Proceedings of the 28th IEEE
EMBS Annual International Conference
New York City, USA, Aug 30-Sept 3, 2006

Design and Implementation of a Mobile-Care System over Wireless Sensor Network for Home Healthcare Applications

Ren-Guey Lee[1], Chien-Chih Lai[1], Shao-Shan Chiang[2], Hsin-Sheng Liu[1],
Chun-Chang Chen[1], and Guan-Yu Hsieh[1]
[1]Department of Electronic Engineering, National Taipei University of Technology, Taipei, Taiwan, R.O.C.
[2]Department of Electrical Engineering, Lunghwa University of Science and Technology, Taoyuan, Taiwan, R.O.C.

***Abstract*—According to home healthcare requirement of chronic patients, this paper proposes a mobile-care system integrated with a variety of vital-sign monitoring, where all the front-end vital-sign measuring devices are portable and have the ability of short-range wireless communication. In order to make the system more suitable for home applications, the technology of wireless sensor network is introduced to transmit the captured vital signs to the residential gateway by means of multi-hop relay. Then the residential gateway uploads data to the care server via Internet to carry out patient's condition monitoring and the management of pathological data. Furthermore, the system is added in the alarm mechanism, which the portable care device is able to immediately perceive the critical condition of the patient and to send a warning message to medical and nursing personnels in order to achieve the goal of prompt rescue.**

***Keywords*—Mobile-care, wireless sensor network, home healthcare.**

I. Introduction

Along with the approaching of aging society, the most important issue is the long-term home healthcare service for senior citizens. The probability that a senior citizen suffers from a chronic disease is relatively high, and due to diseases, a chronic patient may be unable to look after oneself in daily life, or patient's conditions must be observed for a long term. Under such situations, the required medical care or patient's condition monitoring must be provided through professional medical personnels so that the consumed manpower and social cost will be considerably high. In order to further reduce the waste of medical resources and achieve real-time care service, the concept of tele-care emerges by integrating the information and communication technologies [1], [2]. Therefore, it is an inevitable trend to create an appropriate home healthcare service by making use of tele-care.

This paper primarily carries out design and development of the home healthcare system focused on the chronic patients with heart disease and hypertension. In the existing home tele-care system, data access at the patient-end is still by way of wired transmission from the vital-sign measuring devices (e.g. cardiograph and hemadynamometer etc.). And the existing front-end capturing devices are not easy to carry due to the size, so the patient's vital signs must be measured in a specific location of the house. Therefore, considering the convenience of carrying and using at home, this paper proposes a home mobile-care system with mobility by introducing the concept of mobile-care [3]–[6] and the technology of wireless sensor network (WSN) [7]–[10], as shown in Fig. 1. Since all the front-end vital-sign measuring devices are portable and possess the ability of short-range wireless communication, which are called mobile-care devices, the patients' vital signs can be measured at any time any place at home. The captured vital signs are first transmitted to the residential gateway (RG) installed in the patient's home by means of multi-hop relay via the nodes of the WSN at home. Then the physiological data is uploaded to the care server at the care center set up in the hospital via Internet so that the professional medical and nursing personnels can analyze the monitoring results and provide appropriate care services.

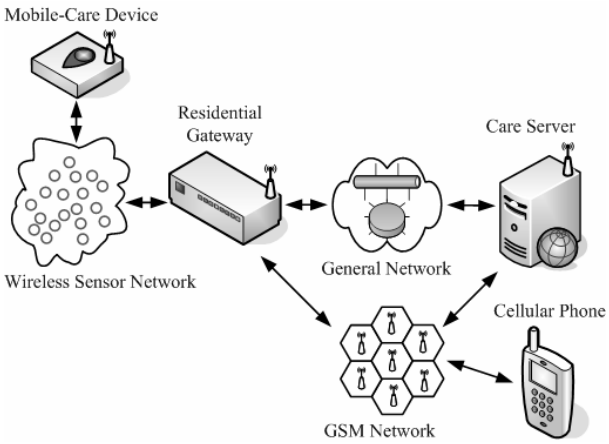

Fig. 1. The architecture of the proposed home mobile-care system.

In Section II, we first introduce the architecture of the proposed home mobile-care system. Then the circumstance of system usage and design of the system are described in detail in Section III and Section IV respectively. Finally in Section V, the feasibility of the proposed system is validated by means of experiment results.

II. The Architecture of the Home Mobile-Care System

The architecture of the home mobile-care system is shown in Fig. 1. According to the state of illness, the patient wears the specific mobile-care device to measure the vital-sign

parameters. Then the captured data is transmitted to the RG by the short-range wireless communication module in the device in order to continuously monitor and record the patient's condition.

Due to the limited transmission range of the mobile-care device, the patient may walk everywhere in the house and probably go out of the transmission range. Then the device will lose connection with the RG so that the possible symptom records will be missing. In order to extend the transmission distance between the RG and the mobile-care device, a sufficient amount of wireless sensor nodes are arranged to build a WSN in the patient's home. The wireless sensor nodes utilize the same short-range wireless transmission media as that the mobile-care device uses. Consequently, no matter where the patient walks within the house, the WSN always can get connected with the mobile-care device and transmit the captured vital-sign parameters from the mobile-care device to the RG by means of multi-hop relay.

The RG is primarily responsible for collecting and recording the patient's vital-sign data and then uploading to the care server by way of the existing cable network, such as Ethernet and CATV network etc.

The care server is located in the care center in the hospital. It is primarily in charge of analyzing and storing the data from every RG into database so that the medical and nursing personnels can monitor the patients' conditions. In case the analysis result determines an emergency happening to patients, the care server immediately sends out a warning message via GSM network to alert the care provider (such as patient's family or nurses), even directly call the ambulance to patient's residence so as to rescue in time.

III. The Circumstance of System Usage

In this section, the circumstance of system usage and the workflow of the care system are illustrated respectively by examples of chronic patients with heart disease and hypertension.

A. In the Case of Heart Disease

At any time the patient wears a portable cardiograph. By means of the RG and WSN, the remote care server regularly acquires the cardiopathy patient's electrocardiogram (ECG) pattern and gains heart rate (HR) to determine if the patient suffers from arrhythmias or heart rate variability (HRV) etc. Whenever the patient's condition becomes critical, the care server will automatically alert the care provider. The circumstance of system usage is shown in Fig. 2. The system workflow is described as follows:

(1) The care server requests the RG to collect the patient's heart rate.
(2) The RG requests the mobile-care device to capture the patient's heart rate.
(3) The mobile-care device responds the patient's heart rate to the RG.

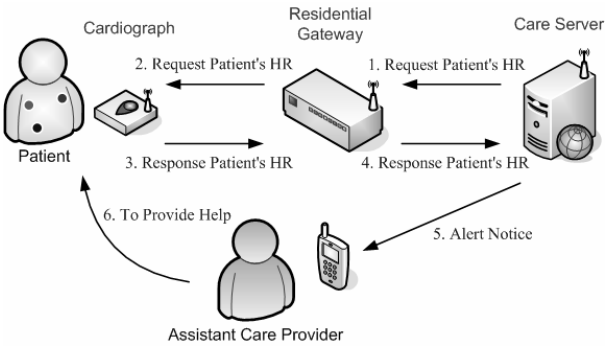

Fig. 2. Circumstance in the case of heart disease.

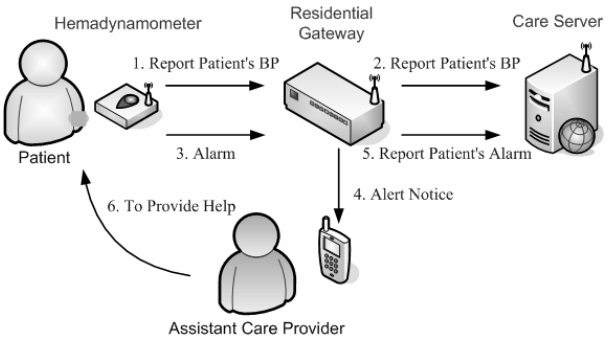

Fig. 3. Circumstance in the case of hypertension.

(4) The RG responds heart rate to the care server.
(5) The care server analyzes the heart rate. If the analysis result reveals abnormal heart rate, the care server sends out the alert message to notify the care provider.
(6) The care provider promptly goes to the patient's residence to provide help.

B. In the Case of Hypertension

At any moment the patient wears a wrist-type hemadynamometer. The remote care server regularly gets blood pressure (BP) of the patient by way of the RG and WSN. While the patient feels uncomfortable, the patient can press the help button on the hemadynamometer so that the RG automatically forwards the alert message to notify the care provider for prompt help service. Fig. 3 shows the circumstance of system usage, and the system workflow is detailed as follows:

(1) The mobile-care device reports the measured blood pressure back to the RG.
(2) The RG uploads the measured blood pressure to the care server.
(3) The patient feels uncomfortable and presses the help button on the mobile-care device to alert the RG.
(4) The RG sends the emergency call-help message to the care provider.
(5) The RG reports the emergency call-help message to the care server.
(6) The care provider immediately goes to the patient's residence to help.

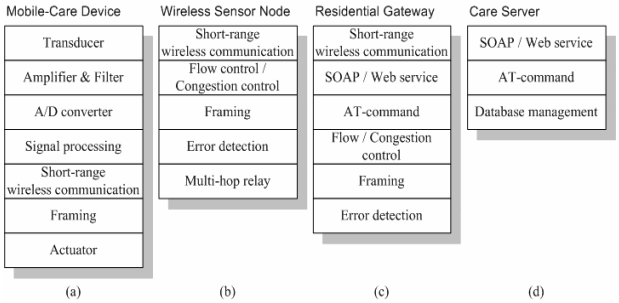

Fig. 4. The functions of the home mobile-care system: (a) mobile-care device, (b) wireless sensor node, (c) residential gateway, (d) care server.

IV. Design of the Mobile-Care System

The proposed home mobile-care system can be divided into four major parts, the mobile-care devices, the WSN, the RG and the care server. The designs and functions of the subsystems with regard to the four parts are described respectively as follows.

A. Mobile-Care Devices

This device mainly utilizes a bio-sensor. It first transforms the patient's vital-signs into analog voltages to be preprocessed by amplifiers and filters. Then the device digitizes the analog signal by an Analog-to-Digital (A/D) converter. At last the digital signal is processed and encapsulated into packets which are transmitted to wireless sensor nodes by means of short-range wireless communication. Fig. 4(a) shows the key functions diagram of the mobile-care device.

B. Wireless Sensor Network (WSN)-Wireless Sensor Nodes

The WSN generally consists of several wireless sensor nodes. Each node is provided with the ability of short-range wireless communication for forwarding the packets between the wireless mobile device and the RG. Because wireless sensor nodes transmit data packets by means of multi-hop relay, it must verify the validity of the packets before forwarding and must determine the forwarding time according to the network flow in order to achieve flow/congestion control. Fig. 4(b) shows the kernel functions of a wireless sensor node.

C. Residential Gateway (RG)

The RG communicates with wireless sensor nodes by means of short-range wireless communication to collect and store the patient's physiological parameters. It encapsulates the physiological data into XML format with SOAP header to transmit using the technology of web service. So it can pass through various firewalls to achieve the function of cross-platform service. In addition, if an emergent call-help message is received from the WSN, the RG will dispatch the alert message in AT-command format to the cellular phone of the care provider by way of GSM modules to complete the procedure of the emergency call-help. Fig. 4(c) illustrates the kernel functions of the RG.

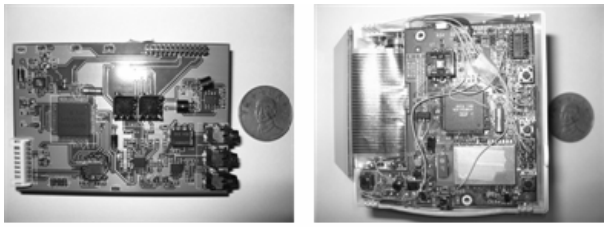

Fig. 5. Mobile-care devices: (a) a portable cardiograph, (b) a wireless wrist-type hemadynamometer.

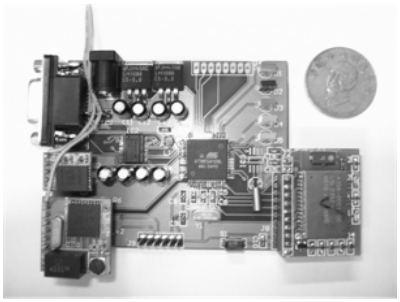

Fig. 6. A wireless sensor node.

D. Care Server

The care server communicates with the RG by the technology of Internet service so as to collect and store each patient's physiological parameters for monitoring and analyzing patients' conditions. If it is judged that the patient is in a critical condition, the care server will immediately send an alert message to the cellular phone of the care provider for help. The kernel function diagram of the care server is shown in Fig. 4(d).

V. Implementation Results

In this section, a system prototype is implemented according to the design and functions of the home mobile-care system described above.

The development of mobile-care devices is aimed at patients with heart disease or hypertension, and Fig. 5 is the entity picture of devices. The portable cardiograph uses MSP430F449 micro controller manufactured by Texas Instruments (TI) Corp. as the major component incorporated with front-side analog signal processing circuit. And the wireless wrist-type hemadynamometer is integrated with ATmega169V micro controller produced by Atmel Corp., analog circuit, pump and valve mechanism. Nevertheless, both devices are installed Bluetooth module to have the ability of short-range wireless communication.

The wireless sensor node uses ATmega128L micro controller made by Atmel Corp. as the kernel component. The medium of communication between nodes is by means of frequency-shift keying (FSK) radio frequency (RF) modules, and the communication between nodes and the mobile-care device is by way of Bluetooth modules. Fig. 6 demonstrates an entire sensor node.

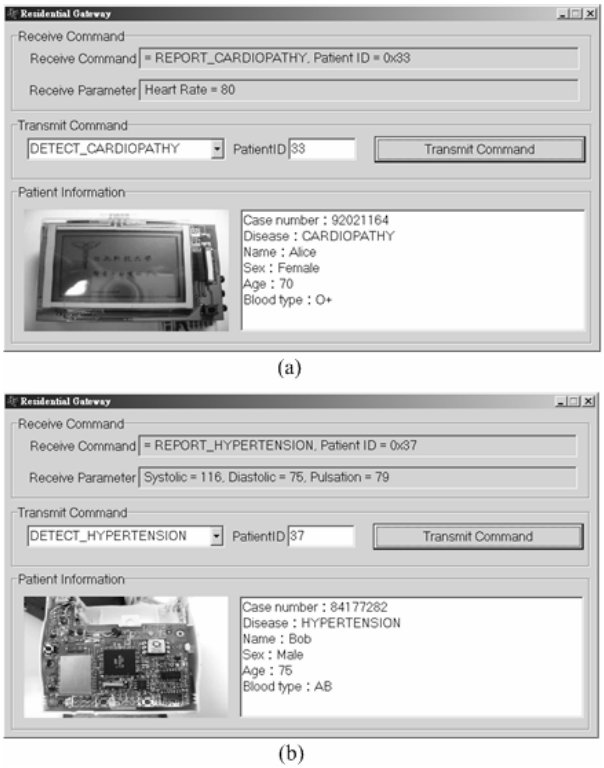

Fig. 7. The running window of residential gateway: (a) for heart rate measuring, (b) for blood pressure measuring.

The software run in the RG is programmed by the Windows-based development software C++ Builder to run on personal computer (PC) platform. Fig. 7 demonstrates the running windows of the RG that display the captured heart rate and blood pressure respectively.

The back-end programs run on the care server are developed by the Windows-based development software Visual Basic incorporated with the database SQL Server 2000 for recording the physiological information of patients from each RG. Furthermore, when the patient's condition becomes critical, the server system will automatically send out a call-help message to the care provider. The running results of the back-end care platform are shown in Fig. 8.

VI. Conclusions

This paper proposes a home mobile-care system possessing the mobile ability. The entire system consists of four major divisions, which are the mobile-care device, the WSN, the RG and the care server. The mobile-care device is responsible for measuring patient's physiological parameters. The WSN is used for extensive data transmission distance. The RG is in charge to collect patient's physiological information. And the care server is provided with a database management system. The system is capable of performing long-term monitoring of patients' conditions, and is provided with warning rescue mechanism. The implementation results can further validate the feasibility of the proposed home mobile-care system.

In this paper, the implemented system prototype is only aimed at the patients with heart disease and hypertension, and is validated its feasibility. Nevertheless, the system can be upgraded by adding functions on other chronic diseases such as asthma and diabetes in order to achieve the monitoring of integrated multi-physiological parameter measures and the purpose of care providing. Furthermore, the RG is running on a PC-based platform. The programs can be transplanted to an embedded system platform in order to reduce the cost and size. In current stage, the care server is only for the use of data storage. In the future, it can introduce the technology of data mining so that it can further carry out the analysis of patient's condition and the tracing of medical history.

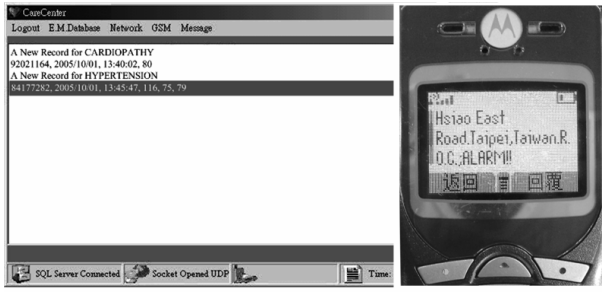

Fig. 8. The back-end care platform: (a) the running window of the care server, (b) the call-help message received by the care provider.

Acknowledgment

This work was supported by the National Science Council, Taiwan, R.O.C., under Grant NSC 94-2213-E027-012.

References

[1] R.-G. Lee, H.-S. Chen, C.-C. Lin, K.-C. Chang, and J.-H. Chen, "Home Telecare System Using Cable Television Plants—An Experimental Field Trial," *IEEE Trans. Inform. Technol. Biomed.*, vol. 4, no. 1, pp. 37–44, Mar. 2000.

[2] R.-G. Lee and K.-C. Chang, "A Short Message Service Based Design for a Portable Tele-Alarm Device," *J. Biomed. Eng. Applicat., Basis Commun.*, vol. 14, no. 3, pp. 109–114, June 2002.

[3] B. Woodward, R. S. H. Istepanian, and C. I. Richards, "Design of a Telemedicine System Using a Mobile Telephone," *IEEE Trans. Inform. Technol. Biomed.*, vol. 5, no. 1, pp. 13–15, Mar. 2001.

[4] K. Siau, "Health Care Informatics," *IEEE Trans. Inform. Technol. Biomed.*, vol. 7, no. 1, pp. 1–7, Mar. 2003.

[5] R. S. H. Istepanian, E. Jovanov, and Y. T. Zhang, "Guest Editorial Introduction to the Special Section on M-Health: Beyond Seamless Mobility and Global Wireless Health-Care Connectivity," *IEEE Trans. Inform. Technol. Biomed.*, vol. 8, no. 4, pp. 405–414, Dec. 2004.

[6] J. R. Gallego, A. Hernandez-Solana, M. Canales, J. Lafuente, A. Valdovinos, and J. Fernandez-Navajas, "Performance Analysis of Multiplexed Medical Data Transmission for Mobile Emergency Care Over the UMTS Channel," *IEEE Trans. Inform. Technol. Biomed.*, vol. 9, no. 1, pp. 13–22, Mar. 2005.

[7] I. F. Akyildiz, S. Weilian, Y. Sankara-subramaniam, and E. Cayirci, "A Survey on Sensor Networks," *IEEE Commun. Mag.*, vol. 40, no. 8, pp. 102–114, Aug. 2002.

[8] K. Lorincz, D. J. Malan, T. R. F. Fulford-Jones, A. Nawoj, A. Clavel, V. Shnayder, G. Mainland, M. Welsh, and S. Moulton, "Sensor Networks for Emergency Response: Challenges and Opportunities," *IEEE Pervasive Comput.*, vol. 3, no. 4, pp.16–23, Oct./Dec. 2004.

[9] W. Ye, J. Heidemann, and D. Estrin, "Medium Access Control With Coordinated Adaptive Sleeping for Wireless Sensor Networks," *IEEE/ACM Trans. Networking*, vol. 12, no. 3, pp. 493–506, June 2004.

[10] S. H. Choi, B. K. Kim, J. Park, C. H. Kang, and D. S. Eom, "An Implementation of Wireless Sensor Network for Security System using Bluetooth," *IEEE Trans. Consumer Electron.*, vol. 50, no. 1, pp. 236–244, Feb. 2004.