A Bluetooth based 5-HD Measurement System for u-Healthcare

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Abstract

A u-Healthcare system should support mobility and accessibility besides sorts of medical information. The 5-HD (Healthcare Data) includes digitalized ECG, Blood pressure, Body composition, Body Temperature and Weight. In this work, we design and implement a new 5-HD measurement system that includes data collection modules and a smartphone application based on the Bluetooth communication. Each data collection module can generate digitalized biomedical signal continuously and send it to the user's smartphone application. The application can process and show up the signal and healthcare data as a kind of all-in-one type through the united user interface and also can forward to the designated healthcare server system. We also had adjusted the Bluetooth application data format to maximize the data transfer rate among the modules and smartphone application. The 5-HD measurement system can give us more easiness, accessibility and mobility for the u-Healthcare environment than any special-purposes handy or mobile measurement system.

Keywords: *u-Healthcare, 5-HD, Smartphone, Bluetooth*

1. Introduction

Smartphone is now very important and essential device for the modern works, social lifestyle, and activities. Today, the smartphone is no more limited as a voice communication tool that provides many useful methods in the digital and analog field as a powerful multimedia communication and data handling device. In the u-Healthcare area, the smartphone also has been a very important mobile device that provides and manages one's personal medical information such as blood pressure, body composition and glucose value. In medical device and information area, mobile information system services are rapidly increasing and being used on supporting efficient mobile healthcare service in ubiquitous environment. This ubiquitous healthcare so called u-Healthcare opens a new area in medicine so as to provide easy inspection and disease prevention with mobile devices instead of huge, heavy and expensive biomedical devices [1]. A biomedical device has to measure the bio signals from the bio sensors and has to process the signals through computer system in many ways according to result what it want to get. In many cases, sensors connect to device with electric cables. The electric cable is capable to transmit a stable signal but sometimes cables would make electromagnetic interference among the signal paths and cause the complicate installation and maintenance. Moreover, these cables limit the distance between sensors and device, dues to decrease the system mobility. If there is a short-ranged local area network around a body, we can

construct a kind of wireless links among the sensors and device that can eliminate the most of cable problems, and it can help implementing efficient healthcare system under the ubiquitous environment. In the biomedical area, many information devices adopt Zigbee or Bluetooth technology on forming a wireless network [2, 3]. The smartphone already has nice wireless communication method as Wi-Fi and/or Bluetooth. So if one wants to make wireless network for personal medical information, one just adopts a smartphone as communication device. Especially in the u-Healthcare area, the smartphone has enough power for data processing and network on u-Healthcare data and it is capable for the most of the healthcare data management.

In this work, we had designed and implemented a new 5-HD measurement system for u-Healthcare service through Bluetooth communication, and analyzed its accuracy and data transfer performance for each healthcare data. The rest of this paper is composed as follows: Chapter 2 shows the design concept of the 5-HD measurement system. Chapter 3 explains the data collection module architecture, android application software stack and Bluetooth communication structure, and shows the performance analysis results in Chapter 4. Finally we concluded in Chapter 5.

2. 5-HD Measurement System Design

The u-Healthcare system would be designed for its own purpose and implemented as an individual system or several function group of healthcare system. Almost u-Healthcare system also provides a server system to maintain or analyse the periodic healthcare data. In the area of u-Healthcare system, the communication method between sensor client and server system would be very important and it is close to the body area network that provide local biomedical signal measurement system around a body to support healthcare information system [4, 5]. In this work, we design and implement healthcare data collection modules and android application connects each other through Bluetooth communication network to measure the 5-HD such as ECG (Electrocardiogram), BP (Blood Pressure), BC (Body Composition), BT (Body Temperature) and Weight. The Bluetooth based healthcare measurement system makes low-cost short range communication links from the data collection module to the android smartphone instead of high-cost healthcare equipment, and gives easiness and mobility. The android smartphone also provide mobile computing power for data processing and connecting server system over the internet. The server system holds the measured 5-HD sent from the android application and retrieves or sends the saved data back at anytime, anywhere. Figure 1 shows the typical ECG example of 5-HD measurement system.

The system consists of three data collection modules and an android smartphone application. The data collection modules are designed and implemented in a 3 kinds of type: a multi-function module, a BP module and a Weight module. The multi-function module can measure ECG, BT and BC as a patch type. The BP module is designed for measuring blood pressure only as a wrist type. We use a commercial digital scales as the weight module and make it works with android application altogether. The android application implemented as an integrated measuring program for all 5-HD. It provides 5-HD handling and managing subprograms respectively through a single user interface and sustains Bluetooth connection between a single module and application at a time. It also can accumulate the 5-HD inside the smartphone memory and can send them in a part or whole volume to a specified u-healthcare server system with 11073 standards [6].

Figure 1. 5HD Measurement System (ECG case)

3. System Implementation

3.1 Data Collection Modules

In this work, we designed and implemented two data collection modules: a multifunction module and BP module. The uMedix Co. has been working on module design, implementation on PCB, manufacturing and test stages. At first time, we design the two modules in one because ECG, BP and BC has analog amplifier part altogether and use the same analog circuit for analog signal amplifying, low pass filtering and phase shifting. At the end of design, we found there are too many substances in the blood pressure signal that could not handle enough with the analog filter unit and replaced the analog amp and analog sensor with a digital sensor unit and finally designed the BP as a separate module. The multifunction module catches the bio signals include ECG waveform, BC signal level and temperature signal from human body directly, amplifies the signal in OP amp circuits with low pass filter, performs AD converting, data buffering and Bluetooth communication on the CSR BC4 Bluetooth MPU [7]. The ECG waveform and BC signal can get from the ECG pads and metallic BC terminals. The ECG pads are attached to the V2 and V3 point around LA to get the single pole signal [8]. The BC4 PCM signal is used as PWM (Pulse Width Modulation) signal to get the BC signal from human body. The temperature signal can get from thermal sensor on another metallic pod. Figure 2(a) shows the block diagram and implemented result of the multifunction module.

The BP module also designed and implemented as a separated module alike the multifunction module and a sensitive digital pressure sensor unit is connected to the BC4 MPU through I^2C interface without any analog part or circuit [9]. The enclosure contains the module and sensor unit inside and can fasten the human wrist with tie-up band. To make it easy for human's blood pulse from wrist, the digital sensor also enclosed in the elastic bubble cap that can receive the transient pressure from the blood pulse. Figure 2(b) shows the block diagram of the BP module. The digital pressure sensor samples blood pressure value from bio signal at the rate of 50 per second, convert into the digital data and directly sends to the CSR BC4 MPU through I^2C interface. The virtual machine processes the digital blood pressure data and transmits it through the Bluetooth protocol stack.

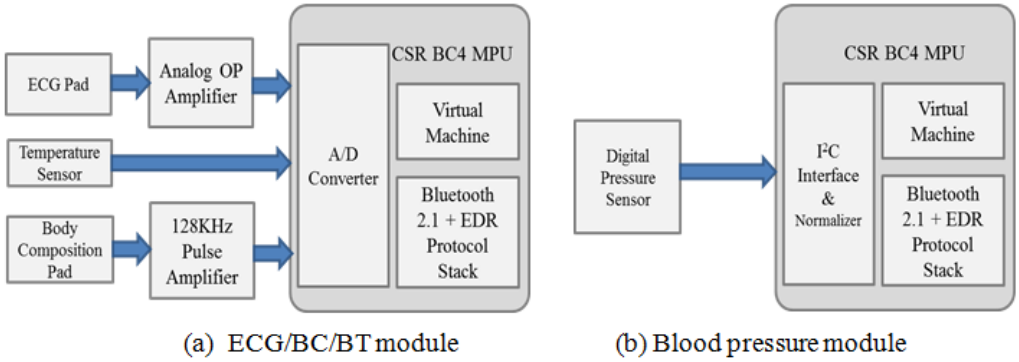


Figure 2. The Block Diagrams of the Multifunction Module and BP Module

3.2 Android Application

The android program includes 5-HD measuring methods and other service methods. Each method receives digitalized healthcare data sent from the specified data collection module, processes the data and shows up the results on the smartphone screen. Each method also can send the final data at the end of every measurement trial to the specified server if need in group or separated fragment on the data history methods. All shared data such as user's name, bio information and metrics can be shared with the shared preference layer. Data from data history and part of measuring can be connected with the shared database through SQL interface layer. Figure 3 shows the application software stack and Figure 4 shows the typical user interface of each method.

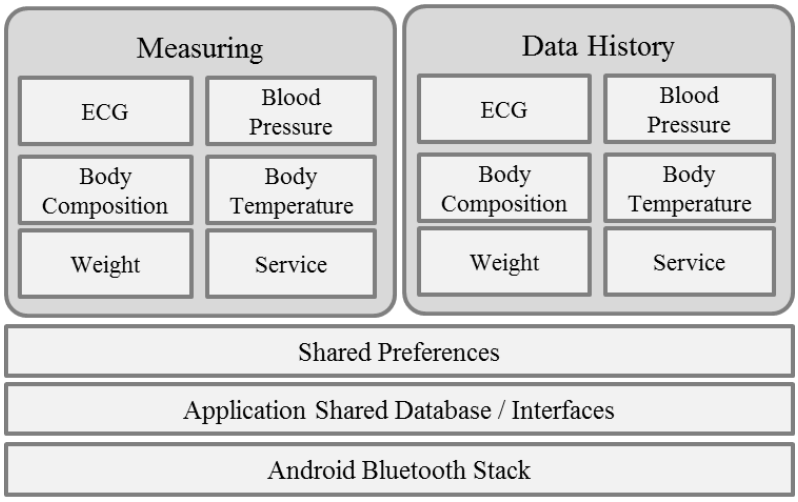
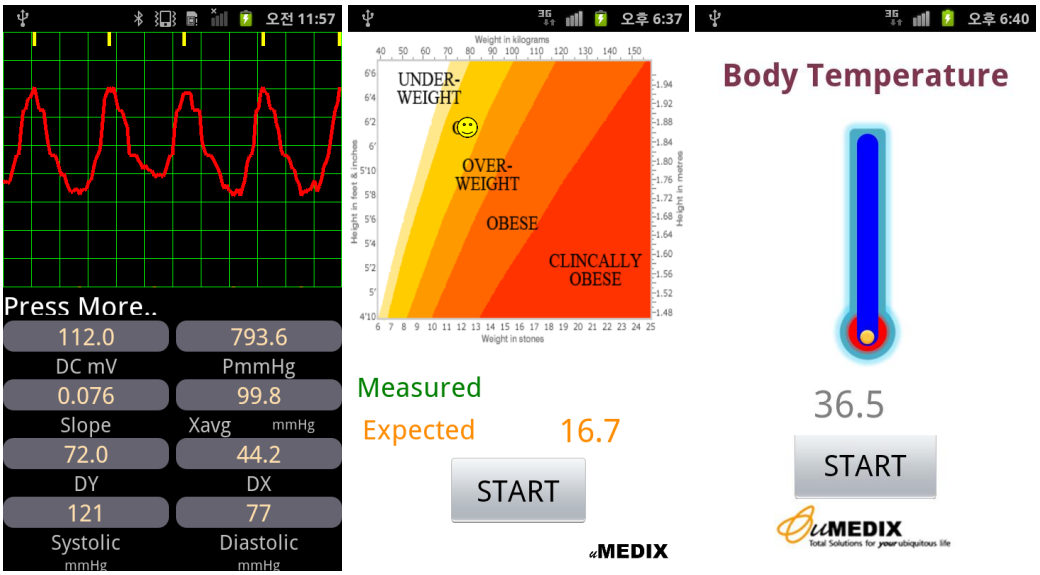


Figure 3. Android Application Stack

(a) ECG Method



(b) Blood pressure method (c) Body composition method (d) Body temperature method

Figure 4. Typical User Interface of 5-HD Methods

The ECG method processes the data during 30 seconds, calculates R-R interval and heart rate, and shows the ECG waveforms on the specific view. To get the heart rate, we calculate R-R intervals between one peak and another peak repeatedly [10, 11]. The peak detection algorithm check the time between two consecutive R peaks of waveform in a series of data stream and calculates the period as R-R interval. If there is some irregular R-R interval, we can find out one's heart may have some kind of problem.

The blood pressure BP method processes the data during 60 seconds, calculates systolic, diastolic and pulse values from data peaks and waveform shapes. It checks the high peak value and low peak value from waveform. If there are over 3 consecutive peaks in 4-second period, we can catch the peak difference between high peak and low peak. From the transient function between peak differences, we can calculate the systolic, diastolic and pulse value at the end of the measurement.

The body composition BC method process the data during 30 seconds, calculates the percentage of muscle in one's body. To measure the percentage of muscle, we applied the 128 KHz pulse wave as PWM signal between two electrodes grabbed by hands. The BMI (Body

Mass Index) and other body fat factors can be calculated from one's height and weight data [12].

The body temperature BT method checks LM60 data output and converts into the readable degree value [13]. The LM60 gives a variant current according to the temperature and we can get the digital current variation from the ADC of BC4 MPU. The weight WGT method gets the data from commercial scales through Bluetooth and shows result in KG. The scale supports the Bluetooth API connected with other Bluetooth client.

The main interface and sub method interfaces of 5-HD methods are targeted to SAMSUNG Galaxy S android smartphone with OS version 2.3.6. All application methods are implemented with the Eclipse indigo workspace with Android 3.2 SDK API level 13 for supporting target device.

3.3 Bluetooth Communication

In this work, we implemented Bluetooth communication with BT2.0 and BT2.1+EDR specifications [14]. Every data collection module operates the CSR BC4 MPU that originally designed to handle the Bluetooth communication. A built-in Bluetooth stack generates Bluetooth data packet on the SPP profile and encapsulates user APDU. Each data collection module has its own APDU format in firmware code interacts with CSR Bluetooth stack. Due to the BC4 task message handling architecture, the real application data transfer rate would be up and down according to the firmware functions for each specific application action. So, we have to adjust the APDU format and data size to maximize the data transfer rate as shown in performance analysis. Although we implemented Bluetooth stack with BT2.0 and 2.1+EDR, the SPP profile cannot meet the high speed data transmission function and just supports the low rate data transfer. Actually, the SPP can only transmit less than 250 bytes APDU per second with best performance in our work.

4. Performance Analyses

4.1 Data Accuracy

Data accuracy is a very important factor of u-Healthcare device. Most of home healthcare devices or handheld devices such as a tonometer, a glucose meter for diabetes has less than 5% measuring accuracy. In this work, we compared the results of 5-HD measurement system with the results of commercial healthcare devices. For 4 kinds of commercial healthcare devices and our 5-HD measurement system, 30 peoples participated and we have had 10-times trials for each individual. The ECG and BT data were measured simultaneously, and measured the BC next. The BP was the last measurement for a participant. At the end of the measuring, we calculated the average difference and deviation between each commercial healthcare device and 5-HD measurement system. The deviation can be derived from the average differences between two measuring devices and it means the measuring accuracy. Among the 5-HD, we did not measured weight data because we use commercial scale as a weight data platform that the weight device could not be included our own work. The results show that the 5-HD measurement system also has less than 5% data accuracy at the test round. Table 1 shows the comparison results.

Table 1. Data Accuracy Comparison Results

	Commercial device	Average Difference	Accuracy (%)	Measuring Factor
ECG	Prince 180A (Healthcare4all Co.)	12.6 msec.	2.7	R-R interval
BP	Omron R6 (Omron Co.)	6.4 mmHG	4.3	Systolic
BC	Inbody U070B (Biospace Co. Ltd)	1.6	4.8	Muscle %
BT	Philips TH80 (Philips Co.)	0.7°	4.9	At Chest

4.2 Bluetooth Data Transfer Rate

The Bluetooth data transfer rate could be varied according to the data payload size of the APDU in Bluetooth protocol packet. For the best data transfer performance, we changed the APDU payload size for every 5-HD methods and measured the real data transfer rate at the point of android application. As the Bluetooth protocol packet size was dedicated, the data transfer rate is only the factor of APDU data payload size. Figure 5 shows the data rate according to the APDU data payload size on SPP profile. At the peak point with APDU data length 16, Bluetooth SPP profile sends its maximum data rate around 200 bytes/sec. and slow down as the payload size increased over 16 bytes.

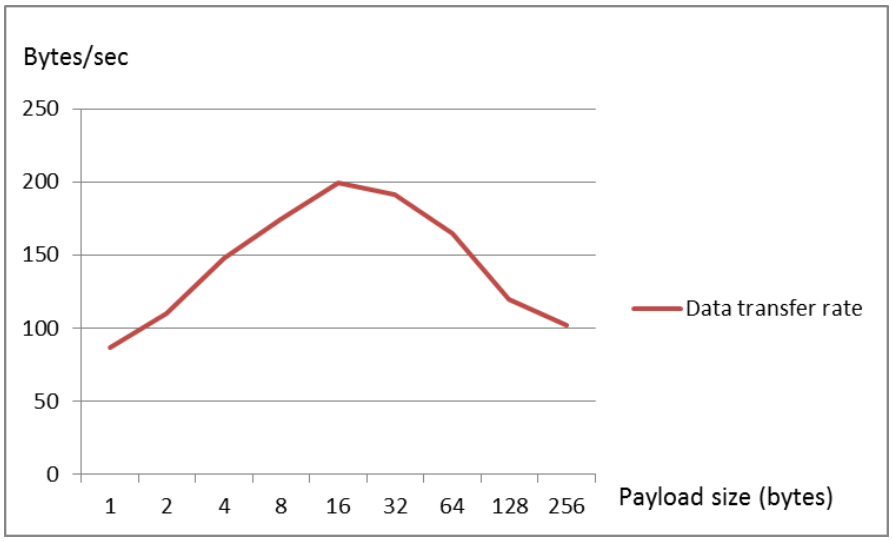


Figure 5. Bluetooth Data Transfer Rate vs. APDU Payload

5. Conclusion

The 5-HD measurement system can provide five major healthcare data under ubiquitous healthcare environment includes ECG, BP, BC, BT and Weight. This system gives easy way to measure, show up and manage the digitalized healthcare data continuously for any other u-healthcare application or services. The data collection module generates biomedical data continuously and transfer to the application that can handle the digital data application on the smartphone via Bluetooth communication method. The smartphone application handles and manages the data as a kind of u-healthcare data hub to show up the data through appropriate user interface or send the data to the server system. In this work, the 5-HD measurement system has almost the same accuracy as the commercial healthcare devices. The data processing performance depends on the Bluetooth communication performance rather than smartphone itself. To maximize the data processing performance, we had adjusted the Bluetooth application data transfer format to get the best data carry on. For each healthcare data, we finally get a meaningful data transfer rate that matches up the best performance under the Bluetooth environment.

This 5-HD measurement system can mix the merits of the wireless communication and mobile device, and can give more easiness and mobility under the current u-Healthcare environment than other healthcare system with low cost. Furthermore, this system provides very kind and instinct user interface for anyone who wants to use on one's own smartphone. As a part of u-Healthcare environment, this system can be widely used as a basic smart hub or terminal that can help easy healthcare measurement and management.

In this work, we didn't implement the biomedical data analyses for diseases or symptoms because only a doctor can inspect patient. So, we should only concentrate the data service system for more convenient inspection for doctors. The next step on this work would be moved on the device access control for multiple 5-HD measurement system in a single host data centre such as set-top box or ACU for ubiquitous home care service or applications.

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