J. Biomed. Eng. Res.
Vol. 22, No. 4, 377-383, 2001

# 인터넷을 통한 원격환자 모니터링

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*(2001년 6월 20일 접수, 2001년 8월 17일 채택)*

# Remote Patient Monitoring through the Internet

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*(Received June 20, 2001. Accepted August 17, 2001)*

**요 약** : 본 논문에서는 의사가 인터넷을 통해 원격지에 있는 환자들의 활력징후 신호를 관찰하면서 필요시 응급 조치를 조언할 수 있는 원격· 환자 모니터링 서비스를 기술하고 있다. 본 서비스는 모니터링 정보 서비스(MIS), 활력징후 모니터링 서비스(VSMS), 멀티미디어 자문 서비스(MCS)의 서비스 객체들로 구성되어 있다. 의사는 모니터링 정보 서비스를 활용하여 현재 모니터링 중인 환자의 이름, 나이, 성별, 증상, 주소, 현재의 위치 등을 알 수 있으며, 활력징후 모니터링 서비스를 통해서 심전도, 호흡, 체온, 혈압, 혈 중 산소 포화농도 등의 활력징후들을 관찰할 수 있다. 멀티미디어 자문서비스는 의사가 실시간 멀티미디어 화상회의 기능을 이용하여 환자의 모습을 보면서 보호자 혹은 환자에게 필요한 응급조치를 취하도록 조언할 수 있도록 한다. 본 서비스는 2개의 다른 시나리오에 의거하여 100 Base-T 이더넷 LAN환경에서 실험에 성공하였다.

**Abstract** : In this paper, we present an intensive patient monitoring service through the Internet, which enables medical doctors to watch their patients in a remote site, to monitor their vital signs and to give them some advices for first-aid treatment. The service consists of three service objects: Monitoring Information Service (MIS), Vital Sign Monitoring Service (VSMS) and Multimedia Consulting Service (MCS). Through the MIS, medical doctors can get information about the patients currently under monitoring, including their names, ages, genders, symptoms, current main complaints and current locations. The VSMS enables medical doctors to monitor in real-time patients' vital signs such as electrocardiogram (ECG), respiration, temperature, blood oxygen saturation ($SpO_2$), invasive blood pressure (IBP), and non-invasive blood pressure (NIBP). It also generates alarms when the patients are likely to be in a critical situation. The MCS provides a real-time multimedia desktop conferencing facility for watching patients and instructing attendants to administer some first-aid treatment. We carried out some experiments according to two different scenarios. The intensive patient monitoring service was functioning well in a 100Base-T Ethernet LAN environment.

**Key words** : Patient Monitoring, Vital Sign Monitoring, Multimedia Consulting Service, Monitoring Information Service, Vital Sign Monitoring Service.

## INTRODUCTION

Typically, patient monitoring has been performed to watch, warn, or caution if there is a life-threatening event; physiological parameters such as ECG, blood pressure, body temperature, $SpO_2$, respiration are measured, processed and interpreted to assess the patient state [1-6]. Presently, patient monitoring systems are mostly installed in ICUs (Intensive Care Units) or CCUs (Coronary Care Units). However, many chronic patients discharged from hospitals, elderly and disabled people at home also often desperately need intensive monitoring. The cost of sending nurses or medical doctors to attend patients at home is very high. To provide a comparably reliable and comfortable but inexpensive way of monitoring for those people using recently available telecommunication technologies, we developed three services: Monitoring Information Service (MIS), Vital Sign Monitoring Service (VSMS) and Multimedia

<속보논문>

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*Consulting Service (MCS). Since most people at home* can hook up to the Internet through public telephone network due to the recent popularity of the Internet, we put emphasis on the availability over the Internet.

In designing the services for monitoring patients at home through the Internet, we take into account the following functional requirement [1].

(1) Vital signs crucial to assess the patient state, such as ECG, respiration, temperature, $SpO_2$, invasive blood pressure, and non-invasive blood pressure, should be continuously monitored in real-time.
(2) A life-threatening or intervention-required situation should be identified to generate alarms, which prompt medical doctors to pay attention. Not only the extremely high or low state of heart rate, respiration rate, and blood pressure, but also the malfunction of the instruments such as ECG lead faults should be immediately informed.
(3) *Medical doctors and patients should be able to talk* face to face with each other.
(4) Medical doctors should be able to browse a list of patients currently being monitored and to obtain fundamental patient information such as their names, ages, genders, main complaints, current locations, etc.
(5) Medical doctors should be able to remotely control monitoring hardware equipments, such as ECG lead *selection and the start and stop of noninvasive blood* pressure measurement.

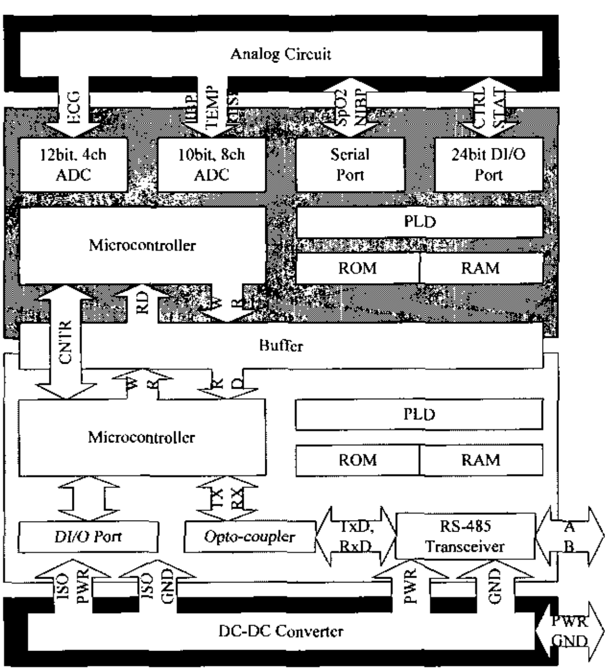
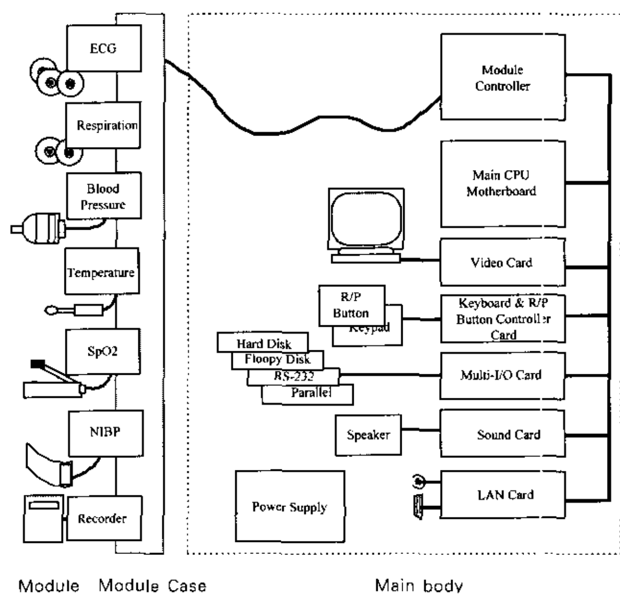



Fig. 1. The hardware architecture of vital sign monitoring modules

In this paper, our description is focused on the remote patient monitoring and consultation service itself and the overall configuration of the constituent hardware and software components rather than each modules in detail. The details of hardware modules for vital sign monitoring and its interconnection techniques were described in our previous paper [3-6]. The system configuration and the hardware module architecture for vital sign monitoring are shown in Figure 1 and Figure 2, respectively [4].




## SYSTEM CONFIGURATION

Figure 3 shows the overall service concept. The doctor workstation is just a popular multimedia PC, which is equipped with a microphone, speakers, and a video camera. Any additional hardware device is not required. The patient workstation is also based on a popular multimedia PC with a microphone, speakers, and a video camera, but it has an additional biological signal acquisition unit having various physiological parameter modules. Any Windows NT server machine can be a MIS server if a MIS server program is running on it. The servers and workstations are connected through the Internet. Normally, doctor workstations are located in hospitals, but sometimes they may be installed at doctors' home. In most cases, patient workstations are located at patients' home and are connected to the Internet through

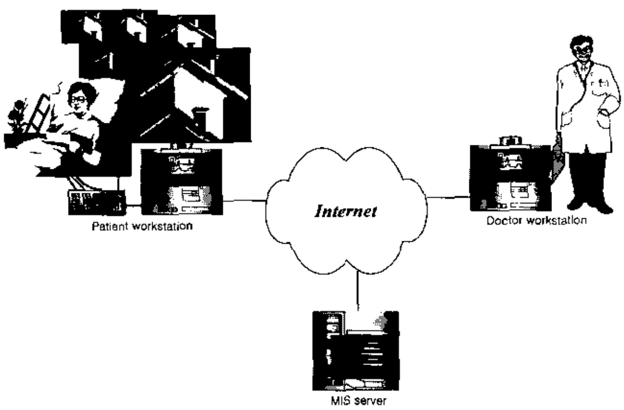



Fig. 3. Overall service concept

an ISDN or a LAN.

## MONITORING INFORMATION SERVICE (MIS)

The MIS is a service that enables the medical doctor to browse a list of patients currently being monitored and to obtain fundamental information such as their names, ages, genders, main complaints and current locations. The MIS server keeps a list of patients currently under monitoring and it also contains the information about what kinds of services are currently active. On initiating the services such as VSMS and MCS, patient and doctor workstations inform the start of the services to the MIS server. The MIS server contains a database management system (DBMS) that stores the information regarding patients and medical doctors. Hospital registrars can add the patient information to the database. They can also modify, remove and retrieve the contents in the database. Upon getting a query from a client, the MIS server searches, retrieves the requested information from the database and sends it to the client. The client can also register patients or medical doctors to the DBMS.

Before starting consultation, medical doctors usually browse a list of patients to find their patient or a patient who needs a doctor's attention. They then get the IP address of the patient and make a connection to him. Patients also browse a list of medical doctors to find their physician and to know the doctors currently available for consultation on the Internet.

By exchanging User Datagram Protocol (UDP) messages, all the interactions are performed between a MIS server and its clients. The MIS server shows updated information about which medical doctors are currently consulting with which patient.

Eventually, the MIS server will record all the monitoring and consultation history performed on the Internet. It will also record all the advice and instructions given to the patients and life-threatening events or warnings identified by VSMS server. They are stored with time and date. A MIS server is designed to monitor multiple VSMS and MCS sessions at the same time.

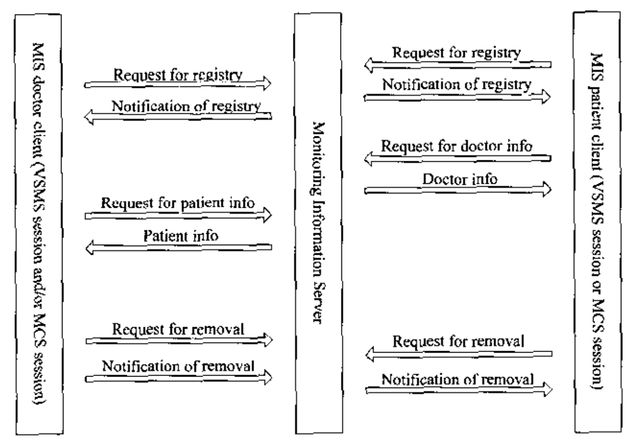



Fig. 4. Messages between a MIS server and the clients

## VITAL SIGN MONITORING SERVICE (VSMS)

The VSMS is a service that enables medical doctors to monitor in real-time patients' vital signs such as electrocardiogram (ECG), respiration, temperature, blood oxygen saturation ($SpO_2$), invasive blood pressure (IBP), and non-invasive blood pressure (NIBP). Presently, patient's critical situations could be identified with integrated monitoring of patient variables: heart rate, respiration rate, blood pressure, oxygen saturation, and temperature. At the critical situation, sound and visible alarms are generated to alert the medical doctors in remote sites. The medical doctors can also change hardware settings such as ECG leads and trigger NIBP measurement, adjust the chart speed and sensitivity of physiological signal graphs, and review the trend of patient physiological variables.

The service is implemented using client/server architecture. The VSMS server is a conventional PC equipped with a real-time biological signal acquisition unit having various physiological parameter modules for amplifying, digitizing, and processing biological signals.

The IEEE 485 and HDLC protocols are used for the communication between the PC and the acquisition unit. The VSMS server is a modified version of the component-style bedside patient monitor we developed, which performs the acquisition of biological signals, process them to get patient vital signs and to generate alarms [3-6]. The VSMS server necessarily has a single monitoring session in which biological signals are acquired, processed and transmitted to its clients in real-time through the Internet. We call it a local monitoring session. A VSMS server can manage multiple clients simultaneously. If multiple clients are connected to a single VSMS server, it sends the same biological signal data to its clients one at a time. Normally, the VSMS server is located at a patient bedside.

The VSMS client runs on a conventional PC with a VSMS client program. It shows all the information it receives from the server; draws biological signal data, displays physiological variables, and it annunciates alarms. In the VSMS client, there may exist many monitoring sessions. Each session shows all the information including biological signals for a specific patient. We call it a remote monitoring session. Normally, the VSMS client is located on a doctor's desktop and can accommodate many remote-monitoring sessions. In other words, a medical doctor can monitor many patients at the same time.

During the VSMS session, there exist two types of messages: administration messages and data messages. Administration messages are used to inform or control the state of monitoring sessions, while data messages include waveforms, hardware control commands and physiological parameters extracted from the signal. Figure 5 shows messages between a VSMS server and its clients during the vital sign monitoring.

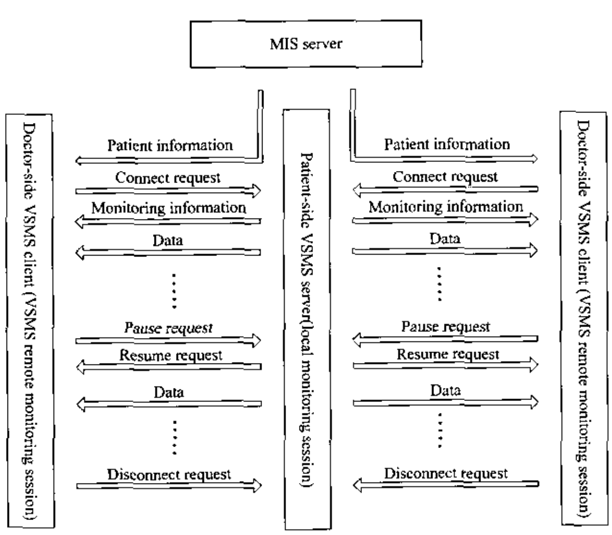



Fig. 5. Messages between a VSMS server and the clients

## MULTIMEDIA CONSULTING SERVICE (MCS)

The MCS service provides real-time multimedia desktop conferencing facilities for watching patients and instructing attendants to administer some first-aid treatment. Two medical doctors can confer together about patient's current situation with simultaneously watching the same patient vital signs.

Like other services, the service is also implemented using client/server architecture. The server captures the image and sound from the camera and microphone, and sends them to its client. On reception, the client just plays them. A MCS server corresponds with a single MCS client, and there can exist a MCS server and a MCS client on each PC. To provide MCS, the PC needs to have a H.261 video compression board and a G.711 audio CODEC board. The message exchange between a MCS server and its client is similar to the one in the VSMS.

## SYSTEM IMPLEMENTATION

We have developed the above three services under a Windows NT 4.0 environment. Each service is implemented as an independent component, which follows Microsoft's Component Object Model (COM). We defined a common application programming interface, which is called PMAPI (Patient Monitoring API). All the service components implement the common PMAPI interface. There is a main program that dynamically links various service components in run-time environment. It assumes that the service components implement PMAPI interface. The MIS, VSMS, MCS components are written in C++ language and Win32 API [7]. After analyzing the system, we designed and coded many C++ classes. We used the Rational Rose that is an object-oriented analysis and design tool [10]. The MIS and VSMS clients are also implemented as ActiveX controls that can be inserted into Web pages [9]. Data communication through the Internet is implemented using WinSock API. Since each service is implemented as a separate component having common PMAPI interface, the system is modular, extensible, and easily customizable. We used commercialized H.261

compression and G.711 audio CODEC boards.

## RESULTS AND DISCUSSION

We built 2 patient workstations, 2 doctor workstations and a MIS server. The demo system includes all the workstations, the MIS server, an additional web server and a web client. The web server not only provides the documents about how to use the services, but also provides a starting point of the services. It contains the IP addresses of MIS servers. The patient workstations are with a biological signal acquisition unit, microphone, speakers and a video camera, and the doctor workstations with a microphone, speakers and a video camera. The web server runs the Microsoft Internet Information Server (IIS) on a Windows NT environment. The Microsoft Internet Explorer 5.0 is used as a web browser in the web client. We used a 100 Mbps fast Ethernet switch to connect all of these machines. The MIS server is a Windows NT server on which the MIS server program we developed for maintaining monitoring information is running. The demo system configuration is shown in Figure 6.

Figure 7 shows the monitoring information screen of MIS server. It displays a list of patients and doctors, each entry of which contains a name, an ID, service status, an IP address, an age, an address, a phone number, etc. This information is retrieved from the database of the MIS, using the ID its client sent. The entries can be added, modified or removed in the MIS server.

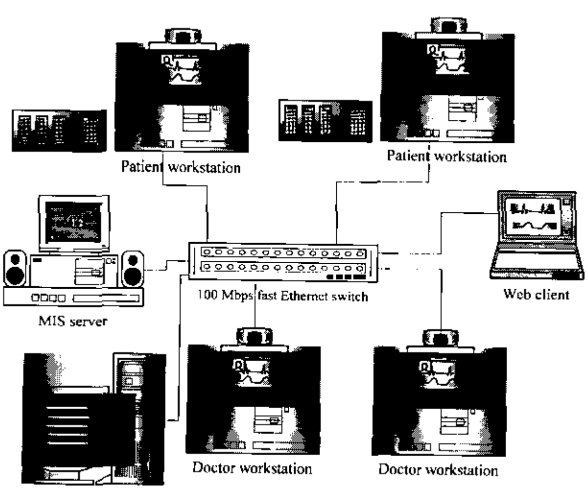



Fig. 6. Demo system configuration

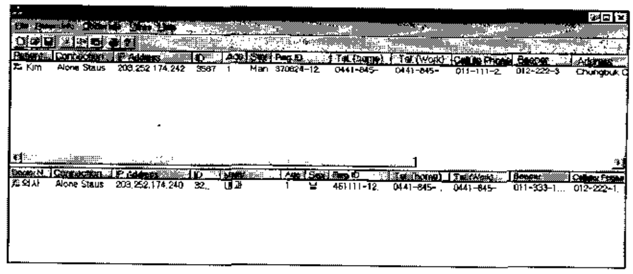


Fig. 7. Monitoring information screen of MIS server

MIS clients (patient workstations or doctor workstations) or web clients running Microsoft Internet Explorer can get the monitoring information from the MIS server through the Internet. A medical doctor can start consulting or monitoring for a specific patient by selecting a patient and the services of his interest. Figure 8 shows the monitor screen of the doctor workstation running the VSMS and MCS clients. In fact, the corresponding patient workstation has the appearance similar to the doctor workstation.

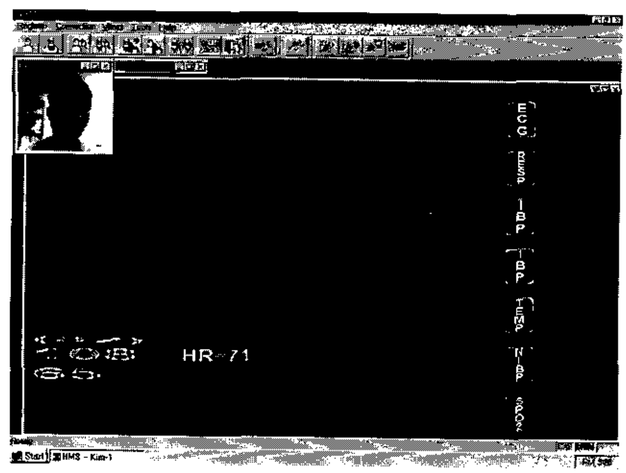


Fig. 8. Doctor workstation screen

Through the above overlay window, the medical doctor can watch his patient in a remote site (the overlay window is the MCS client window). Although there is no window for audio, he can also talk to his patient. On the VSMS client window, there are ECG, respiration, IBP and $SpO_2$ waveforms. The current body temperature value and its trend are shown at the TEMP bar and systolic, diastolic pressure values and their average at the NIBP bar.

For each channel, there is a button between the waveform display region and the numeric display region. A mouse click on the button brings up an option dialog box for signal input, data acquisition, signal processing,

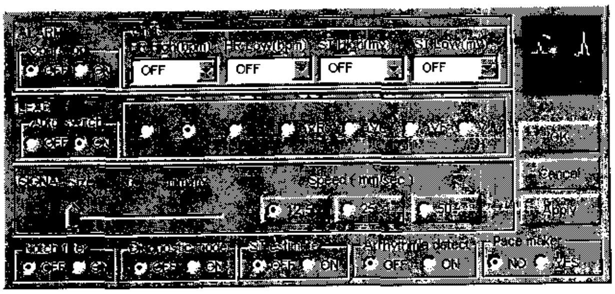


Fig. 9. Option setting dialog box for ECG channels

and waveform display of the corresponding channel. When the options for signal acquisition or signal processing are changed, the change is immediately informed to the patient workstation, which will carry into effect the change. Figure 9 shows an option setting dialog box for ECG channels.

We tested the above system according to two different scenarios. First, we made two monitoring sessions, each of which correlated a pair of a doctor and a patient. In the experiment, one medical doctor monitored one patient, while the other medical doctor consulted with the other patient. There was no problem in observing biological signals with simultaneously capturing and displaying about 15 frames of images. There was no delay when we remotely changed data acquisition hardware settings. Figure 10 shows the configuration.

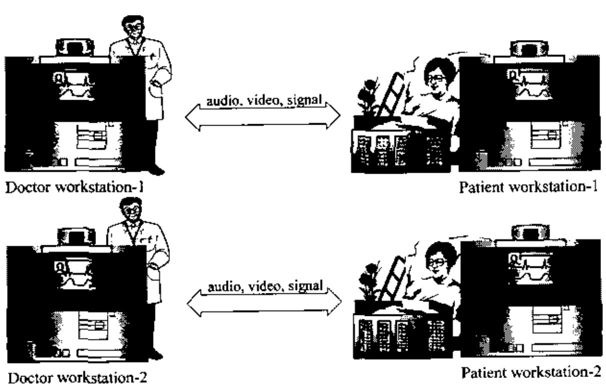



Fig. 10. Scenario-1 configuration

In the second scenario, we started a single VSMS server session for a patient and one MCS session between two medical doctors. In other words, two medical doctors located at two different sites were monitoring a patient's vital signs with talking face to face together. Each doctor's workstation acts as a VSMS client, a MCS server, and a MCS client, while the patient workstation acts only as a VSMS server. In this case, there was no difficulty in observing biological signals with capturing and displaying about 15 frames of images, too. There was no delay when we remotely changed data acquisition hardware settings. Figure 11 shows the configuration.

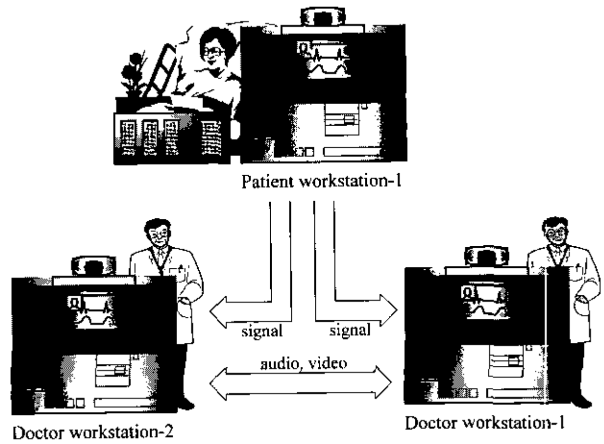



Fig. 11. Scenario-2 configuration

We did not involve many workstations because of the lack of hardware devices. However, It was evident that the 100Base-T Ethernet could deliver high performance enough to accommodate a reasonable number of the intensive patient monitoring sessions. Currently, we are planning to test the system on a home ADSL network.

## CONCLUSIONS

The intensive patient monitoring service we described here enables medical doctors to watch their patients in a remote site, to monitor their vital signs in real-time and to give them some advice for first-aid treatment through the Internet. Through the experiments, we showed that three different services required for intensive patient monitoring were functioning well in a 100Base-T Ethernet network environment. Presently, we are expanding the MIS database to store biological signals, alarms generated during monitoring, doctor's reports and instructions. We are also converting the service components to accommodate wireless biomedical monitors [11].

## REFERENCES

1. Seung-Hun Park, Jung-Hyun Park, Se-Hyun Ryu, Taegwon Jeong, Hyung-Ho Lee and Chu-Hwan Yim, "*Real-Time Monitoring of Patients on Remote*

*Sites*", Proc. of 20th Annual International Conference, IEEE/EMBS, vol. 20, pp. 1321-1325, Hong Kong, Oct. 1998

2. H. Lee, S. Park, E. Woo, "*Remote patient monitoring service through World-Wide Web*", in Proc. IEEE EMBS '97, 19th Annu. Int. Conf., Chicago, USA, 1997, paper no. 3.1.2-e.
3. E.J. Woo, S.H. Park, K.S. Kim, K.H. Choi, S.T. Kim, C.W. Moon, B.M. Jun, H.C. Lee, H.J. Kim, J.J. Seo, K.M. Chae, and J.C. Park, "*Development of a patient monitoring system: overall architecture and specifications*", J. of KOSOMBE, Seoul, vol. 18, no. 1, pp. 17-24, 1997
4. E.J. Woo, S.H. Park, K.S. Kim, K.H. Choi, S.T. Kim, C.W. Moon, B.M. Jun, H.C. Lee, H.J. Kim, J.J. Seo, and J.C. Park, "*Development of a module-based bedside monitor for patient monitoring*", J. of KOSOMBE, Seoul, vol. 18, no. 2, pp. 133-146, 1997
5. E.J. Woo, S.H. Park, K.S. Kim, K.H. Choi, S.T. Kim, H.C. Lee, J.J. Seo, and H.J. Kim, "*Intra-bed networks in a patient monitoring system*", J. of KOSOMBE, Seoul, vol. 18, no. 4, pp. 373-380, 1997
6. S.H. Park, E.J. Woo, K.S. Kim, K.H. Choi, S.T. Kim, H.J. Kim, and J.J. Seo, "*Inter-bed networks in a patient monitoring system*", J. of KOSOMBE, Seoul, vol. 18, no. 4, pp. 381-388, 1997
7. J.G. Webster, Encyclopedia of Medical Devices and Instrumentation, NY, Wiley & Sons, 1988
8. R. Davis, Win32 Network Programming, Reading, MA, Addison Wesley, 1996
9. Denning, ActiveX Controls Inside Out, Redmond, Washington, Microsoft Press, 1997
10. G. Booch, Object-Oriented Analysis and Design, 2nd ed., Redwood City, CA, The Benjamin Cummings Publishing Company, 1994
11. Glen C. Crumley, Noel E. Evans, William G. Scanlon, J. Brian Burns, and Tom G. Trouton, "*The Design and Performance of a 2.5-GHz Telecommand Link for Wireless Biomedical Monitoring*", IEEE Trans. on Information Technology in Biomedicine, vVol. 4, no. 4, pp. 285-291, 2000