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A CDMA-based Ubiquitous Emergency Healthcare System

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Abstract— **In this paper, we report on the prototype development of a CDMA-based ubiquitous emergency healthcare system(CUEHS) to be used by emergency rescuers to get guidances from emergency medical doctors in providing first-aid treatments for patients on an ambulance. Five vital biosignal instrumentation modules have been implemented, which include noninvasive arterial blood pressure (NIBP), arterial oxygen saturation(SpO_2), 6-channel electrocardiogram(ECG), blood glucose level, and body temperature. Measured patient data is 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 are able to establish an ubiquitous emergency healthcare service system.**

Keywords— **CDMA, emergency telemedicine system, biosignal monitoring ubiquitous emergency healthcare system**

I. 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 while an emergency medical doctor-guided first-aid treatment is provided – is of critical importance [1].

As a digital cellular phone technology, code division multiple access(CDMA) is characterized by high capacity and small cell radius, employing spread-spectrum technology and a special coding scheme. In Korea, the first CDMA-based networks in the world are now covering almost whole country, which can be very effectively used in realizing a ubiquitous emergency healthcare system. It is very convincing, therefore, that a portable integrated telemedicine system equipped with a CDMA-based telecommunication module 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 with 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 medical 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 first progress in our on-going project, "Development of a CDMA-based emergency telemedicine system (CETS)".

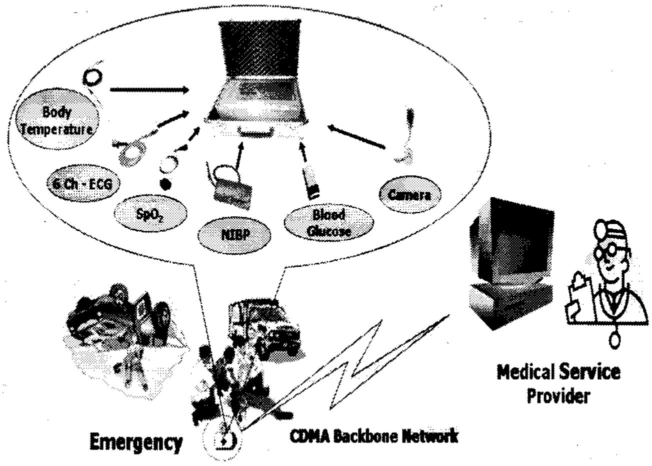

Fig. 1. Usage scenario of the CETS

II. METHODOLOGY

As shown in Fig. 1, our strategy is to build the CETS within a portable case to be carried by emergency rescuers. A prototype system is composed of biosignal instrumentation modules, a central processor module with a touch-screen LCD display and a CDMA-based PDA phone. The vital biosignals include noninvasive arterial blood pressure (NIBP), arterial oxygen saturation by pulse oxymetry(SpO_2), 6-channel electrocardiogram(ECG), body temperature, and blood glucose level.

Fig. 2 shows a functional block diagram of the ubiquitous emergency healthcare service system including the CETS. First part is a main unit of the CETS that is set in ambulances to be used by emergency rescuers. Five vital biosignal instrumentation modules have been implemented. The detailed specifications of each measurement module are as follow.

For a 6-channel ECG measurement, we used 4 surface electrodes(RA, LA, RL, and LL) for six channel recording. 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. Measured ECG signal is then converted to a digital signal with sampling rate of 250Hz for further processing such as heart rate(HR) estimation. Performance evaluation of the developed ECG module was accomplished using a commercial ECG simulator (Patient-Simulator 214B, DNI Nevada Inc. USA).

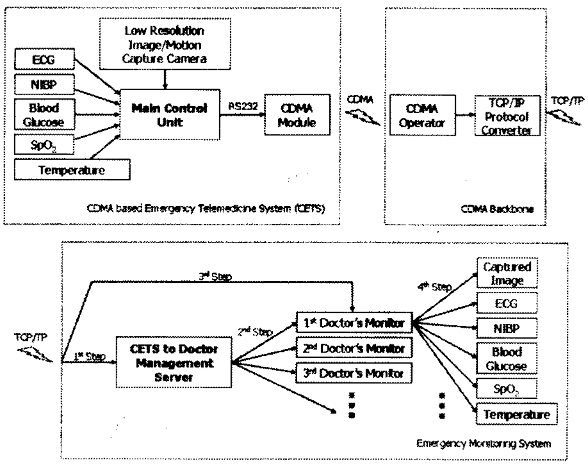

Fig. 2. Functional block diagram of the ubiquitous emergency healthcare system including the CETS.

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

An SpO_2 module was developed using a commercial finger clip sensor (8000H, NONIN, USA) connected to a main unit which includes the required electronic circuitry and software. 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 for 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(TB-100, Hubidic, Korea) to be digitally interfaced.

As shown in Fig. 2, the second functional block is a CDMA-backbone networks which are provided by a cellular phone service company(KTF, Korea), where the signal protocol is converted from CDMA to TCP/IP. The third functional block is a monitoring system at the emergency room in a hospital. It is based on one data-distribution server operating in four steps, through which the measured patients' data from multiple CETSs are transferred to each doctor's PC as assigned at the first connection. 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 thereafter it maintains the connection between the corresponding doctor's PC and the requesting CETS as marked by the 2nd and 3rd steps in Fig. 2.

In order to evaluate the usability (applicability) as well as the performance of the CETS in real situation, we tested the developed system in emergency environments at Jeju Island, Korea[3][4]. As the largest island in Korea – 73km wide and 41km long with a total area of 1,845km^2, Jeju Island is lying south of the Korean peninsula an hour's flight from Seoul. There are 557,235 total populations but relatively few medical centers are available. The test was performed in collaboration with the Seogwipo City Medical Center and the Seogwipo City 119 Rescue Center. We evaluated the connectivity and communication quality of CDMA data transmission all over the whole Jeju Island with the developed system set on an ambulance.

III. RESULTS

Fig. 3 is pictures of 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. Total dimension of the CETS is 330x330x100mm and weighs 3kg including a heavy-duty carrying case. User interface program of the CETS was developed for operational simplicity and efficiency considering the fact that users are rescuers in emergency situations.

The CETS provides large graphic icons on a 640x480 pixel color graphic LCD with a touch screen function.

Results of the performance evaluation of the biosignal modules of the CETS in our laboratory are summarized in Table 1. For various simulated patient conditions with a range of 40~240(BPM) of HR, the developed ECG module produced good estimation 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 result showed an accuracy within an error range of ±2%. In glucometer evaluation, we obtained a good linearity and accuracy within an error range of ±1%.

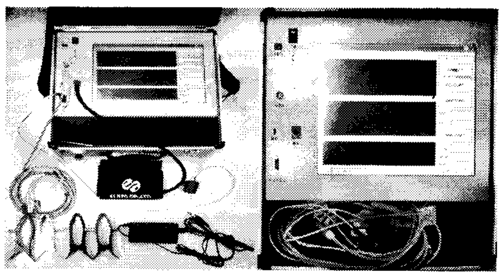

Fig. 3. Photograph of the developed prototype of portable CETS.

TABLE I
PERFORMANCE EVALUATION RESULTS OF THE CETS IN THE LABORATORY

	NIBP	SpO2	ECG(Heart Rate)	Glucose level
Evaluat-ion Method	simulator	simulator	simulator	Test set-up
	BPPump2M Bio_tek, USA	Oxitest plus7 DNI Nevada Inc, USA	PS214B DNI Nevada Inc, USA	Calibration strip set
Number of test	100	100	100	100
Evaluat-ion value	Error range	mean % error	mean % error	Error range
	Within ±5mmHg	2%	0.9%	Within ±1%

Fig. 4. Practical application in running ambulance car in rural area (JEJU Island, Korea)

The embedded PDA phone provides a wireless connection through the public telecommunication networks. The CETS performed well in all measurements with simulator outputs and sending the measured data to a preassigned server at emergency medical center (the 1339 Seoul Area Emergency Call Center, Korea) in practically real-time.

Fig. 4 shows sample pictures of the practical applications. The CETS was tested in a running ambulance car in order to evaluate performance in real emergency situations. It was tested in a big city (Seoul, Korea) and rural area (Jeju Island, Korea) which was thought to have rich and poor conditions of CDMA networks, respectively.

The performance of data transmission showed no significant difference between two test sites. Only time delay for a switching between adjacent base stations was found to be longer in rural area, but any other critical problem to possibly hinder the practical application was not experienced in both cases.

Fig. 5 shows a screen display of the developed Remote Emergency Monitoring System (remote-EMS). It was developed for emergency medical doctors in the emergency room. As shown in Fig. 5, the remote-EMS displays the real-time waveforms of 3 channels out of the 6-channel ECG and the photo-plethysmogram(PPG) from SpO_2, and text display of heart rate, systolic/diastolic pressure, body temperature, and blood glucose level. It is controlled by the management server which performs the data recording of the transmitted data.

IV. Conclusion

We have developed and tested a prototype system of the CDMA-based ubiquitous emergency healthcare service system. The system was designed to be used by emergency rescuers to get guidances from emergency medical doctors in providing first-aid treatments for patients on an ambulance. In the developed prototype system, the measured and transmitted vital information consists of five physiological waveforms and variables such as 6-channel ECG, noninvasive blood pressure, oxygen saturation level, blood glucose level and body temperature.

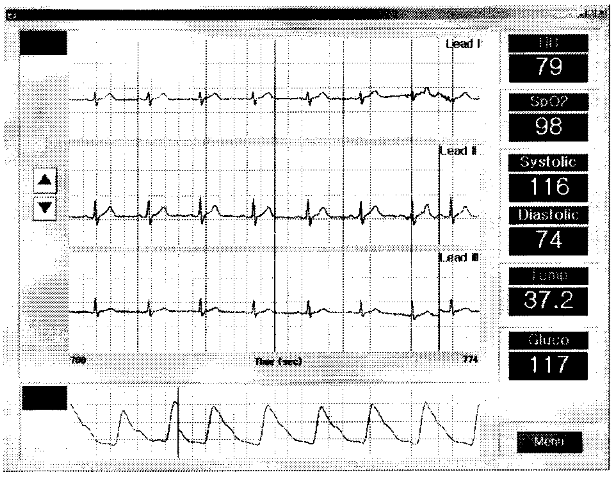

Fig. 5. Screen display of the Remote Emergency Monitoring Program for emergency medical doctors in the emergency room .

The most important feature of our system is that it uses CDMA backbone networks. CDMA-based networks now covers practically whole country in Korea and are being actively used for cellular phone services. Since it is based on the ad-hoc networking technology, we can connect this network everywhere and anytime, so literally an ubiquitous service is possible. Another feature of our system is a capability to provide a point-to-point connection by the data distribution management server, through which we can operate the total system in lower cost as well as more flexible way.

Acknowledgment

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