A Wireless Body Sensor Network Platform for Ubiquitous Health Care

Young-Dong Lee*, Do-Un Jeong** and Wan-Young Chung***

*Graduate School of Software, Dongseo University, Busan, Korea, ydlee2@gmail.com
**Division of Internet Engineering, Dongseo University, Busan, Korea, dujeong@dongseo.ac.kr
***Division of Internet Engineering, Dongseo University, Busan, Korea, wychung@dongseo.ac.kr

ABSTRACT

Recent advancement in wireless communication technology and electronics has enabled the development of low power sensor network. Wireless sensor network are often used in remote monitoring control applications, health care, security and environmental monitoring. In this study, wireless body sensor network platform for Ubiquitous health care has been designed, fabricated and tested. The system consists of a micro-controller with internal flash program memory, low power radio transceiver, power battery, a serial port, I/O expansion connector as the input port of sensor interface circuit. An ATmega128L 8-bit ultra low power RISC processor (Atmel Ltd., USA) with 128KB flash memory as the program memory and 4KB SRAM as the data memory was used for hardware platform. To approve the capabilities of the fabricated sensor network platform for wireless body sensor network applications, ECG measuring circuit was attached to the sensor network platform and the performance of the TinyOS-based sensor network platform was checked.

Keywords: Wireless Body Sensor Network, Ubiquitous Health Care, Low Power, ECG, TinyOS

1. INTRODUCTION

Nowadays, low power sensor network technology is very important in wireless communication technology. Wireless sensor network has been often used in remote monitoring control applications, Ubiquitous health care, security and environmental monitoring[1]. Wireless sensor networking has composed of small, low-power [2], and low-cost devices that integrate limited computation, sensing, and radio communication capabilities.

With the maturity of sensing and pervasive[3] computing[4] techniques, extensive research is being carried out in using sensor networks for health care. The concept of ubiquitous health care is to use unobtrusive sensors that are placed around the person's body to form a wirelessly connected network[5].

Figure 1 shows system configuration of Ubiquitous health care for monitoring the status of the patient. The health parameters on the body of a patient were monitored via internet/IEEE 802.11(WLAN) by PC or PDA. The system consists of sensor nodes, a base-station and display unit, that is, PC or PDA. The sensor node, which have multiple sensing elements, in attached to a subject for monitoring health parameters, and the data from the sensor unit is sent to the base-station via a RF transmitter. One of the major design issues addressed for the sensor node was to develop a small size, low power wireless sensor node [6] which can be attached on the body of the person. The base-station is a stand-alone unit, which is able to receive the data from sensor node using a RF receiver, store it and also transfer it to a mobile unit using Internet/IEEE 802.11(WLAN).

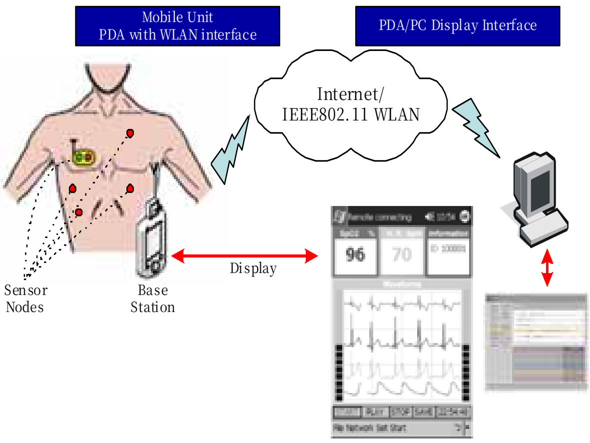

Figure 1 : Ubiquitous health care system for monitoring the status of the patient.

In this study, wireless body sensor network platform for Ubiquitous health care was designed, fabricated and tested. In addition, ECG measurement circuit was attached and tested to TinyOS-based sensor network platform.

2. SYSTEM DESIGN

2.1 Device Design

Figure 2 shows the block diagram of the fabricated body sensor network platform in this study, which consists of five major modules: a micro-controller with internal flash program memory, low power radio transceiver, power battery, a serial port, I/O expansion connector as the input port of sensor interface circuit.

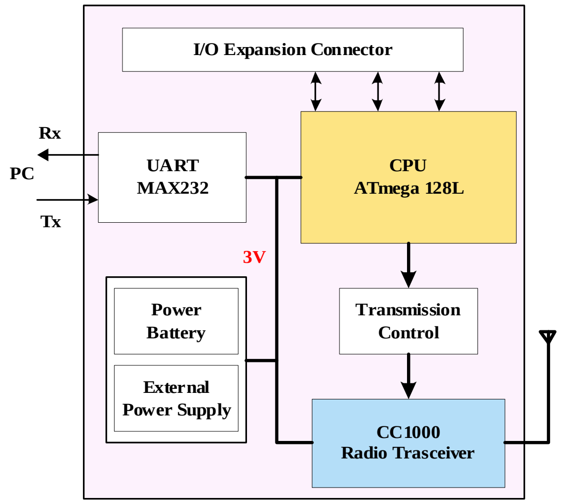

Figure 2 : The block diagram of fabricated body sensor network platform

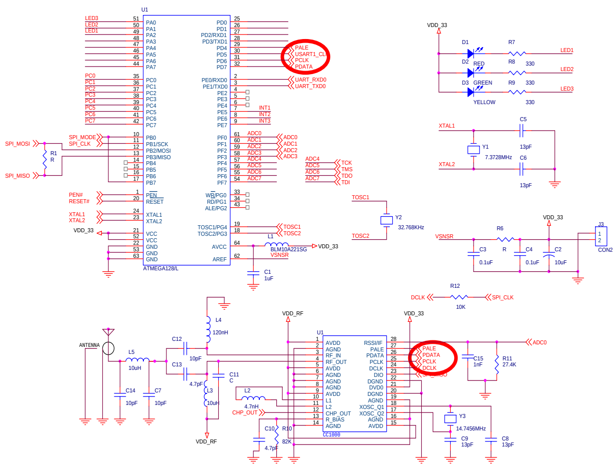

Figure 3 : Schematic of sensor network platform.

An Atmel ATmega128L running at 8MHz and delivering about million instructions per second (MIPS) was used as the main micro-controller in the sensor platform. Normally ATmega128 can be used for micro-controller in sensor node, however Atmel ATmega128L was used to save operating power in our study[7]. This 8-bit micro-controller has 128KB flash program memory, 4KB static RAM, 10-bit analog-to-digital converter, four hardware timers, 53 general-purpose I/O lines, two external universal asynchronous receiver transmitter (UART) and one serial peripheral interface (SPI) port. A CC1000 RF wireless transceiver (Chipcon Ltd., Norway) was used as a radio transceiver module chip, and the transceiver operated in the ISM band at 433MHz or 916MHz with a maximum data rate of 76.8kbps and had three LED's for output.

To save operating power, TDMA(Time Division Multiple Access) cycle method has normally used in the field of sensor network. In this study, the operating mode was divided by two modes, active mode and sleep mode. At active mode in our study, the hardware consumes about 33mA (3V). In sleep mode, the system draws only 30uA of current, enabling the battery to last for more than a year. Also, the indoor radio transmitting range is approximately 20-30m. When many sensors on a sensor platform have to communicate with a micro-controller on the same sensor platform, standard communication interfaces such as Serial Peripheral Interface (SPI) or Integrated Circuit (I2C) allows to share a single communication bus to the micro-controller. The I/O subsystem interface consists of I/O expansion connector that we designed to interface with a variety of sensing and programming boards.

The I/O expansion connector could be used when the micro-controller was programed and could also be used to communicate with other devices and to communicate to a PC as role of a gateway node. The gateway node have a standard UART (RS-232) interface to provide data to any UART protocol based device and control signal to micro-controller.

For supplying power to the sensor platform, 3V battery was used to supply the power for the micro-controller (ATmega128L) and radio transceiver. The micro-controller has been optimized for low-power, battery operated systems. The sensor network platform was operated by a specialized event-driven operating system, called TinyOS[7] that provides the software building blocks necessary to gather and transmit the data.

2.2 ECG Measuring Interface Circuit

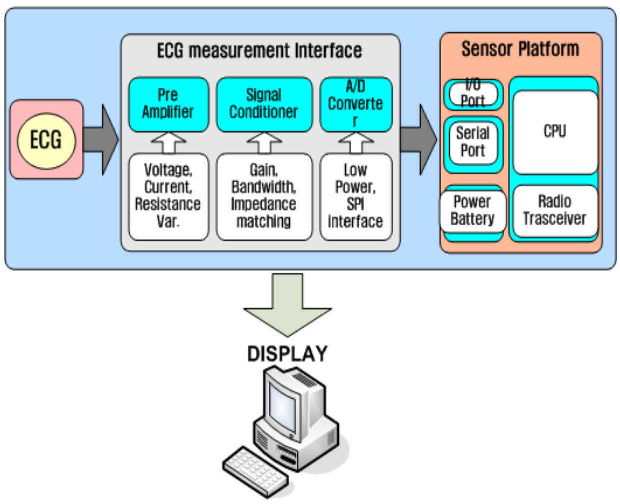

Figure : 4 The block diagram of ECG measuring interface circuit

Recent research has focused on the development of wireless sensor network and pervasive monitoring systems that can monitor the status of a patient (ECG, Temperature, Blood Pressure, SpO_2, Pulse wave, etc.) for Ubiquitous health care applications.

In this study, ECG measuring interface circuit were designed, fabricated and the fabricated sensor platform was attached by the interface and then tested. A 12-bit A/D converter MCP3204 (Microchip, USA) for analog-to-digital converting was used in the ECG measurement interface circuit. The output digital signal of the interface circuit was connected to the fabricated sensor network platform.

The block diagram of Bio-amp for ECG measurement is displayed in Figure 5. The Bio-amp is required to properly amplify the output signal from ECG and signal converting, filtering. Performing input impedance was 12 ㏁ and CMRR (Common Mode Reject Ratio) was 106dB in the signal detection part of Bio-amp.

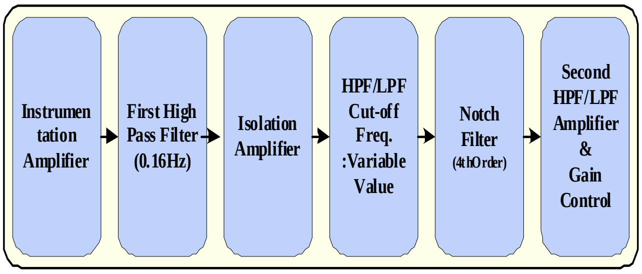

Figure 5 : The Block Diagram of Bio-amp.

The output signal of the interface circuit was connected to the fabricated sensor network platform. The fabricated ECG (Electrocardiogram) measuring interface circuit is shown in Figure 6. The amplifier of the ECG measurement system is UAF42 (Burr-Brown, USA) integrated circuit (IC). A notch-filter was designed and the cut-off frequency of the notch-filter was 60Hz and Q was 6 in the designed notch-filter. To avoid high-frequency noise through the band-pass filter, the UAF42 was used as an active filter.

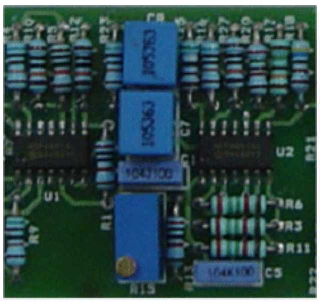

Figure 6 : The fabricated ECG measuring interface circuit

3. EXPERIMENTAL TESTING AND RESULTS

Figure 7 shows the fabricated sensor network platform. The fabricated platform have to be attached on the body of the patient so we tried to reduce the platform size. The size of the micro-controller used in the platform was about 1.4in×1.4in in size, and RF Transceiver module is lesser than 1in×1in, resulting in the total size of the board was approximately 2.9in×2.9in in our fabricated platform. A CC1000 RF wireless transceiver was used as a RF transceiver chip for wireless sensor networking as shown in Figure 2.

The commercialized UHF data transceiver module chip (CC1000, Chipcon Ltd., Norway) were integrated in single chip. In contrast, at optimum input supply voltage, the CC1000RF wireless transceiver consumes 14.8mA to transmit at 3mW and consumes 5.3mA to have a receive sensitivity of -20dBm.

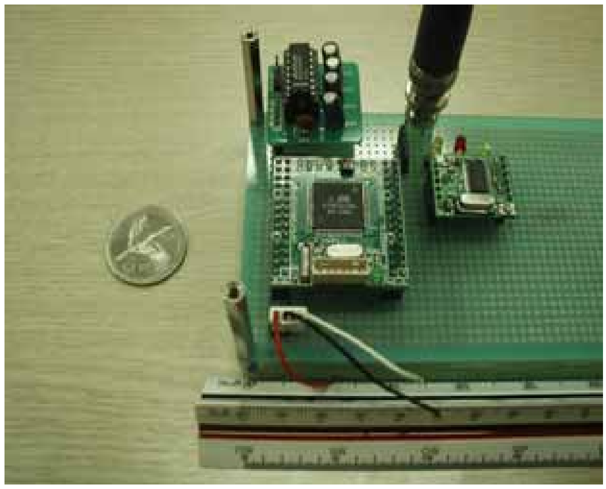

Figure 7 : Fabricated wireless sensor network platform.

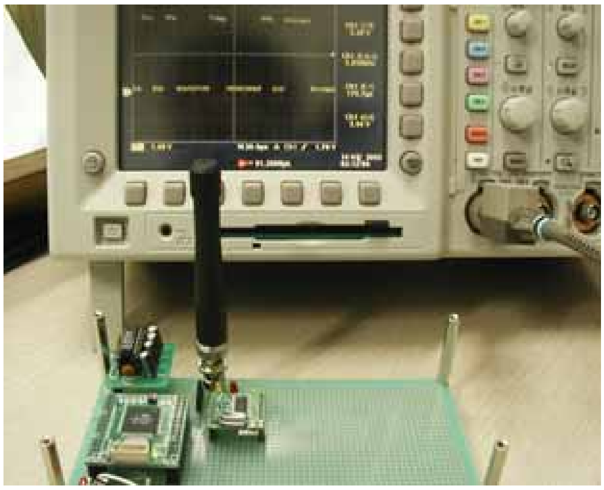

Figure 8 : Testing of the fabricated platform

When simultaneously communicating with other sensor platform, the CC1000 RF wireless transceiver consumes 12mA. In this time, the RF transceiver offer transmission data rates of approximately 76.8Kbps.

Figure 8 shows test system for the fabricated for wireless body sensor network. The fabricated platform consists of three parts. The First parts consists of a micro-controller, the second part consists of a radio transceiver from control signal of the micro-controller. The third part consists of a serial port for send sensor data back to the PC. The sensor network platform was tested successfully to obtain the required RF signal from the micro-controller and RF transmitter. This part of the sensor network platform and base station was able to communicate in the range of 30~100m.

TinyOS-software components have been written to implement data-acquisition and wireless media-access control protocols for the fabricated transceiver board. The TinyOS-based platform will operate on a standard TinyOS component to receive packets and broadcast them via a serial port or an ethernet connection.

Figure 9 shows ECG waveform date which transmitted the sensor network platform attached with ECG and a interface circuit to a gateway node. The ECG data was transferred from a gateway node to PC via UART (RS-232).

In this study, An ECG measurement interface circuit was also operated well and can transfer a patient's ECG date to the first sensor network platform. This ECG output data was can be amplified, sampled, transmitted and reconstructed to input signals at a rate of 256 8-bit samples per second. The ECG data was successfully transferred from the sensor network platform to a gateway platform. And finally the ECG data was successfully monitored by the PC.

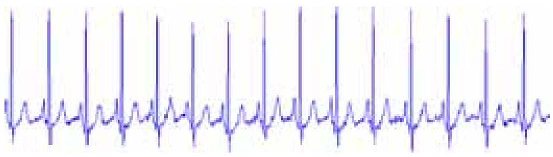

Figure 9 : The waveform of the fabricated ECG measurement system.

4. CONCLUSIONS

In this paper, wireless body sensor network architecture consisted of micro-controller, RF transceiver and ECG measurement interface circuit was designed and fabricated. To approve the capabilities of the fabricated sensor network platform for wireless body sensor network applications, ECG measuring circuit was attached to the sensor network platform and the performance of the TinyOS-based sensor network platform was checked. Using the small sized fabricated sensor network, the health parameters of patient can be monitored under their natural physiological states. The sensor network system have a series of sensing, processing, communication. The power consumption problem was deeply considered during platform design.

The fabricated sensor platform was attached by the interface and then tested. The ECG data was successfully transferred from the sensor network platform to a gateway platform.

Based on these results, smaller size and lower power consuming sensor platform development will be focused on, and body sensor network architecture for wireless body area network applications will be studied further.

REFERENCES

[1] I.F. Akyildiz et al., "Wireless Sensor Networks: A Survey," Computer Networks, vol. 38, 2002, pp. 393-422.

[2] G. Asada, M. Dong, T. Lin, F. Newberg, G. Pottie, H. Marcy, and W. J. Kaiser, Wireless integrated network sensors: Low-power systems on a chip. In Proceedings of the 24th IEEE European Solid-State Circuits Conference (Den Hague, The Netherlands, Sept. 21–25). Elsevier, 1998, 9–12.

[3] K.J. Liszka, M.A. Mackin, M.J. Lichter, D.W. York, D. Pillai and D. S. Rosenbaum: Keeping a Beat on the Heart, IEEE Pervasive Computing, Oct-Dec 2004; 3(4):42-49.

[4] G. J. Pottie and W. J. Kaiser, "Wireless Integrated Network Sensors,"Commun. ACM, vol. 43, no. 5, May 2000, pp. 551-58.

[5] C. Shen, C. Srisathapornphat, and C. Jaikaeo, "Sensor Information Networking Architecture and Applications," IEEE Pers. Commun., Aug. 2001, pp. 52–59.

[6] M. Dong, G. Yung, and Kaiser, W. Low-power signal processing architectures for network micro sensors. In Proceedings of the 1997 International Symposium on Low-Power Electronics and Design (Monterey, Calif., Aug. 18–20). IEEE, New York, 1997, 173–177.

[7] J. Hill, System Architecture for Networked Sensors, doctoral thesis, Dept. of Computer Science, Univ. of California, Berkeley, 2003.