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Development of Reusable and Expandable Communication Platform for Wearable Medical Sensor Network

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Abstract— To meet the various communication requirements of the wearable medical sensor network, the reusable and expandable wireless communications platform has been developed. The connection between the central monitoring unit and the sensors around the body is implemented using the Bluetooth technology. And the data can be uploaded and downloaded to an external internet server by the CDMA modem or Bluetooth LAN Access point (LAP). The system used PDA as a central monitoring unit which records and displays the data received.

Keywords—**Wearable health management system, telemedicine, Bluetooth, CDMA, medical sensor network, sensor communication, mobile phone**

I. Introduction

The problem of an aging population coupled with declining birth-rate is creating acute and unsustainable generational disparities. The percentage of old people who generally require more medical resources is growing, while the percentage of young people who can work and support the social welfare system by means of tax is decreasing. As a result the total cost of medical service grows rapidly. And the burden per one working person is growing more rapidly. So providing appropriate medical service to the old people at the manageable expense is an important pending question.

More old people tend to live alone and such trend will not change soon. One of the medical services for those who live alone is alerting medical center when medical emergency situation occurs. When medical emergency situation like heart attack or stroke happens, the most important factor that decides mortality rate is the time it takes to see a doctor and receive appropriate medical treatment [1]. With no one nearby, the time it takes for the patient to be discovered and to receive medical treatment can be unavoidably long. The wearable health management system which alerts the medical center when emergency situation occurs can improve the quality of life.

To lower the total cost of medical service, two strategic approaches are considerable. First, the total cost of care can be saved if the disease is detected at its early stage or if it can be prevented [2]. Second, the general approach for cutting down expenses is by reducing human labor factor and by automating the process. One of possible solution that can be inferred from two approaches will be the automated monitoring of the people by means of small wearable or portable device, which has the ability of detecting the change of the health status.

To make such concept possible, three technical innovations are required. They are wearable sensors, artificial intelligence and communication method. In this paper we will define the communications requirements and implement them using existing Bluetooth and mobile technology.

There have been various approaches for implementation. At early works, there is usually one or a few multiple sensors connected by wire, and transmitted by relatively short range RF transceiver to the nearby receiver [3] [4] [5] [6] [7]. The receiver usually records the data and transmits it to the medical center through the internet, if necessary. Though simple and enough for research purpose, these custom built RF communication can only work for limited space and usually lack inter-operability or standard. To overcome this limit, mobile phone [8] or Wireless LAN technology [9] was adopted. Meanwhile the number of the sensors required for monitoring grows up, because relatively small number of the sensors could not provide the information required to determine the health status. Multiple sensors can be connected simultaneously either by wired [10] [11] or wireless connection [12].

In this paper, the focus of architecture design lies on the expandability and reusability of the network. Because the two other technical barriers, wearable sensors and artificial intelligence, have not yet been solved, there can be various trial experiments and corresponding work to develop the communication part of the system. This work is to help the biomedical engineers to build their own wearable health system by using the communication platform without concerning or modifying it.

II. Methodology

The basic functions of the communication platform for the wearable health management system are to handle the sensor data and to report the processed information to external medical center (Fig. 1). So the design of the platform can be divided into three parts which are sensor interface module, central monitoring unit and external server interface.

1) *Sensor Communication Module (SCM)*: There can be various sensors connected to the SCM. Each sensor will have different data bandwidth and reporting frequency requirement. Sometimes several sensors will be connected

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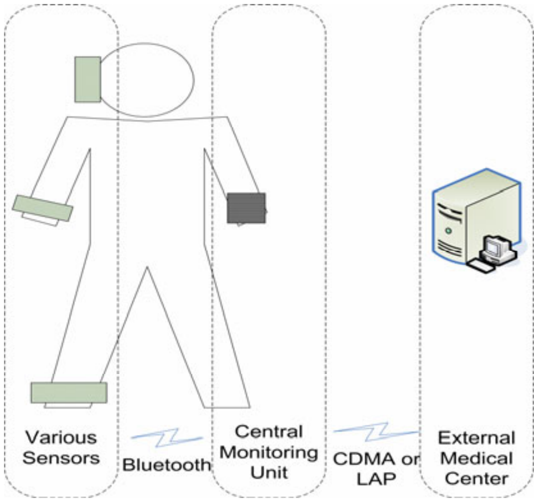

Fig. 1. The basic function of the communication platform

to the one SCM. For example the chest belt is good location to measure the Electrocardiograph (ECG) signal and the breathing movement of the chest wall. In such a case it would be better one module handles the communication. Because the number of the sensors required can vary, the modulation scheme should be able to handle ad-hoc networking. The interface between the controller of the sensor and the communication module should be simple. Sometimes there will be enough power from the sensor part, and sometimes not. The battery should be easily manageable.

2) *Central Monitoring Unit (CMU)*: The CMU has to manage the sensor network connection. Common function of the CMU includes the recording and displaying of the data.

3) *External Server Interface*: The health information especially the emergency detection alarm signal should be able to be reported to external medical center anywhere and anytime at economical cost. The communication method based mobile technology has good area coverage. However the cost of the phone bill related mobile phone makes it less affordable for continuous reporting. Considering the main target is old people who spend much of their time in their home, access point based approach is also appropriate. So multiple access concept, which selects best communication method based on the situation is required.

These design requirements will be implemented by standard based approach.

III. Results

A. Sensor Communication Module

The Bluetooth module by Hitachi Maxwell Inc. which incorporates CSR Bluecore02 core (CSR Inc.) is used. The total module size is 25 mm by 25 mm. The connection interface between SCM and the sensor is 10-pin header.

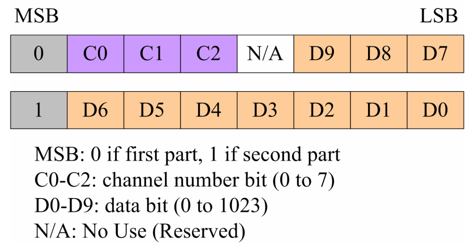

Fig. 2. The data packet structure for the SCM

The pin assignment is displayed in Table 1. Universal asynchronous receiver-transmitter (UART) was adopted for the serial interface, because most microcontrollers have built in support for it. Two bytes represents one data packet (Fig. 2). Up to 8 number of the sensors can be connected to the one SCM. Each channel has its own channel number.

The SCM can be powered from the sensor part or from the rechargeable Li-ion battery. It also has the rechargeable circuitry. The module consumes 26.5 mW during transmission and 3.5 mW during idle state.

B. Central Monitoring Unit

The linux PDA Yopy3700 (Gmate Inc) has been used for central monitoring unit. It has built in CDMA 2000 1x module, which makes it ideal for reporting unit. And there is one CF card slot for expansion which is used for Bluetooth CF card (SysOnChip Inc.). Open source Bluetooth stack (Bluez) [13] up to RFCOMM [14] was ported to the PDA.

The GTK based connection manager was developed to manage the connection. To connect the SCM to CMU, the following step is required. When there is new member to the sensor network, the user first scans the area. After the nearby unit reports their existence, the user can add the SCM. During add process, the user can edit the name of the module and the maximum bandwidth.

TABLE I
Sensor Interface Pin Assignment

Pin No.	Appearance		
	Name	Direction	Description
1	GND	-	Power Ground
2	V_BAT	I	DC input (5.0 input)
3	GND	-	Power Ground
4	Power	O	4.0V battery output
5	RXD	I	UART data input
6	TXD	O	UART data out
7	RTS	O	UART Ready to Send
8	CTS	I	UART Clear to Send
9	DCD	O	Data Carrier Detect
10	/RST	I	Reset

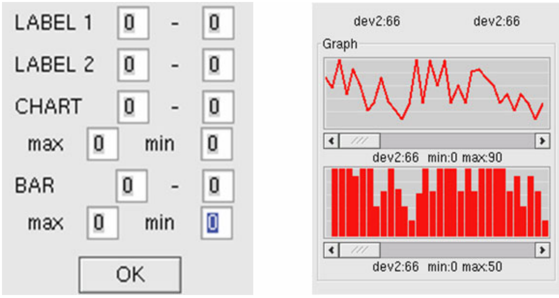

Fig. 3. The chart configuration and the display example

The user can select the sensor data to be displayed by selecting the SCM number and the corresponding channel number. The user can also select the display type one of following; value label, bar graph and chart graph. Because of the limited screen of PDA, the number of the total display is limited to two value labels, one bar graph and one chart graph. The user can adjust the scale of the graph, by selecting the maximum value and the minimum value to be displayed.

The incoming sensor data is recorded with the time tag they received.

Fig. 4 shows the picture of the SCM and CMU together.

C. *External Server Interface*

Multiple access using CDMA and Bluetooth LAP is developed. The user can select appropriate communication method based on situation. By using multiple access the communication between the central monitoring unit can be made everywhere, while maintaining economical competence. The default data file to send is the recorded sensor data file. However for there is difference in data transfer rate, sending the recorded file can cause bottleneck. The biomedical engineer who builds their system will decide what parameters to send. For this purpose, we provide sample program to be modified.

Fig. 4. The picture of the platform showing two scm with varying battery and the central monitoring unit.

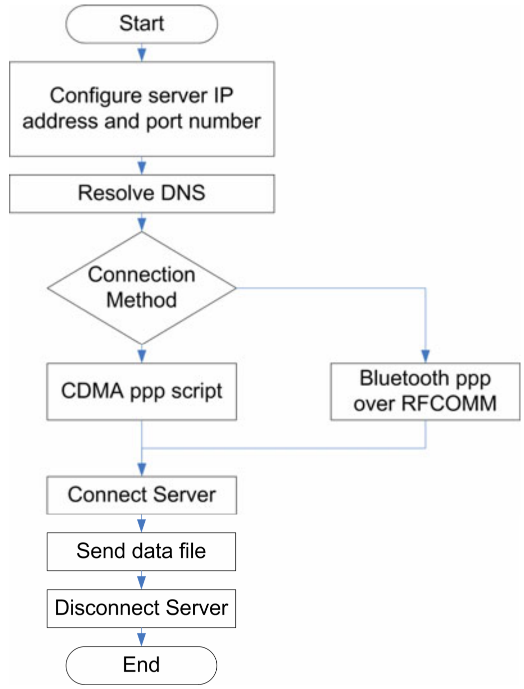

Fig. 5. The flowchart for the external server communication

The said speed of CDMA 2000 1x is 144 kbps. But due to the various limitations the measured speed is below 50 kbps. Fig. 5 shows the flowchart for the connection.

IV. Discussion

The total number of the sensors that can be connected to the network is 56. While this number seems enough for current state, the number can further increased by using the parking mode by the Bluetooth [14]. However the increased number will make the management more complex. In this case the one of main problem of the wireless sensor network is the increased number of the battery makes user experience complicated, for the lasting time of the each battery will vary. To solve the problem, battery status monitoring is required for future development.

V. Conclusion

The sensors can be connected to the network by sending data to the SCM according to the packet structure. Up to 8 sensors can be connected to the one SCM via UART, while up to 7 modules can be connected to the central monitoring unit by Bluetooth connection. The central monitoring unit can manage the piconet and records or displays selected data. Using CDMA or Bluetooth LAP based on the situation, the processed data can be sent to the external sever.

The biomedical engineer will be able to build their own wearable health management system more quickly and easily using this platform.

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