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HSDPA (3.5G)-Based Ubiquitous Integrated Biotelemetry System for Emergency Care

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***Abstract*—We have developed the second prototype system of Ubiquitous Integrated Biotelemetry System for Emergency Care(UIBSEC) using a HSDPA(High Speed Downlink Packet Access) modem to be used by emergency rescuers to get directions from medical doctors in providing emergency medical services for patients in ambulance. Five vital bio-signal instrumentation modules have been implemented, which include noninvasive arterial blood pressure (NIBP), arterial oxygen saturation (SaO2), 6-channel electro-cardiogram(ECG), blood glucose level, and body temperature and real-time motion picture of the patient and GPS information are also taken. Measured patient data, captured motion picture and GPS information are then transferred to a doctor's PC through the HSDPA and TCP/IP networks using stand-alone HSDPA modem. Most prominent feature of the developed system is that it is based on the HSDPA backbone networks available in Korea now, through which we will be able to establish a ubiquitous emergency healthcare service system.**

I. Introduction

In order to live a decent life in modernized countries, health is the most important factor to be satisfied first. The advancement of medical technology in 21th century helps people released from the fear of various kinds of diseases, but outbreak of medical emergency situations has not been well prepared yet. In emergency situations, promptness and the appropriateness of treatment are the most critical factors [1]. A lot of studies have shown that early and specialized prehospital management contributes to emergency case survival. The prehospital phase of management is of critical importance, i.e., accurate triage to direct the patient to the closest most appropriate facility, and emergency medical doctor-guided first-aid treatment [2],[3].

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 patient's 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.

In this paper, we report the second progress in our on-going project [4], "Ubiquitous Integrated Biotelemetry System for Emergency Care(UIBSEC)".

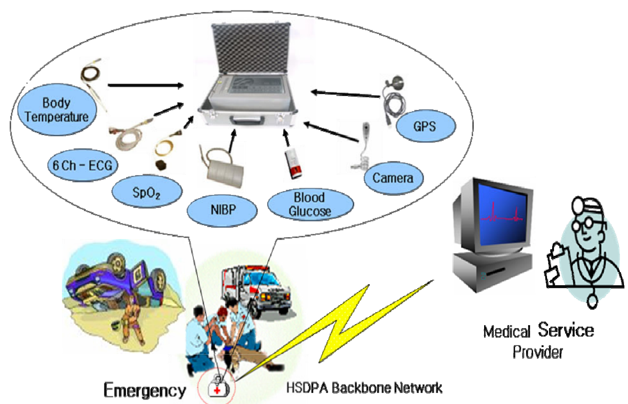

Fig. 1. Usage scenario of the UIBSEC.

As shown in Fig. 1, our strategy is to build the UIBSEC within a portable case to be carried by emergency rescuers. Major components of the system are biosignal instrumentation modules, a CCD camera module, a GPS module, a central processor module with a touch-screen LCD display, and a HSDPA modem. The vital biosignals are noninvasive arterial blood pressure (NIBP), arterial oxygen saturation (SaO2), 6-channel electrocardiogram (ECG), body temperature, and blood analysis for glucose. On-scene real time motion picture is separately implemented using a CCD camera module. In this report, we present a description of the second prototype device.

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II. Materials and Methods

A. Total System Description

Fig. 2. The HSDPA-Based UIBSEC

Fig. 2 shows the developed system. Basically it has five bio-signal measurement functions and two additional functions(Camera, GPS). Comparing with previous prototype system, the second prototype system supports motion picture capturing and its transmission, real-time character message service for effective medical feedback and transmission of GPS information on the way of ambulance transportation. We also have developed a client distribution server to use the communication bandwidth more effectively. The developed UIBSEC has many peripheral instruments that are used for measuring biosignals. The detailed specifications of each measurement modules 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 200Hz for further processing including heart rate (HR) estimations. Performance evaluation of the developed ECG module was accomplished using a commercial ECG simulator (PS214B, 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. Performance of the developed NIBP module was verified using a commercial simulator (BPPump2M, BIO_TEK, and USA). A 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(TB-100, Hubidic, Korea) 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. We use a commercial PC camera(CobraCam, COCAM, Korea) having a USB interface to capture the patient image. This module is easy to control the photographing position and has an image resolution of 320 by 240 pixels. We transmitted the captured image with the rate of 3frame/sec. Ambulance position information acquired using GPS module can provide a useful function such as the shortest transferring path, traffic information to avoid congestion and estimated time of arrival and so on. We used a commercial GPS module (BU-353, GSAT, Taiwan) connected to the UIBSEC via USB interface. The GPS data of NMEA protocol was transmitted to the emergency medical center.

For telecommunication function, we used HSPDA modem. HSDPA (High Speed Downlink Packet Access) [5] is the system enhancement of W-CDMA networks which provide an improved peak data transfer rate and an increased throughput for world-wide wireless systems [6]. It was published in Release 5 of 3.5GPP UTRA-FDD specifications and has been prevailing over the world and become the standard of 3.5G wireless communication networks. In case of the South Korea which has one of the most developed and advanced wired and wireless network infrastructure in the world, SK Telecom launched commercial HSDPA service on May 15, 2006 and KTF did on June 30, 2006. With their theoretical downlink speed of 14.4 Mbps, telemedicine systems can benefit from the features currently feasible on wired communication networks. Thus we applied wireless HSDPA module to the UIBSEC. A main control unit (MCU) was developed on a tablet notebook computer to make user-interface that is easy to use and to develop. This computer has a 12.1 inch touch screen LCD (1024 pixel X 768 pixel resolution), 2 USB ports that is used as data communication pathway between MCU and each measurement modules with using USB hubs. A user-interface was made with using visual C#.NET^{TM} (Microsoft, USA) on .NET^{TM} platform which is a next generation development platform that supports features of computer language and operating system independent.

B. User interface and basic operation of the UIBSEC

Fig. 3 shows user interface of the UIBSEC. At first, a doctor in front of monitoring system in the emergency center waits for an attempt of connection from the UIBSEC in the moving ambulance. If there is request of the UIBSEC, the monitoring system will make a connection with the UIBSEC with help of distribution server. After completion of the connection, five biosignals and patient's motion picture are transmitted to the monitoring system. Then, the doctor can send a treatment order to the UIBSEC in the ambulance by character message.

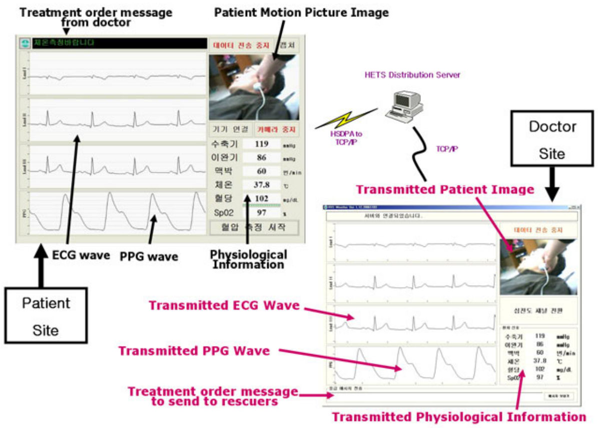

Fig. 3.User interfaces of the patient's site in the ambulance and the doctor's site in the emergency center.

C. *Client Distribution Server for UIBSEC*

Client distribution server is necessary for managing the connection between UIBSEC and medical doctor's client program when massive connection requests occurred in real emergency environment. This server basically has a P2P (Peer to Peer) scheme. UIBSEC requests the emergency medical center to find and connect a medical doctor not occupied with other UIBSEC. Client distribution server keeps monitoring the connections between all UIBSEC and assigned doctor's client in an effective way, and automatically connects the doctor who has waited for the longest time with the UIBSEC requesting connection.

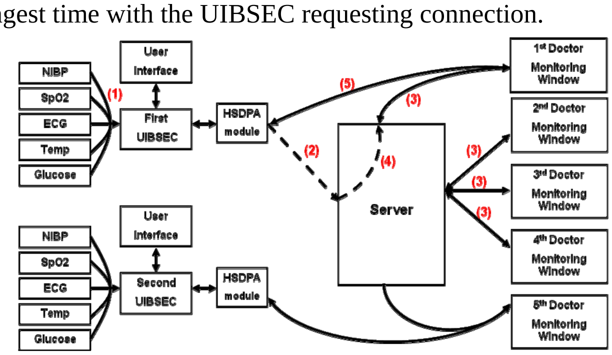

Fig. 4. Flowchart of UIBSEC client distribution method

Fig. 4 shows the process from measuring the patient's biosignal using UIBSEC to transmitting it to the emergency center through network distribution server.

(1) On ambulance transfer, UIBSEC measures patient's biosignal and transmits the information to the main system.
(2) UIBSEC requests for connecting to client distribution server through HSDPA module.
(3) Client distribution server looks for a medical doctor who's waited for the longest time.
(4) Assigned medical doctor would be connected with requesting UIBSEC through Packet Tunneling.
(5) After the connection, data is notionally communicated with the medical doctor's client program one on one.

Before applying the wireless HSDPA module to the UIBSEC, a set of four preliminary tests was performed to verify practical transmission capability of wireless network via 3.5G HSDPA module. The four tests are briefly described in Table I. We presented another report as more detailed research result for implementing the client distribution server[7].

TABLE I. A SET OF TESTS FOR PERFORMANCE EVALUATION

ID	Test Item	Description
I	Correctness	Check If the server replies correctly
II	RTT (Round-trip-time)	Measure the average loopback time for pinging
III	Throughput	Measure the maximum data transfer rate at three phases : S / R / S+R (S: send, R: receive)
IV	Image transmission	Measure the averaged value of FPS (frame per second) and image size

III. RESULTS

A. *Performance evaluation in a laboratory*

TABLE II. PERFORMANCE TESTS IN LABORATORY

Module	Method	Range	Error range
NIBP	Oscillometric	20 ~ 300 mmHg	< 5 mmHg
ECG	6ch ECG	Lead :I, II, III aVR, aVL, aVF	HR error (within 1%)
Temperature	IR thermometer	15 ~ 45 'C	within 0.5 'C
SpO2	Finger clip sensor	80 ~ 97 %	within 1 %
glucometer	Strip sensor	40 ~ 600 mg/dl	40~100 : < 4 mg/dl 100~200:< 10 mg/dl 200~600:< 5 mg/dl

Results of the performance evaluation are summarized in Table II. 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 mmHg. Over various range of SpO2 levels, the output showed accuracy within an error range of 1%. In thermometer evaluation, the results obtained showed good linearity and accuracy within an error range of 0.5 'C

The overall performance of HSDPA is, as seen in Table III, quite lower than the theoretical specification. We see that the maximum downlink speed was only 81.12 KB/s or 648.96 Kbps, which is about 4.4% of the theoretical maximum value of 14.4 Mbps. Moreover, this ratio was remarkably lowered to 1.57%. As for the maximum uplink speed ratio of 20.21 KB/s or 161.68 Kbps, however, the ratio was recorded to be 42%, which was considered relatively reasonable. We give a full detail of this result in [7].

TABLE III. OVERALL EXPERIMENT RESULT OF HSDPA

ID	Test Item	Sent	Received	Error Rate
I	Correctness	1000	1000	0
II	RTT (ms)	109.0	843.0	196.49
III	Throughput (KB/s)			
	i. Send	8.9	20.21	13.33
	ii. Receive	29.37	81.12	64.76
	iii. Send (with R)	10.7	20.21	17.1
	iv. Receive (with S)	9.6	28.9	26.8
IV	Image transmission			
	i. FPS	1	7	1.92
	ii. Image size (KB)	1.78	8.14	6.7

IV. DISCUSSION

In our first prototype system[4], we applied the system to real emergency cases and confirmed the efficacy of UIBSEC in emergency case. We have developed the second prototype system of UIBSEC with some modification of data transmission method using HSDPA and addition of functions like capturing a motion picture and GPS information. The system was designed to be used by emergency rescuers to obtain guidance from emergency doctors for the provision of first-aid treatment in an ambulance setting. In the developed prototype system, the measured and transmitted vital information consists of physiological waveforms and variables, namely, a 6-channel ECG, blood pressure, oxygen saturation level, blood glucose level and body temperature.

The advantages of the described HSDPA-based data transmission model include the rapid, massive and safe transmission of measured data without time or space restriction. This study, demonstrates that the developed UIBSEC provides real-time, reliable multi-parameter health monitoring. We plan to apply this second system to real emergency cases with cooperation of 119 Korean rescue team, May 2007.

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