TELKOMNIKA, Vol. 11, No. 4, April 2013, pp. 1750~ 1756
ISSN: 2302-4046

A Low-Cost Remote Healthcare Monitor System Based on Embedded Server

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Abstract

In the paper, we propose a scheme about a low-cost remote healthcare monitor system based on embedded server between home and hospital. In the scheme, we design an embedded server based on an ARM9 microprocessor. The embedded server supplies all kinds of interfaces such as GPIO interfaces, serial interfaces. These interfaces can acquire all kinds of physiology signals such as Electrocardiograph, heart rate, respiration wave, blood pressure, oxygen saturation, body temperature and so on through connecting the sensor modules. The network is based on local area network and adopts the Browser/Server model. Each home with an embedded server is as a server endpoint and the hospital is as a Browser endpoint. Every embedded server owns an independent static internet protocol address. The doctors can easily acquire patient's physiology information through writing patients internet protocol address on any computer browser. The embedded server can store patient's physiology information using database in an 8 GB SD card. The doctor can download the database information into the local computers. The system can conveniently upgrade all software in the embedded server only on a remote hospital computer. The remote healthcare monitor system based on embedded server has advantages of low-cost, convenience and feasibility.

Keywords*: low-cost, embedded server, remote healthcare monitor.*

1. Introduction

Financing health care systems are extremely problematic in many countries, such as in the United States, where healthcare coverage is still not universal, there is considerable proclivity to use expensive and new medical technology, and a significant portion of healthcare spending is accounted for by third-party payers. New financing systems will have to account for the greater healthcare needs of the elderly, especially in light of their increased numbers, older ages, and the continued development of expensive, new medical technologies [1]. So there is a great deal of interest these days in home or remote area monitoring of patients, particularly to cost considerations. If the same diagnostic information can be obtained from an ambulatory patient as can be found in the hospital, it is clearly more cost effective to do the monitoring in the home [2]. Advancements in electronic technology, communication technology, and information technology give opportunities to new telemedicine models for providing health monitoring in out-of-hospital conditions, and there is an increasing demand to provide home-based health care in China and other parts of the world [3].

In this paper, we propose a low-cost remote healthcare monitor system based on embedded server. The system architecture is shown in Figure 1. The network is based on local area network (LAN) and adopts the Browser/Server model. Each home with an embedded server is as a server endpoint and the hospital is as a Browser endpoint. An embedded server owns an independent internet protocol (IP) address. The module CSN808 is as a multi-parameter physiological module which can acquire physiological such as Electrocardiograph (ECG), heart rate, respiration wave, blood pressure, oxygen saturation, body temperature and so on. The patient wears the CSN808 module which connects with an embedded server through RS232 and the doctors can easily acquire patients' physiology information through writing patients IP address on computer browser in the hospital. At the same time, the physiology information is stored on an 8GB SD card of the embedded server.

Received January 5, 2013; Revised February 5, 2013; Accepted February 17, 2013

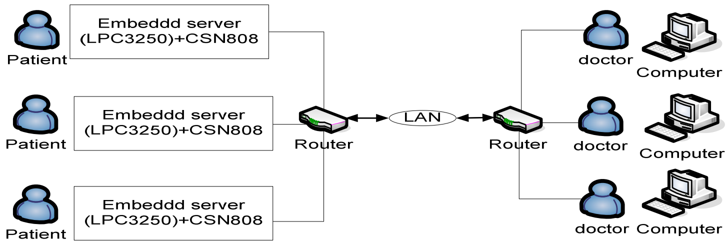

Figure 1. Architecture of Remote Home Medical Monitoring Network

We choose NXP Semiconductor's ARM9 microprocessor LPC3250 as the CPU of an embedded server and runs Linux as a real time operating system (OS). The Boa as a single tasking HTTP server software in the Linux OS makes LPC3250 become an embedded server. The common gateway interface (CGI) is a protocol that transmits data between the user web browser and the web server. SQLite is an embedded SQL database which records historical physiology information from patients at home. The embedded server communicates with CSN808 through RS232.

The doctors can get the webpage or invoke an executable program stored at the embedded server through the web browser and the Boa web server. Figure 2 shows system setup of the remote home medical monitoring network.

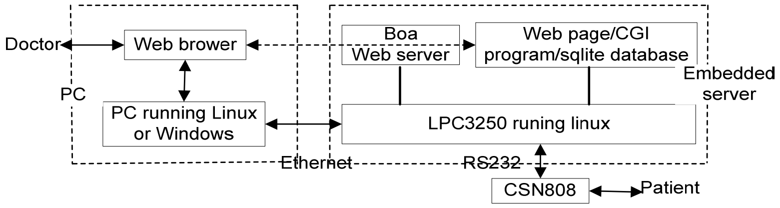

Figure 2. System Setup of the Remote Home Medical Monitoring Network

2. Hardware

We choose NXP Semiconductor's ARM9 microprocessor LPC3250 as the embedded server CPU. We use CSN808 module as a multi-parameter physiological module which integrates six kinds of sensors. Compared with other ARM9 chips, LPC3250 has many advantages. NXP Semiconductor designs the LPC3250 for embedded applications requiring high performance and low power consumption. NXP achieved their performance objectives using an ARM926EJ-S CPU core with a Vector Floating Point co-processor and a large set of standard peripherals, including USB On-The-Go. The LPC3250 operates at CPU frequencies up to 266MHz. The basic ARM926EJ-S CPU Core implementation uses a harvard architecture with a 5-stage pipeline. The ARM926EJ-S core also has an integral Memory Management Unit (MMU) to provide the virtual memory capabilities required to support the multi-programming demands of modern OS. The basic ARM926EJ-S core also includes a set of DSP instruction extensions including single cycle MAC operations and native Jazelle Java Byte-code execution in hardware. The NXP implementation has one 32KB Instruction Cache and one 32KB Data Cache.

For low power consumption, the LPC3250 takes advantage of NXP Semiconductor's advanced technology development expertise to optimize Intrinsic Power, and software controlled architectural enhancements to optimize Power Management. The LPC3250 also includes 128 to 256KB of on-chip static RAM, a NAND Flash interface, an Ethernet MAC, an LCD controller that supports STN and TFT panels, and an external bus interface that supports SDR and DDR SDRAM as well as static devices. In addition, the LPC3250 includes a USB 2.0 Full Speed interface, seven UARTs, two I2C interfaces, two SPI/SSP ports, two I2S interfaces, two single output PWMs, a motor control PWM, four general purpose timers with capture inputs and compare outputs, a Secure Digital (SD) interface, and a 10-bit A/D converter with a touch screen sense option [4]. Hardware architecture of the embedded server is shown in Figure 3.

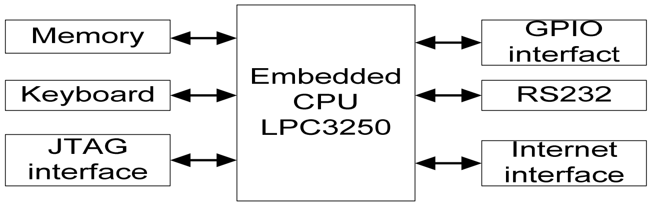

Figure 3. Hardware Architecture of the Embedded Server

CSN808 is a multi-parameter physiological module which measures and monitors heart wave, heart beat rate, blood pressure, oxygen saturation, body temperature. Module has below features:

a. Compact size (130*93*18mm) and installed easily.
b. Parameters: ECG, SpO2, NIBP, Temperature, HR, PR, RR.
c. Sample the I-lead, II-lead, V-lead ECG data simultaneously.
d. Applicable to adult, pediatric and neonate.
e. Detailed error information prompt.
f. Anti-HF electro surgical unit and defibrillator proof.
g. Module can communicate with ARM9 embedded server through RS232.

3. Software

Software of the embedded server consists of the embedded Linux OS, the embedded server Boa and the application software including JavaScript, CGI, SQLite. Software architecture of the embedded server is shown in Figure 4.

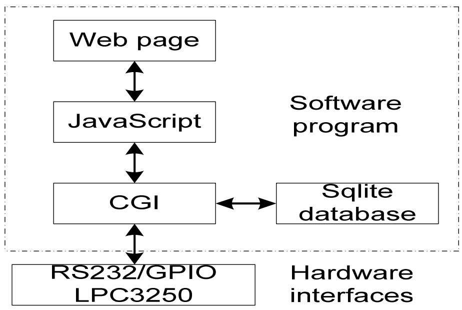

Figure 4. Software Architecture of the Embedded Server

3.1. Software Description

Boa. Generally speaking, the embedded devices have limited resources and don't need to handle the requests of many users simultaneously. Therefore they do not need to use the most commonly used Linux server Apache. Web server which is specifically designed for embedded devices are applied in such case. This kind of Web server requires relatively small storage space and less memory to run, which makes it quite suitable for embedded applications. Boa is a single task Web server. The difference between Boa and traditional Web server is that when a connection request arrives, Boa does not create a separate process for each connection, nor handle multiple connections by copying itself. Instead, Boa handles multiple connections by establishing a list of HTTP requests, but it only forks new process for CGI program. In this way, the system resources are saved to the largest extent [5].

JavaScript. JavaScript is the main scripting language for Web browsers, and it is essential to modern Web applications. The script language is embedded into the HTML page and it is easy to control the page and develop the Web server. It implemented as part of a Web browser in order to provide enhanced user interfaces and dynamic websites.

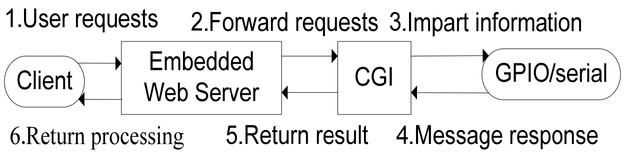

Figure 5. Interaction between the Client and the External Interfaces through CGI

CGI. Web server is mainly achieved by CGI, which is a process running on the Web server and a standard for interfacing external applications with information servers. The flow chart is shown in Figure 5, where the client interacts with the external interfaces through CGI. In addition, CGI defines that Web server how to send information to the external programs, which output HTML code and how to handle the content after receiving the information of expanded applications [6]. CGI programs can be produced in any programming language, for example, Shell scripting language, Perl, Fortran, Pascal and C language and so on [5].

SQLite. SQLite is an open source embedded database. It is completely independent without external dependencies which can be more easily used in embedded system, run in all major OS and supports most of the computer language [7].

3.2. Software Configuration

As embedded system with limited resources, this system uses cross-compilation build environment debug way. For embedded Linux, a PC is used as the host machine. The host machine is installed Linux system, arm-linux-gcc and cross compiler for the target processor, associated development tools and debugging tools.

In the system we select 2.6.27 Linux kernel and the version of the kernel provides full support for LPC3250 processor. The work of embedded Linux OS needs transplant Linux OS. Transplanting work includes: kernel configuration, modifying on the appropriate architecture code, connecting script, loading the file system, transplanting driver. And then build the mirror program to flash of the system board, Linux development platform is built.

0.94.13 version of embedded server Boa is selected. Boa needs to establish a Boa directory in the root file system “/etc/boa”. A configuration file “boa.conf” is copied into this directory and will be loaded when the Boa boots. This file must be edited before the Boa program is running.

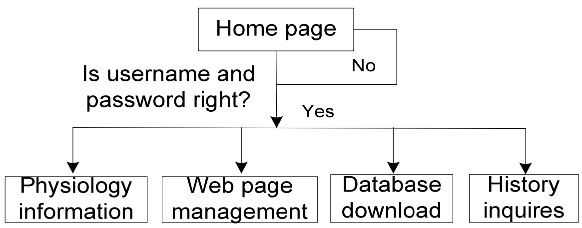

Figure 6. Webpage Architecture of the System

3.3. Software design

Webpage design uses HTML language and JavaScript language with dreamweaver8 software tool. Figure 6 shows webpage architecture of the system. Firstly, doctors log in home page which needs a username and password. If username and password is right, doctors can enter the sub webpage. Sub webpage consists of four web pages that are showing of physiology information, management of webpage, database download and history inquiry. Webpage which shows physiology information is shown in Figure 7. It mainly shows all kinds of physiology data of patients such as ECG, heart rate, respiration wave, blood pressure, oxygen saturation, body temperature and so on. The function of the second webpage updates program in time such as webpage update, bottom layer drive update, CGI program update, database update and so on and it is shown in Figure 8. The function of webpage of downloading database easily makes doctors download database which records historical physiology information and it is shown in Figure 9. Doctors download physiology information of patients in the local database and manage it conveniently. The function of webpage of history inquiry makes doctors see the historical physiology information easily which is stored in SD card using SQLite database.

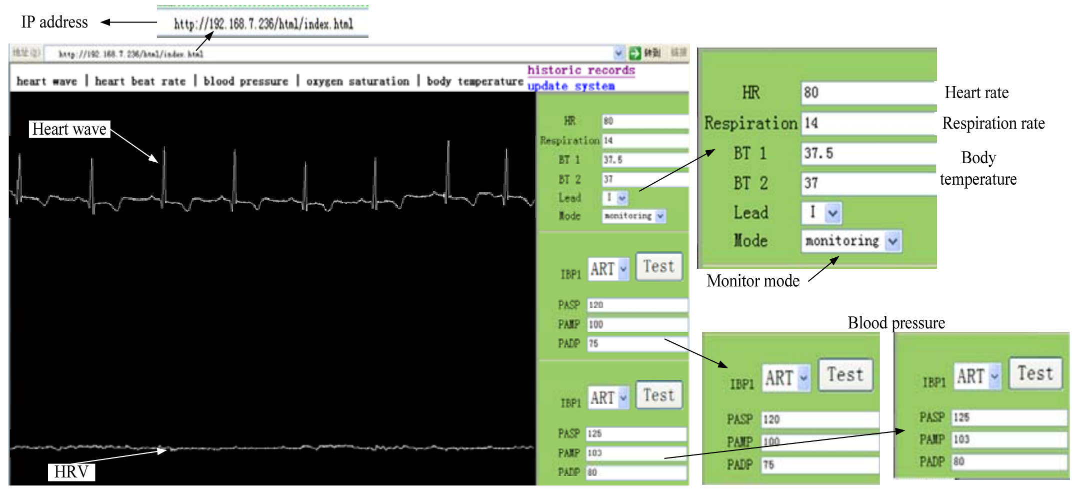

Figure 7. The Webpage Shows the Physiological Information.

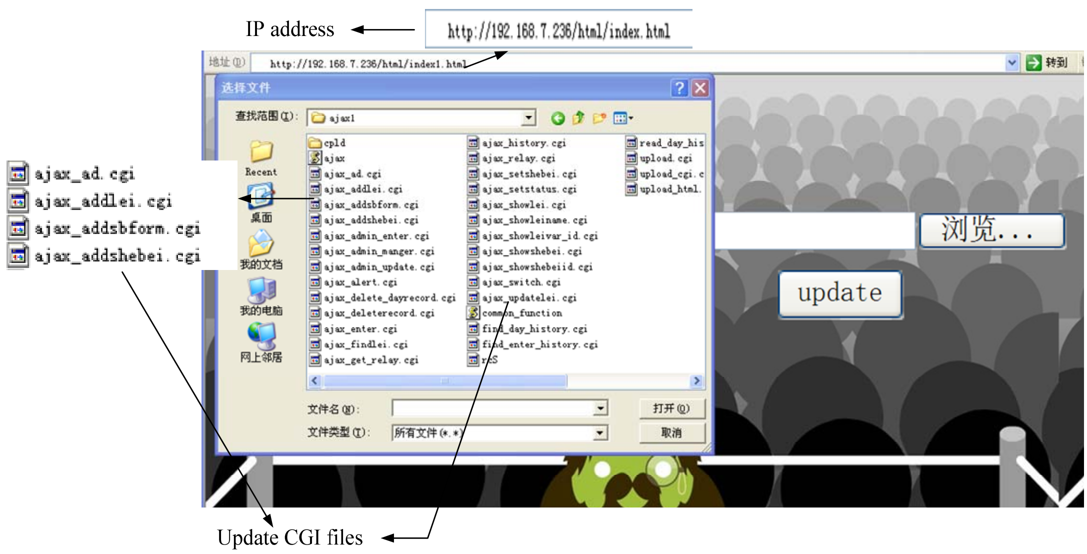

Figure 8. The Webpage Shows Management Function

The C language is chosen to write CGI program in the present paper. This service technology makes browser and server interactive. The browser sends a request to CGI with two methods, “GET” and “POST”. We use “GET” method in this paper. CGI receives the request and runs the relative program. If CGI wants to send an answer to browser, CGI needs use C language standard “printf” function to output the answer.

Embedded database SQLite provides 83 Application Program Interface (API) interface functions of C language, making operation of the database is very simple. In this system we only use four API interface functions which are “sqlite3_open”, “sqlite3_exec”, “sqlite3_get_table” and “sqlite3_close” respectively. These functions are used to realize storing and acquiring of physiological information in the embedded server.

Figure 9. The Webpage Shows Historic Records

4. Technical Performance of the System and Usage

To verify the performances of the measurement system, experiments were conducted using twenty healthy subjects (20 xanthoderm, 10 male, and 10 female) aged between 21 and 40 years (mean 30.70 years and standard deviation 5.37years) and five doctors acquired the physiological information through the web using different computers at the same time. The experimentation has concerned as follows:

- Sustainability of physiological data.
- Real time of physiological data.
- Reliability of storage function.
- Precision rate of physiological data transmission.

ECG data were sampled at 200 samples per second, thus resulting in a generation of 1600 bps per lead for the ECG. SpO2, HR, BP, and temperature data were updated with are fresh rate of 1/s, thus adding only a small fraction of data to be transmitted. The system bandwidth was about 100Mbps, enough for data transmission. Trough continuous 4 hours test, ECG data transmission was interrupted only in 2% of the cases, and the other physiological information such as SpO2, HR, BP, and temperature data were not interrupted. During physiological data transmission, all collected data were stored in the local embedded server. In the previous studies [8], BP/SpO2 transmission was interrupted in 9% of the cases and real-time ECG transmission was interrupted in 27%. As shown in Figure 10, the system based embedded server presented an excellent robustness, reliability and stable.

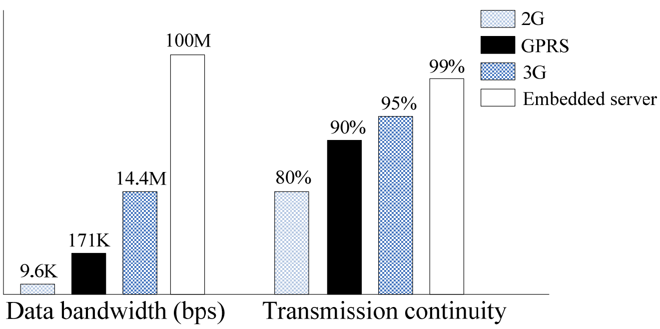

Figure 10. Compared based on Different Transmission Systems

The low-cost remote healthcare monitor system based on embedded server has been tested to verify its feasibility. The patient is monitored using CSN808 module which connects with an embedded server through RS232 and the doctor can log in the browser in this embedded server in the hospital. The physiological data is displayed in the browser in a real time. Doctor downloads database about patients physiological information successfully and updates software only taking several seconds.

5. Conclusion

In this article, we have presented a low-cost remote healthcare monitor system and discussed the hardware and software based on embedded server LPC3250.

Compared with other similar system of remote healthcare monitor, our scheme has many advantages. Firstly, as shown in Figure 10, system supplies enough transmission bandwidth. ECG data are sampled at 200 samples per second, thus resulting in a generation of 1600bps per lead for the ECG and ten leads only about 16Kbps. Secondly, our embedded server has many great functions. We only use a RS232 interface connecting CON808 and other interfaces such as GPIO interfaces, AD interfaces, SPI interfaces and IIC interfaces are not used. These interfaces may be developed to monitor other information such as Parkinson [9] in the future. Thirdly, the network adopts the Browser/Server model. Compared with Client/Server model, Browser/Server model is simple to use, convenient to maintain, and easy to extend, particularly to upgrade software in the embedded server. For example, if the doctor in the hospital wants to upgrade the system software, he only needs log in the home webpage and enter into update webpage which only takes several seconds.

We will develop a graphical interface using Qt technology on the touch panel LCD in the future work [10, 11]. The Qt program can make patients better interact with the doctors and CSN808 or other sensor module. For example, the patients can acquire the doctor advice in time and the LCD also can show the physiological information in a real time.

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