A CDMA-BASED EMERGENCY TELEMEDICINE SYSTEM WHICH INCLUDE FIVE VITAL BIOSIGNALS

Il Hyung Shin*, Jaemin Kang*, Seung Yup Lee*, Yong Won Jang*, and Hee Chan Kim**

* Interdisciplinary Program, Biomedical Engineering Major, Graduate School and
** Department of Biomedical Engineering, College of Medicine and
Institute of Medical & Biological Engineering, Medical Research Center,
Seoul National University, Seoul, Korea

hckim@snu.ac.kr

Abstract: In this paper, we report upon the prototype development of a CDMA(Code Division Multiple Access)-based Emergency Telemedicine System(CETS) to be used by emergency rescuers to get directions from medical doctors in providing emergency medical services for patients on ambulance. Five vital biosignal instrumentation modules have been implemented, which include noninvasive arterial blood pressure (NIBP), arterial oxygen saturation (SaO_2), 6-channel electro-cardiogram(ECG), blood glucose level, and body temperature and on-the-spot image of the patient is also taken. Measured patient data is then transferred to a doctor's PC through the CDMA and TCP/IP networks using an embedded PDA phone. Most prominent feature of the developed system is that it is based on the CDMA backbone networks, through which we will be able to establish a ubiquitous emergence healthcare service system.

Introduction

In emergency situations, it has always been recognized that promptness and the appropriateness of treatment is the most critical factor. Recent studies have shown that early and specialized prehospital management contributes to emergency case survival. The prehospital phase of management – in particular accurate triage to direct the patient to the closest, most appropriate facility – is of critical importance [1].

It is very convincing therefore that a portable integrated telemedicine system can be used for the patients in emergency situation to get a rapid medical treatment in prehospital setting. The functional objective of this kind of system is to provide clinical information about the patient in emergency situation, such as vital biosignals including real-time on-the-spot images, to emergency medical doctors at a distance. Thereby, the unit provides the facility for rapid and appropriate directions to be given by experts, and enables the rescuer or the supervisor to manage changes in health condition with helpful treatment. This type of system will result in reduced mortality and dramatically improved patient outcomes. In this paper, we report the progress in our on-going project, "Development of a CDMA-based emergency telemedicine system (CETS)".

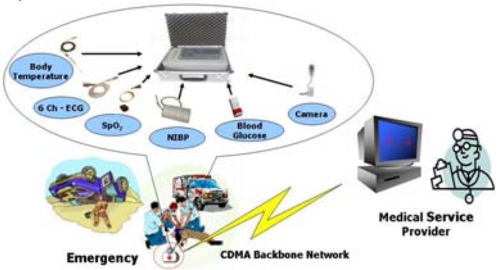

Figure 1: Usage scenario of the CETS, the portable device.

As shown in Figure 1, our strategy is to build the CETS within a portable case to be carried by emergency rescuers. Major components of the system are biosignal instrumentation modules, a central processor module with a touch-screen LCD display, and a CDMA-based PDA phone with a CCD camera module. The vital biosignals are noninvasive arterial blood pressure (NIBP), arterial oxygen saturation (SaO_2), 6- channel electrocardiogram (ECG), body temperature, and blood analysis for glucose, electrolyte, gas, and cardiac markers. On-scene photography is separately implemented using a CCD camera module in the PDA phone used for tele-reporting device.

In this intermediate report, we present a description of the prototype device and the first results of the performance evaluation tests in the laboratory and practical tests in suburban area which has a poor medical service.

Materials and Methods

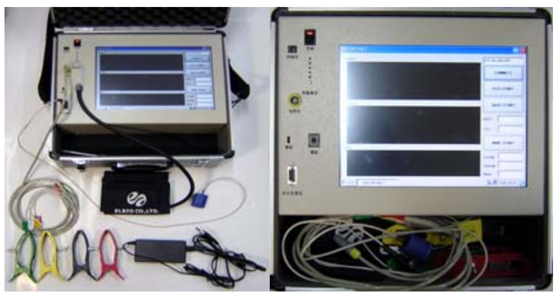

Figure 2: Prototype of portable CETS system.

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Figure 2 shows a whole portable CETS system. This system has many peripheral intruments that are used for measuring medical biosignal. The detailed specifications of each measurement module are as follow.

For a 6-channel ECG measurement, we used 4 electrodes for six channel recording. The analogue circuitry of the ECG module consists of an instrumentation amplifier, a notch filter and a non-inverting amplifier with a total gain and bandwidth of 80dB and 100Hz, respectively. The ECG signal is converted to a digital signal with sampling rate of 500Hz for further processing including heart rate (HR) estimations.

Performance evaluation of the developed ECG module was accomplished using a commercial ECG simulator (Patient-Simulator 214B, DNI Nevada Inc. USA).

The NIBP module was constructed using, a motor, a pump, solenoid valves, a wrist cuff and a small semiconductor pressure sensor (MPXM2053, Motorola, USA). All electronic circuitry and the program for the oscillometric pressure measurement were developed in this laboratory [2]. Performance of the developed NIBP module was verified using a commercial simulator (BPPump2M, BIO_TEK, and USA).

An SpO_2 module was developed using a commercial finger clip sensor (8000H, NONIN, USA) connected to the main unit, which includes the required electronic circuitry and program. The performance of the developed SpO_2 module was verified using a commercial SpO_2 simulator (Oxitest plus7, DNI Nevada Inc, USA).

A glucometer module was developed using a basic potentiostatic amperometry circuitry and uses commercial electrochemical-type glucose strips (Truchek®, ELBIO, Korea) for convenience. The performance of the developed module was evaluated by test resistor sets provided by the strip vendor.

A body temperature module was developed by refurbishing commercial infra-red thermometer to be digitally interfaced. The developed module was tested inside a heated chamber over the range of 25~40(^{o}C) with one degree steps.

Following Figure 3 shows a functional block diagram of the total emergency healthcare service system including the CETS. First part is a main unit of the CETS that will be set in ambulance to be used by emergency rescuers. Five vital biosignal instrumentation modules have been implemented, which include noninvasive arterial blood pressure (NIBP), arterial oxygen saturation (SaO_2), 6-channel electro-cardiogram (ECG), blood glucose level, and body temperature. These five modules are controlled by Main Control Unit (MCU). And MCU communicates with CDMA module that has built-in antenna via RS-232C (RS232) data communication protocol.

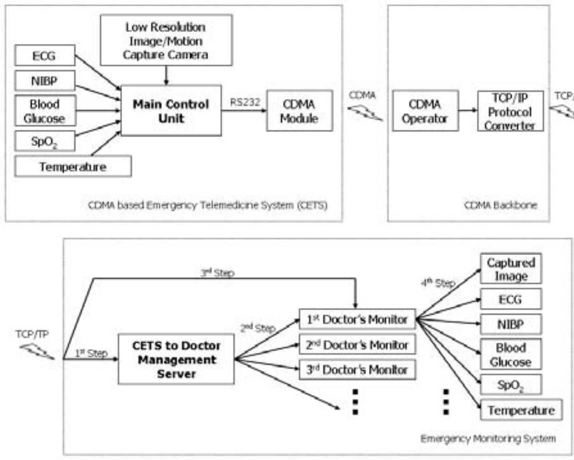

Figure 3: Functional block diagram of the total emergency healthcare service system including the CETS

As shown in Figure 3, the second functional block is a CDMA backbone network which is provided by a cellular phone service company, where the signal protocol is converted from CDMA to TCP/IP. Last one is a monitoring system at the emergency room in a hospital. It has one data distribution server operating in four steps, through which the measured patients' data from multiple CETSs can be transferred to each selected doctor's PC directly. As the first step, when a connection request signal comes from one CETS via TCP/IP protocol, the server finds a doctor's PC which is not currently being occupied and it mediates connection between the doctor's PC and the requesting CETS directly as marked by the 2nd and 3rd steps in Figure 3.

Results

Following Figure 4 shows the developed CETS including the five biosignal instrumentation modules, a 12-inch touch screen LCD as input and display, a Li-ion rechargeable battery, and a PDA phone. The total size of the CETS is 360x360x120mm and weighs 1.5kg including the carrying case.

User interface program of the CETS was developed for operational simplicity and efficiency since considering the fact that users are rescuers in emergency situations, any complicated user interface would be counterproductive. The CETS provides large graphic icons on a 640x480 pixel color graphic LCD with a touch screen function. An embedded PDA phone makes a wireless connection through a public telecommunication network. The CETS performs all measurements and sends the measured data to preassigned emergency medical center (the 1339 Seoul Areal Emergency Call Center, Korea) using PDA phone as quickly as possible.

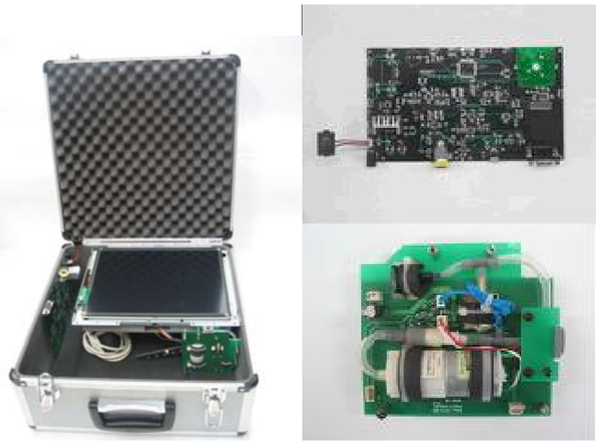

Figure 4: Photograph of the developed CETS and its modules inside a carrying case.

Results of the performance evaluation tests of the CETS in the laboratory are summarized in Table 1. For various simulated ECG outputs with range of 40~240(BPM), the developed ECG module produced HR outputs within an error range of ±1%. The developed NIBP module provided outputs within an error range of ±5%. Over various range of SpO_2 levels, the output showed an accuracy within an error range of ±2%. In thermometer evaluation, the results obtained showed good linearity and accuracy within an error range of ±1%

Table 1: Performance evaluation tests of the CETS

	NIBP	SpO2	ECG (HR)	Glucose level	Body Temperature
Method	simulator	simulator	simulator	Test set-up	Test set-up
	BPPump2, Biotek, USA	Oxitest plus7, DNI Nevada Inc, USA	PS214B, DNI Nevada Inc, USA	Test resistor set	temperature-controlled chamber
Number of Tests	100	100	100	100	20
Perform-ance parameter	Error range	Error range	mean % error	Error range	mean % error
	Within ±5mmHg	Within ±2 %	0.9%	Within ±1 %	1%

Figure 5: Practical Tests in running ambulance car in suburban area (JEJU Island, Korea)

Figure 5 shows a practical test. CETS was tested in running ambulance car in order to evaluate performance on practical emergency situation.

It had been tested in the city (Seoul, the capital of the Korea) and suburban area (JEJU Island, Korea) which have rich and poor CDMA backbone networks respectively

The test result in both areas was similar to one in the laboratory. But each result has some different delay time which has been occurred on changing local CDMA operator. The delay time of suburban area test is longer than one of urban area test. However any other problems had never been occurred for about 30 minutes on the practical test.

Following Figure 6 shows The Remote Emergency Monitoring System (remote-EMS). It was developed for assisting medical doctors and experts who have worked in the emergency room.

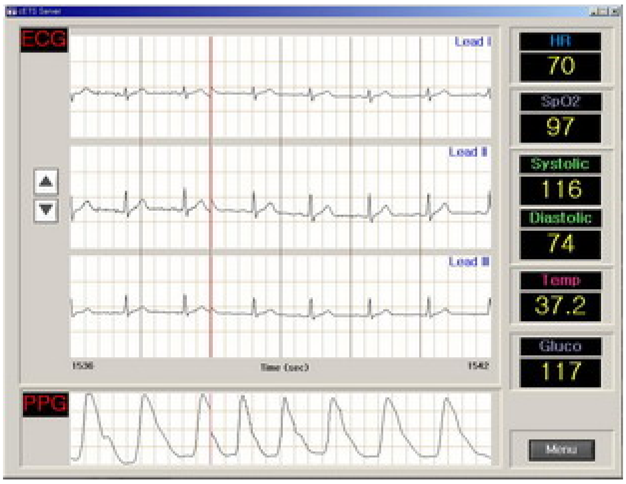

Figure 6: The Remote Emergency Monitoring System for medical doctors and medical experts.

As shown in Figure 6, The remote-EMS is able to show 6-channel ECG signal, Photo Plethysmogram (PPG) related by SpO_2 measurement, heart rate, systolic and diastolic pressure, body temperature, blood glucose level. It was controlled by management server and has printing and recording functions. And on-the-spot snapshot image which has low level resolution is also shown on an independent window.

Conclusions

We have developed and tested a prototype system of the CDMA-based emergency telemedicine system.

The system was designed to be used by emergency rescuers to get directions from medical doctors in providing emergency medical services for patients on ambulance. In the prototype system, the measured and transmitted vital information comprises five physiological parameters and variables, such as 6-channel ECG, noninvasive blood pressure, oxygen saturation level, blood glucose level and body temperature. On-the-spot snapshot or motion pictures of the patient is also taken and transferred as image data for helping doctors understand the patient's medical state.

The most important feature of our system is that it uses CDMA backbone networks. . CDMA-based network has been installed all over the country and used to provide the cellular phone services. Since it is based onthe ad-hoc networking technology, we can connect this network at almost everywhere and anytime, in other words, ubiquitous emergency healthcare serviceis possible. Another structural feature of our system is the capability to provide a a point-to-point connection by the data distribution management server, through which we can construct the total system cheaper and more flexible.

Acknowledgement

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