Ubiquitous Wireless Monitoring System using CDMA Based Portable Device for Chronic Obstructive Pulmonary Disease Patient and Heart Disease Patient

Il Hyung Shin[3], Jae Ho Lee[4], Hee Chan Kim[1,2]

[1]Institute of Medical & Biological Engineering, Medical Research Center, Seoul National University, Seoul, Korea
[2]Department of Biomedical Engineering, College of Medicine, Seoul National University, Seoul, Korea
[3]Interdisciplinary Program, Biomedical Engineering Major, Graduate School, Seoul National University, Seoul, Korea
[4]Department of Internal Medicine, Seoul National University Bundang Hospital, Seoul, Korea

Abstract—**The Purpose of this paper is to develop a code division multiple access(CDMA) based wireless device that is able to measure pulse oxygen saturation(SpO_2) and Electrocardiogram(ECG) for patients' social life in their homes. Until now, some portable devices using wireless network like Bluetooth™ or Zigbee™ have had a narrow connection area. So patients have not used them as ubiquitous device everywhere. However, it is possible to report the patients' data to their doctor any time and anywhere because the developed device uses the CDMA based cellular phone network.**

Keywords— **CDMA, Wireless, SpO_2, ECG, Ubiquitous**

I. INTRODUCTION

A chronic obstructive pulmonary disease and a heart disease patient after treatment in hospital need a continuous monitoring device to measure SpO_2 or ECG for their social life in his home. But the device has been used only in houses because of its big size and consumption of large power at the beginning of their development. So these problems must be solved in order for patients' social life to be comfortable in many ways. In other words, it must have a small size to function as a portable device and a low power consumption to operate for longer time. However, if it can't help the patient under emergency conditions, the patient will not be able to have their social life no matter how small the device gets. Therefore, the purpose of this research is to develop a device that is able to monitor the patient's status continuously so that it is possible for the patients to have their social life.[1] Moreover, the continuous monitored information will be used to find a correlation between bio-signal and the patient's life style by physicians. To achieve this, we have developed a device that is portable and uses CDMA cellular phone network because CDMA network provides a wide range connection and a broad bandwidth. And we also have developed the monitoring software including a server and database for the physicians.

II. MATERIALS AND METHODS

Fig. 1 PDA Module with CDMA module

A. The PDA with CDMA module and Measurement Modules

Bio-signal information that is measured by SpO_2 and ECG module is saved internally and transferred to external TCP/IP server by using PDA based on Microsoft Pocket PC2003 Platform. The PDA that we used is POZ X510(Cyberbank, Korea). The size and the weight of the PDA are 52mm X 112.5mm X 22mm and 151g (include battery), respectively. It has 240pixel X 320pixel TFT LCD and a 64MB internal flash type memory. The power source of the PDA is 1380mAh Li-Polymer battery. Because the CDMA module is included in the PDA, it can use CDMA cellular phone network. Moreover, it has a function of sending text messages to doctor's cellular phone when the measuring values of SpO_2 and ECG exceed the maximum value that is set up by the doctor. We have used an arm band so that the patient could put the PDA in his arm for a long time.

The PDA needs a connector to connect with the measuring modules and to stabilize the power. The size and the weight of the connector are 16.3mm X 16.5mm and 1.7g respectively.

The module to measure the SpO_2 and the ECG is Nonin OEM III Module (Nonin, USA) that has the size of 34mm X 24mm, the weight of 6.6g and the power consumption of 29mW in normal operation.

Also, because of the protocol difference between the PDA and the SpO_2 module, we required a protocol conversion module. The weight of the whole SpO_2 measurement module put on the patient's wrist is about 18.2g. The developed conversion module is covered by silicon and epoxy resin.

And we selected the 8000SM (Nonin, USA), which is a reusable and flexible rubber type SpO_2 sensor because of the patients' dislike for general clip type sensor.

The ECG module was developed by us. Its size and weight are 39.6mm X 47.8mm and 16.1g, respectively. A lead II value of standard ECG is measured only by our ECG module. At first, we have measured the general 6-channel ECG using 3 electrodes. However, in this case, we had to use at least two wires (1^{st} wire for connection with the PDA and 2^{nd} wire for 3^{rd} electrode). So, many patients have spoken out their inconvenience and wanted to get rid of one of the wires. This is a reason why we have measured lead II data only. The ECG module has a 14bit ADC and its sampling rate is 100Hz. And the electrode is a standard gel type Ag/AgCl electrode.

B. The PDA software including data transmission module and A monitoring software including TCP/IP server module and database module

To receive transmitted data via wireless network, we need 3 modules, which are the data transmission client module, data collection server module and database module to save the data efficiently.

The data transmission client supports remote access server (RAS) protocol to convert point to point (PPP) protocol to TCP/IP protocol via CDMA network. It has been programmed using embedded visual C++ 4.0(Microsoft, USA) with Platform Builder 4.2 (Microsoft, USA).

The data collection server is a general TCP/IP server that takes into consideration sudden disconnection from client and has a function of DMZ client for DMZ server of hospital.

The database module saves the data as MS Access^{TM}(Microsoft, USA) format. The saved data in the case of ECG are SpO_2 value, heart rate, photoplethysmography, patient ID, measured date, measured time and patient's status. In the case of ECG, the saved data are ECG, patient ID, measured date and measured time

Both data collection server module and database module is made on Microsoft Foundation Class (MFC) platform using visual C++ (Microsoft, USA).

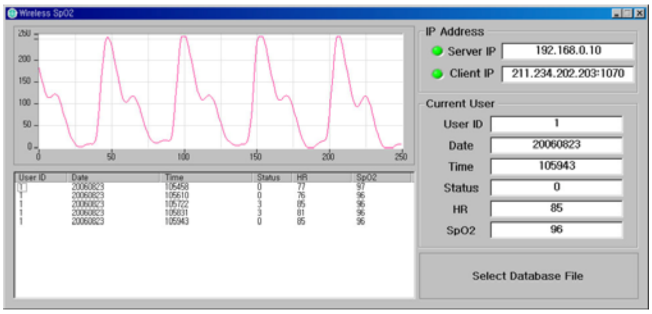

Fig. 2 ECG and SpO_2 monitoring software

To monitor the patient's state, a monitoring software (as Fig. 2) with a user interface is necessary.[2] The monitoring software includes both data collection server module and database module mentioned above. Basically, it has provided transferred SpO_2 data and ECG data via graphs and tables. And it has shown the doctor not only current data but also old data if the doctor would like to re-examine the old ones. The monitoring software is programmed on MS .NET Framework (Microsoft, USA) using visual C#.

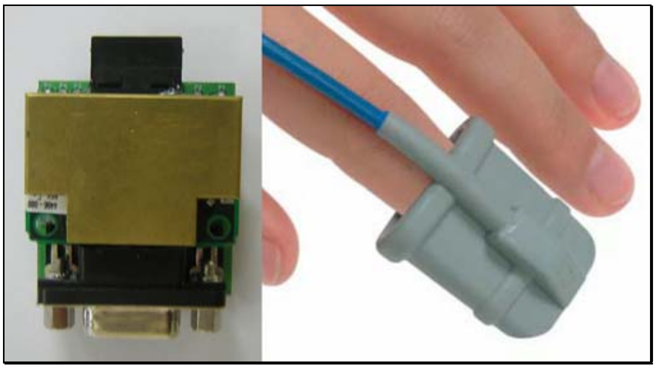

Fig. 3 SpO_2 Module and Flexible SpO_2 Sensor

C. SpO_2 measurement method

To measure the SpO_2, at first the PDA has to connect with the module connector and then that module connector has to be connected the SpO_2 module. Finally, if the SpO_2 module connects with the rubber type SpO_2 sensor, a lightemitting diode will be shining after operating the PDA program. If all readies are completed, the patient's finger has to be inserted in the sensor then be rigid (as Fig. 3 in previous page).

To acquire a data about the patient's social life style, the patient has to choose one of 4 selections, which are walking, eating, going to the restroom and etc. status manually. The selection buttons are on the touch screen LCD. These 4 selections are set up by physicians who will analyze the data. If the patient chooses one of these 4 selections, the PDA turns into power saving mode automatically for reducing power consumption. The SpO_2 data is being measured continuously by the SpO_2 module when the PDA is under power saving mode. After 5 minutes under power saving mode, the PDA wakes up automatically and saves the 4 second data into internal flash memory, then the PDA transmits the acquisition data to the monitoring software including data collection server module. Not past 5 minutes, if the SpO_2 value exceeds the standard one that is set up by physicians, the PDA sends a short message to a doctor automatically. Of course, the PDA also sends the acquisition data within 5 minutes to the monitoring software in the same situation.

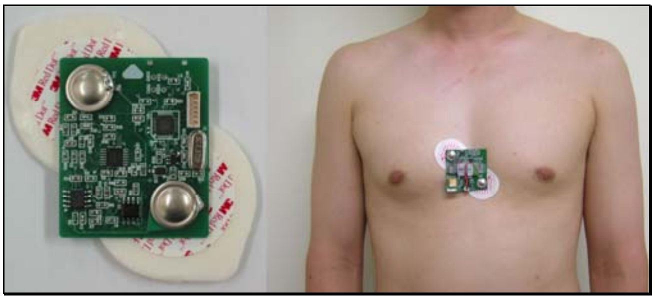

Fig. 4 ECG Module

D. ECG measurement method

The connection method of the ECG devices is the same as the SpO_2 devices. The only difference between the ECG device and the SpO_2 device is a disposable gel type electrode. After the electrodes are connected to the ECG module, the electrodes have to be attached onto the middle of chest (as Fig. 4). A LED will be shining after operating the program.

Using CDMA network, the bandwidth is enough to transmit the whole ECG data to the doctors by real time. However, when the data are sent by the CDMA module, the CDMA module consumes about 1A at most for 7 seconds. So although the ECG module measures ECG continuously, the 4 seconds data are transmitted just every 5 minutes.

But as in the case of SpO_2 measurement, even if the time of acquisition is within 5 minutes, the PDA sends an alert message to the doctor when the patient in emergency status is recognized by the standard of the physicians.

E. Data communication and analysis method

To communicate between the PDA and the monitoring software via TCP/IP protocol using CDMA network, we can use RAS protocol. RAS protocol is provided by Microsoft as Operating System (OS) vender. After the completion of TCP/IP communication, the database module in the monitoring software saves the received data as MS Access format into a hard disk drive of the data acquisition server. The saved data in the database can be always reexamined by the physicians.

In general case, the saved data is converted to MS Excel™(Microsoft, USA) format data files. And then physicians analyzes them using MS Excel™ or MATLAB™ (Mathworks, USA).

III. Results

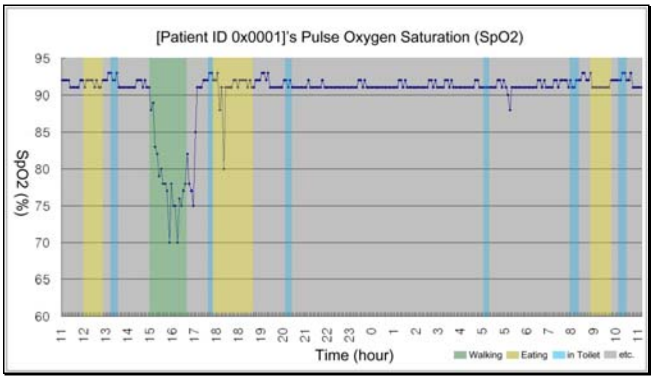

Fig. 5 Result of SpO_2 Measurement for a day

A. Results of SpO_2 data transmission

Fig. 5 is the result of the data that is transferred from a patient's home via CDMA network for about 24 hours. The patient of Fig. 5 has to put on a respirator at all times because he has an idiopathic pulmonary fibrosis. Thus the values of SpO_2 are above 90% of SpO_2 except when he is taking a walk.

From the results of Fig. 5, we can know that a small amount of action does not affect the patient who has put on a respirator. However, a large one like in the state of walking could affect the patient's status and in this case, the wireless SpO_2 device can help the patient

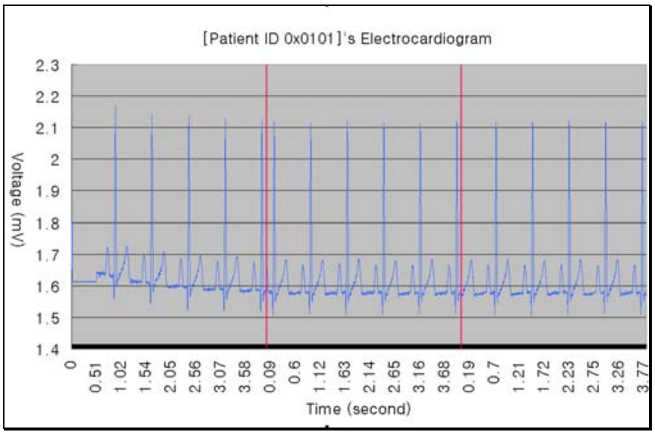

Fig. 6 Result of ECG Measurement for about 10 minutes

B. Results of ECG Transmission

Fig. 6 shows us that the transmitted ECG data from the PDA via CDMA network.

In Fig. 6, the red lines express the index of 5 minute time interval. The data length between two red lines is 4 seconds.

However, as above mentioned, the whole ECG data is saved in the internal flash memory of the PDA. The data in Fig. 6 is acquired from obstructive pulmonary disease patients like the one in the result of SpO_2 transmission because our physicians have not enlisted the patients who are going to participate in the experiment yet.

IV. Discussion

A. Correlation between SpO_2 value and social life

Before the beginning of the experiment, we have expected that the SpO_2 value would change much along the patient's lifestyle but we have not found it.

In the case of a normal person, it has changed much relatively along his actions but this data can not be used in this paper because the purpose of this paper is only for the patient who puts on a respirator all the time.

B. Usefulness of wireless ECG monitor

There is an algorithm that is able to analyze an ECG signal in accordance to the other papers.[3][4] Our wireless ECG device as the wireless ECG monitoring device is good to acquire and transfer the ECG data. So if we apply the algorithm to our device, the heart disease patients must get more efficient help.

C. A problem of short operating time

The operating time has been about 12hours until now.

In spite of reducing the power consumption of the ECG and the SpO_2 modules, its influence in increasing the battery life is very small. However, the vendor of the PDA has reported that a company will produce a double size battery soon. So this problem will be solved in the near time.

D. A problem of long data analysis time

A current analysis method is hard to find a feature of the signals. So we are developing professional analysis tools for analyzing the ECG and the SpO_2 signals.

V. Conclusion

In this paper, we have developed a wireless ECG and SpO_2 device for the patient who wants to live in their home. And to find the correlation between the signals and the patient's life style, we have tried to analyze the data of experiment.

Though our research has some problems yet, we are trying to solve these ones.

We desire that these devices help the patients' social life.

VI. Acknowledgements

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VII. References

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