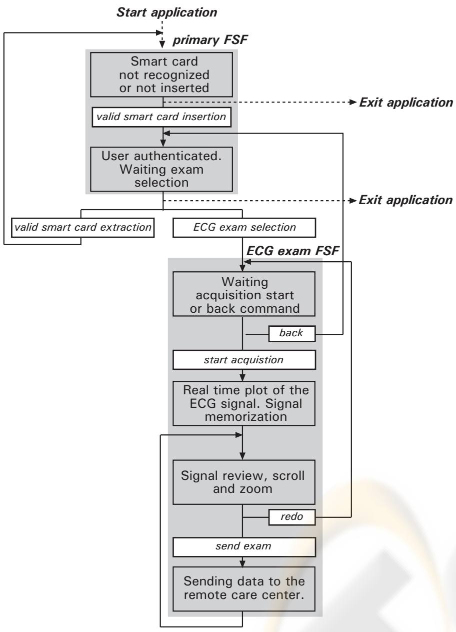

Figure 3: The interaction scheme between the patient and the set-top box application.

4 A PROTOTYPAL 1-LEAD ECG BASE STATION

In order to test our system we realized a simple microcontroller-based Base Station to acquire the patient's bio-signals. The Base Station is a black-box for the patient, and he cannot interact with it beyond the on/off power supply switch. The Base Station is battery powered, for simpler use and improved patient safety, and can include a different number of sensors and acquisition circuitry to serve different remote examination needs.

In the prototypal version presented in this work, it implements a single channel electrocardiogram (lead I) and consists in a classical ECG amplifier coupled with a very simple and low cost Digital Signal Controller (DSC), i.e. the Microchip^{TM} dsPIC30F4013. This is a 16-bit 30MIPS DSC enhanced with DSP hardware, such as a 17-bit x 17-bit multiplier, a 40-bit ALU, two 40-bit saturating accumulators and a 40-bit bidirectional barrel shifter. It also provides several embedded peripherals such as a 12-bit successive approximation analog to digital converter, and an USART, both of them employed in this prototype. The Base Station scheme is depicted in Fig. 4

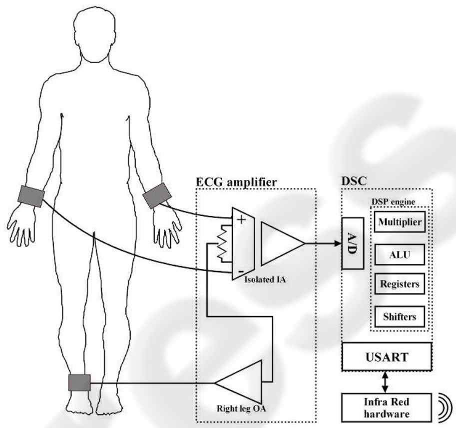

Figure 4: A schematic representation of the prototipal 1-lead ECG base station.

The fundamental characteristics of the Base Station (frequency bandwidth, sampling frequency and the number of bits of the A/D converter) are chosen according to the recommendations of American Heart Association for standardization and specifications in automated electrocardiography (Bailey et al., 1990). The ECG amplifier is a low-pass system with a variable gain up to 2000 and a cutoff frequency of 100 Hz. It consists of an optically isolated instrumentation amplifier with high CMRR connected to the wrists of the patient and a simple inverting operational amplifier connected to the right ankle for electromagnetic coupling noise rejection purpose, so that only 3 disposable (or reusable) electrodes are needed. The DSC is programmed to sample the ECG signal at 250 Hz, and it is interfaced through its internal USART to the DVB-T set-top box.

According to the international recommendations about the patient's safety, the physical connection between the Base Station and the set-top box is represented by an infrared (IR) link. The Base Station embeds a module for the IR transmission of the serial stream, whereas the set-top box exploits an external IR coupler connected to the RS-232 serial port.

In order to reduce both the residual 50/60 Hz environmental electrical noise we have implemented a digital notch filter, whereas a high-pass digital FIR filter (cutoff frequency 0.05 Hz) was added for the baseline drift elimination. All these computations are performed in real-time on the Base Station, since the set-top box is quite slow in processing due to the Java VM and to the applications running on it. On the Base Station has been also implemented a simple QRS detector for heart rate calculation and visualization on the TV screen (Friesen et al., 1990). The RR interval measurement is performed sample by sample, and if it is too far from the standards a warning code is sent to the set-top box to ask the user to control the correct connection of the electrodes. The average heart rate is sent when the acquisition stops and is referred to the average RR during the acquisition window.

5 THE INTERACTIVE APPLICATION: THE MHPHOMECARE XLET

MHPHomecare is a standalone application composed of several threads. It enables the non-simultaneous acquisition from the Base Station of an ECG exam, its visualization on the TV screen, and its sending via modem to the RCC where a server receives and stores the exam.

5.1 Graphic User Interface Thread

Taking into account the differences between PC and TV graphical applications, beyond the Java Abstract Window Toolkit (AWT), also the HAVi (Home Audio/Video Interoperability) API for graphic interfaces have been used (Java, 2007). We used Tiresias as default font, which has been created specifically for the TV screen, providing high readability and basing on the Western European ISO- 8859-1 fonts set.

A specific thread is in charge to create the objects related to the graphic elements composing the different FSFs of the application, and it shows/hides them depending on the current FSF.

5.2 Smart Card Management for User Identification

The smart card is read by means of the SATSA (Security and Trust Services API) classes (Satsa, 2007), that represent the new standard for smart card access in Java. To access the smart card, we used the methods based on the APDU (ISO7816-4) protocol, but the byte constituting the APDU strings are relative to the ACOS2 microprocessor card by Advanced Card Systems Ltd. To read the information stored into the memory of the card it is necessary to provide the CXS code to the method that opens the APDU connection, since the smart card is not a JavaCard (Dvt, 2006). A User Data File on the smart card stores the patient's name and its Personal Identification Code, the treating physician's name and its Identification Number, a permission exam code, some information about the ISP (user ID, password, telephone number) and the server IP address.

A thread, that is active in the primary FSF, verifies the correct insertion of the smart card into the reader, hence reading the User Data File. If the card is not properly inserted and recognized, the Xlet remains blocked on the primary FSF. Once the card has been recognized, the permission exam code is used to allow the user to perform only some specific exams among those available, hence disabling all the other ones.

5.3 Serial Port Management for Exam Acquisition

The serial port control is possible by means of the `it.dtt.comm` package, available on the set-top box used in this application. The communication follows analogue principles we can find in `javax.comm`, and the serial port behaves according with the RS-232 standard. A thread manages the communication through it.

The set-top box sends to the Base Station the commands to start the acquisition and to stop it. Both such commands are simply 1-byte words. The "start" command word is logically divided in two parts, i.e. the actual command to enable the serial port transmission, and a code that identifies the exam the user chose by means of the Xlet application. The set-top box receives from the serial port the samples of the current exam in frames composed of N samples each, where N changes from exam to exam as a function of the sample rate. The application deals with 8 or 16-bit signals (the data are stored in arrays of short). In the current implementation only the ECG is available on the Base Station, and it is acquired at 250 sample/sec, 16 bit/sample. With such sample rate and data width, the maximum re-painting rate of the graphic area where the signal is plotted is 200ms, which in turn means that a frame of input samples must consist of minimum N = 50 samples.

After the exam stops with a "stop" command word, the Base Station sends to the set-top box a last word with the value of the heart rate expressed in bpm so that the Xlet updates with this information the proper FSF.

5.4 Modem Management for Exam Transmission

A specific thread is in charge to manage the modem, and it operates by means of the `org.dvb.net.rc` package (Java, 2007), jointly with the `java.net` and `java.io` packages. The operations performed by means of these packages are: ISP number dialing, ISP authentication and TCP/IP data transfer towards the server by means of a socket opening.

The user can start the transmission to the RCC from the exam FSF simply pressing a key on its remote control. In response to this action, the thread establishes the connection with the ISP using the information previously read from the smart card. Once the connection with the ISP has been established, the thread opens a client socket specifying the IP address of the server of the RCC. This IP address is read from the smart card too, since different users need to send their exams to different RCCs. At this point, the thread sends a stream composed of two main parts: the patient's data and the exam data (collected during the acquisition phase). Once the whole data stream has been sent, the connection is closed and another exam can be acquired.

6 CONCLUSIONS

In this paper, a DVB-T framework for tele-home care was presented along with its prototype implementation.

Thanks to the DVB-T set-top box, which is very similar to a computer with the possibility to be programmed, the system can interact with external custom peripherals and can be connected to the web. Easy to use by people not skilled in digital electronics, and since tele-home care is mainly used to monitor elderly people which eventually falls in the previous category, pushed by the imminent deadline de fined by the UE for the switch-off of the old analog broadcasting transmission system, such tele-home care framework could represent the best solution in terms of quality and costs. Compared to traditional systems, the presence of a visual environment on the TV screen allows a more friendly use providing also more detailed information and feedbacks about the signal quality, and guiding the user through all the exam procedure without any required printed manual.

Experimental results show the high potentiality of the proposed solution and deserve further improvements such as the development of a more powerful base station (or a set of different base station models), the realization of a digital broadcasting system, and the extension to the official sanitary card, currently under trial in some Italian regions and in other European countries. It is actually under test a complete Visual application to read and analyze the exams on the Remote Care Center.

ACKNOWLEDGEMENTS

This work is part of the *Personal e-Care* project, which has been partially founded by INFN, the Nuclear Physics Italian Institute.

REFERENCES

Bailey, J., Berson, A., Garson, A., Horan, L., Macfarlane, P., Mortara, D., and Zywietz, C. (1990). Recommendations for standardization and specifications in automated electrocardiography: bandwidth and digital signal processing. In *Circulation*. American Heart Association.

Dvt (2006). Compatible dtv receivers for the italian market: baseline requirements - DGTVi D-Book 1.1 (rev.4). DGTVi.

Friesen, G. M., Jannett, T. C., Jadallah, M. A., Yates, S. L., Quint, S. R., and Nagle, H. T. (1990). A comparison of the noise sensitivity of nine QRS detection algorithms. *IEEE Transactions on Biomedical Engineering*, 37(1):85–98.

Java (2007). Javadoc for MHP specification. http://www.mhp.org/mhp_technology/mhp_1_0.

Kyriacou, E., Pavlopoulos, S., Koutsouris, D., Andreou, A., Pattichis, C., and Schizas, C. (2001). Multipurpose health care telemedicine system. In *Proc. of the 23rd Annual EMBS International Conference, Istanbul, Turkey*.

Loghelongue, P. (2007). Satellite based telemedicine: Accessibility, quality and safety. In *Proc. Tromso Telemedicine and eHealth Conference, Tromso, Norway, June*.

Mailhes, C., Castanié, F., Henrion, S., Lareng, L., Alonso, A., Weber, J.-L., Zeevi, B., Lochelongue, P., Depeursinge, Y., Kollias, V., and Ferhaoui, M. (2003). The U-R-Safe telemedicine project: improving health care of the elderly. In *Proc. of MIE2003, St.Malo, France*.

Pierucci, L. and DelRe, E. (2000). An interactive multimedia satellite telemedicine service. *IEEE MultiMedia*, 07(2):76–83.

Satsa (2007). Security and trust services API for J2ME (SATSA); JSR 177. http://java.sun.com/products/satsa.