Proceedings of the 29th Annual International
Conference of the IEEE EMBS
Cité Internationale, Lyon, France
August 23-26, 2007.

Implementation of the Relay Server for the Ubiquitous Integrated Biotelemetry System for Emergency Care (UIBSEC) based on 3.5G HSDPA Technology

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Abstract—**When an emergent case occurs, to give proper and immediate emergency treatment to a patient is as important as to transfer him or her to the hospital as early as possible. For this circumstance where first aid usually happens in an ambulance, we developed the Ubiquitous Integrated Biotelemetry System for Emergency Care (UIBSEC) based on wireless 3.5G HSDPA module in order to provide more proper and active medical care to a patient. For this system we performed experimental tests on the HSDPA module to measure practical performance values with respect to throughput and RTT (round-trip-time) and compared the result with the theoretical specifications. In the course of developing this system we created the C#-based Network Solution Library (NSL) which helps drastically reducing the overhead. We applied this library to components of the UIBSEC – two kinds of clients and one central server – and confirmed that it works smoothly in wireless networks and it is useful in the future development process of network applications.**

I. Introduction

RECENT advances in wireless network communication technology opens up the gate towards possibility of applying it to wider range of application. We tried to exploit these new opportunities in the area of biomedical engineering and finally developed the Ubiquitous Emergency Telemedicine System (UIBSEC) which is focused on emergency treatment and biosignal data transmission between an ambulatory nurse in the ambulance and a doctor in the hospital using wireless HSDPA networks.

HSDPA (High Speed Downlink Packet Access) [1] 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 [2]. 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. As of March 19 2007, 100 HSDPA networks have commercially launched mobile broadband services in 54 countries and their peak data throughput differ from market to market [3]. 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 system can benefit from the features currently feasible on wired communication networks. Thus we applied wireless HSDPA module to the UIBSEC. To verify the theoretical specification we experimentally measured their data transfer performance and compared to the specification.

To be able to use this kind of wireless module, we had to solve the restriction of firewalls since the level of security becomes higher and higher nowadays and anonymous and malicious attacks occur frequently. We solved this problem using the client-server architecture based on peer-to-peer (P2P) scheme and the Network Solution Library (NSL). The NSL is the independent network library that is written in C# and aimed at using limited wireless bandwidth more efficiently and optimized for wireless communication. This library is integrated with the UIBSEC and forms its basis.

II. Method

A. The Overall System Description : Ubiquitous Integrated Biotelemetry System for Emergency Care (UIBSEC)

The UIBSEC is wireless emergency healthcare system based on the client and server architecture. It aims at serving timely the appropriate emergency medical care to urgent patients in an ambulance by means of connecting an ambulatory nurse with one of the doctors waiting in the hospital utilizing wireless communication network.

The UIBSEC is composed of three parts: the measuring devices (*device clients*) in an ambulance, the central server (*relay server*), and the monitoring device (*monitoring clients*) in a hospital. Fig. 1 schematically shows the overall diagram of the UIBSEC.

Manuscript received April 16, 2007. This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MOST) (No. M10536060001-06N3606-00110)

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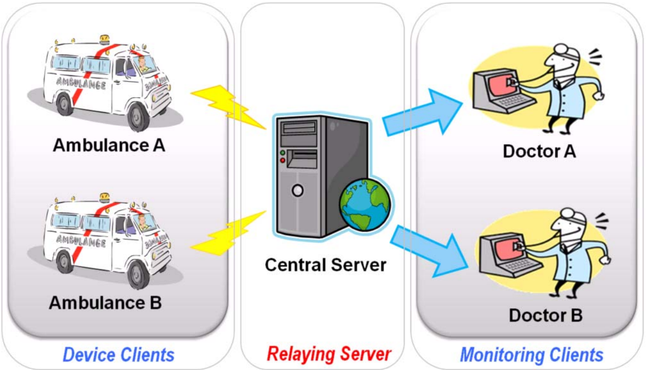

Fig. 1. Overall diagram of UIBSEC containing two clients – a device client and a monitoring client. The relay server is so designed with scalable architecture as to make the number of client connections expandable, if necessary.

The device client is a portable device system to measure a wide variety of biosignals such as ECG (electrocardiogram), NIBP (noninvasive blood pressure), blood glucose, SpO_2, H.R. (heart rate), body temperature, and a web-cam captured image. It is integrated with the C# network application to communicate with the monitoring client (a doctor) through the relay server using wireless 3.5G HSDPA network.

The monitoring client is an application for a doctor in a hospital. It receives and shows graphically all the real-time information sent by the device client so that a doctor can quickly grasp patient's state as comprehensively as possible. In addition it can be used by the doctor reversely to send an urgent prescription or remedy to an ambulatory nurse for immediate medical treatments.

The relay server is a multi-threaded, scalable, and stand-alone and dedicated application made with C# WinSock (Windows Socket) library. Basically, it operates similar to P2P (peer-to-peer) scheme in content-delivery but it provides additional and enhanced functions such as client session management, performance monitoring, and effective data distribution. Details are described in the next section.

B. Biosignal Characteristics for the UIBSEC

The biosignals targeted in the UIBSEC include ECG, NIBP, blood glucose, SpO_2, H.R., body temperature and web-cam captured image and their signal characteristics are summarized in Table I.

TABLE I. BIOSIGNAL CHARACTERISTICS USED IN THE UIBSEC

Biosignal	Sampling Rate	Bit Resolution
ECG	100 Hz	14 bit
NIBP	*Discrete number*	
Blood Glucose	*Discrete number*	
SpO_2	75 Hz	8 bit
H.R.	*Calculated from SpO_2*	
Body Temperature	*Discrete number*	
Captured Image	320x240 px, 8 bit color	

C. The Network Solution Library (NSL) and the Relay Server

The NSL is composed of the network library and the relay server. The network library deals with common features of network-related processing for both client and server and is implemented using C++ with WinSock event handling architecture. The relay server is tightly coupled with the NSL as shown below.

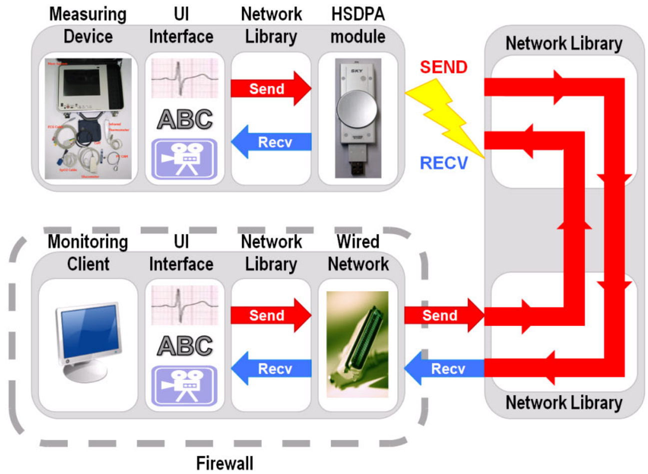

Fig. 2. Block diagram of UIBSEC integrated with the NSL. All three components, i.e., the device client, the monitoring client, and the relay server, have the network library in common. The NSL is specialized for the UIBSEC and optimized for wireless communication.

Since the relay server is independent and stand-alone application, it does not require any other external components such as web-server.

1) P2P-based Scheme: The relay server is conceptually similar to the Rendezvous Points (RP) server [4]. It works transparently between clients and mediates data transmission between them by temporarily buffering data, which is the core aspect of the relay server. This feature is introduced to solve connection problem which frequently occurs between two clients – one at inside and the other at outside firewalls by means of establishing virtual connection between them. Nowadays this kind of problem takes place more frequently since the level of security of local network, where the information must be safely protected and prohibited from being revealed, is becoming higher and higher and this trend will be much more pervasive in the future.

2) Client Session Management: In the UIBSEC the device client communicates with the relay server through wireless HSDPA networks at theoretical downlink speeds up to 14.4 Mbps. However, link disconnections, packets losses and delays in wireless environment are common [5], [6], thus the relay server should be able to detect disconnection as rapidly as possible. This feature has been implemented using the heart-beat detection which is basically similar to socket `KEEP_ALIVE` option.

3) Performance Monitoring: Information on two objects is continuously monitored by the relay server, one about server's worker threads and the other about incoming and outgoing packets. For the worker threads was measured the number of thread loop per second which directly represents overall application performance. For the incoming and outgoing packets that provide very comprehensive information on current network traffic status is included a number of variables such as count and size of sent and received packets and minimum, maximum and average value of them, respectively.

4) Effective Data Distribution: The device client establishes a single connection to the monitoring client – this is the basic concept of P2P network. If this 1:1 connection scheme is expanded in the future to N:N, the relay server can support the entire multiple connections among many clients and enable a client to make multiple connection and data transmission to many peer clients. This feature can reduce redundant use of wireless network and lead to cost reduction by way of the effective use of limited bandwidth.

D. Performance Evaluation Tools & Methods

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. To perform the tests repeatedly with configurable options such as socket receive or send buffer size the C# based application was developed so that the relay server can be optimized to adapt itself to wireless HSDPA networks.

The four tests are briefly described in Table II. They were all carried out using two different communication networks, namely, conventional wired TCP/IP and wireless HSDPA, in which throughput and RTT [6] were taken as the major criteria to evaluate the transmission performance [7].

TABLE II. 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

In Test III the throughput test is split into three different phases comprising uplink phase, downlink phase and simultaneous phase because common communications might occur bidirectionally and bandwidth allocation for downlink and uplink could be asymmetric, particularly in wireless network [8]. For instance, theoretically, HSDPA provides high data throughput in downlink (14.4 Mbps) but uplink data has a limitation in 3G systems (384 Kbps) [9]. Therefore, using this phase-split test scheme, more practical result can be achieved from the experiment.

All tests were performed around the beginning of April 2007 in Seoul, Korea and, throughout the tests, the SKT T-Login service network [10] was used with the Sky [11] IM-H100 modem.

III. RESULTS

A. Network Performance of HSDPA and TCP/IP

To obtain experimental performance data, a set of tests (Test I~IV in Table. II) was run 10 times under the same configuration with wired TCP/IP and wireless HSDPA. The socket option for receive send buffer size was 500kB and the buffer size of the application stage was 10MB.

1) TCP/IP (ethernet)

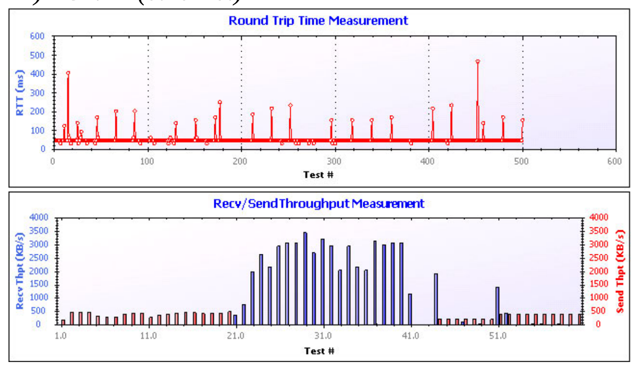

Fig. 3. RTT and throughput test result of wired TCP/IP

TABLE III. OVERALL EXPERIMENT RESULT OF TCP/IP

ID	Test Item	Sent	Received	Error Rate
I	Correctness	1000	1000	0%
		Min.	Max.	Avg.
II	RTT (ms)	15.00	625.00	49.80
III	Throughput (KB/s)			
	i. Send	0.53	505.37	385.99
	ii. Receive	191.90	3457.10	2129.57
	iii. Send (with R)	0.08	512.11	257.71
	iv. Receive (with S)	63.96	3073.31	1255.91
IV	Image transmission			
	i. FPS	6	8	7.2
	ii. Image size (KB)	1.78	13.84	8.81

2) HSDPA (wireless)

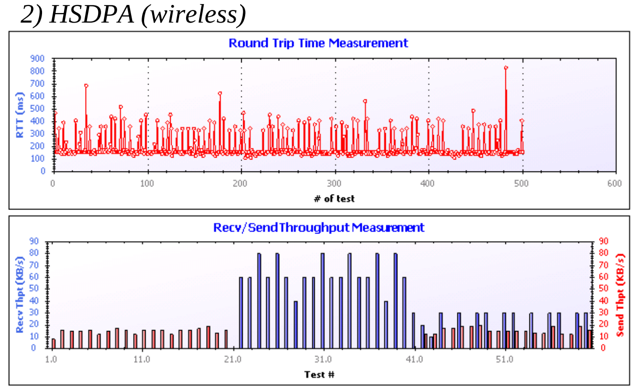

Fig. 4. RTT and throughput test result of HSDPA

TABLE IV. OVERALL EXPERIMENT RESULT OF HSDPA

ID	Test Item	Sent	Received	Error Rate
I	Correctness	1000	1000	0%
		Min.	Max.	Avg.
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

B. Evaluation of the Experimental Performance of HSDPA with the Theoretical Specification

The overall performance of HSDPA is, as seen in Table IV, quite lower than the theoretical specification. In case of Test III-ii (downlink phase) 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% in Test III-iv (simultaneous phase). 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.

C. Application of the HSDPA Module to the UIBSEC

In the tests of the UIBSEC integrated with the NSL and the relay server over HSDPA networks (as to see in Fig. 2.), it was confirmed that the UIBSEC was sufficiently able to transmit all real-time bio-signals simultaneously from the device client to the monitoring client. Snap shots of working system are captured in Fig. 5.

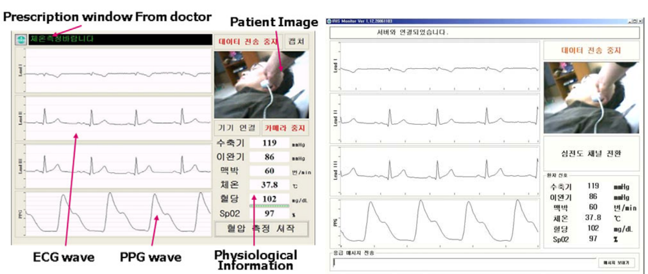

Fig. 5. Snap shots of two working clients (a) left: the device client (b) right: the monitoring client

IV. DISCUSSION

As the experimental result conducted at the beginning of April 2007 in the South Korea, the downlink speed of the 3.5G HSDPA module was much lower than that of the theoretical specification (about 4.4%). This speed corresponds to the 3G CDMA 2000 EV-DO modem. This low performance is resulted from one of, or both of two reasons: the bandwidth limitation of HSDPA network (T-Login service, SKT, Korea), or technical speed restraint of HSDPA modem (IM-H100, Sky, Korea). It is expected that the network service providers will broaden the network coverage and increase the maximum bandwidth, and the modem manufacturers will revise their products for better throughput performance. Therefore, to be able to fully exploit the advantages of 3.5G HSDPA, more time is required.

The NSL which underpins the UIBSEC as well as the relay server was evaluated to be useful and worked well with both wired and wireless networks. All that a network application developer needed to do was just to import the NSL DLL (dynamic linked library) instead of writing conventional and tedious codes repeatedly. It is the compact and simple architecture of the NSL that enables this feature. In addition it is expected that the effective data distribution architecture of the NSL is able to decrease a total charge to use wireless networks where a cost is proportional to total size of packet usage.

ACKNOWLEDGMENT

This work was supported by the Korea Science and Engineering Foundation (KOSEF) grant funded by the Korea government (MOST) (No. M10536060001-06N3606-00110) and in part by the Year 2001 BK21 Project for Medicine, Dentistry and Pharmacy

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