Ubiquitous Home Healthcare Management System with Early Warning Reporting

Seung-Jin Jang[a], Joo-Hwan Lee[a], Jung-Hoon Lee[a], Sung-Bin Park[a], Sung-Oh Hwang[b], Hyoung-Ro Yoon[a], Young-Ro Yoon[a]

[a] Department of Biomedical Engineering, Health Science College, Yonsei University, South Korea

[b] Department of Emergency Medicine, Wonju College of Medicine, Yonsei University, South Korea

highnoon@yonsei.ac.kr

Abstract

The changes of medical environments such as the growth of a patient with a chronic disease and the elderly, and the advance of the IT technology require highly qualified medical service of new paradigm. For the reason, home health management service has been focused with much expectations and interests. Our proposed Home Health Management System (H^2MS) monitors and manages daily physiological status which is easily acquired from multiple-sensor based ubiquitous bio-signal sensor during sleeping, bathing, evacuating, and living at home. H^2MS is largely consisted of four functional subsystems; Multiple-Sensor based ubiquitous bio-signal sensor, Home Health Intermediary Client(H^2IC), Home Health Center(H^2C), and Home Health Service Provider(H^2SP). Each subsystem carried out their own processes and collaborated on a work with each other. H^2MS provides various home health services for the wellness, as well as the elderly, chronic patient's illness, or terminal illness. Also, it is available to suggest various services: an early warning service according to the change of health status, advice service for health improvement, and appointment service for medical treatment. Moreover, this early warning service makes promptly emergency repairs as soon as occurrence of physiologically abnormal symptom. Consequently, early warning reports reduce the frequent intervention of high costed service of medical professionals

1. Introduction

Concept of the health is not only the passive services to allay a pain or to cure a patient who is suffering from a serious illness, but also the active services that include to take preventive measures of illness and to improve physical strength for normal people. According to this expansion of the concept of the health, the Home Healthcare is the management system to use various wire/wireless communication techniques to realize the concept of the health at home.

Social Changes such as improvement of economical level, the rise of the elderly, and the deep concern about health have altered to serve an active medical service from a passive service for the health and medical environment. These demands and expectations will have a big influence on a paradigm of the health and medical services. Additionally, the medical environments have been changed by several factors: the gradually rising cost of the health insurances and medical services, the apparent increase of chronic patients such as cancers, diabetes, and hypertensions, and growing interests in bio-industries.

The Home Health Management is a rapid growth area in the United States [1]. For example, the Home Health Management Services have offered to more about 7.6 million patients who are in serious conditions such as chronic invalids, permanent handicapped, or incurable diseases by more than 20 thousand medical experts in the US. Also, the necessity of the Home Health is very urgent theme in a point of view for curtailment of the health medical costs and the improved health medical services. There are some reports that a cessation of a medical examination for a long-term disease causes a reappearance of that disease, or a different physical/mental disorder.

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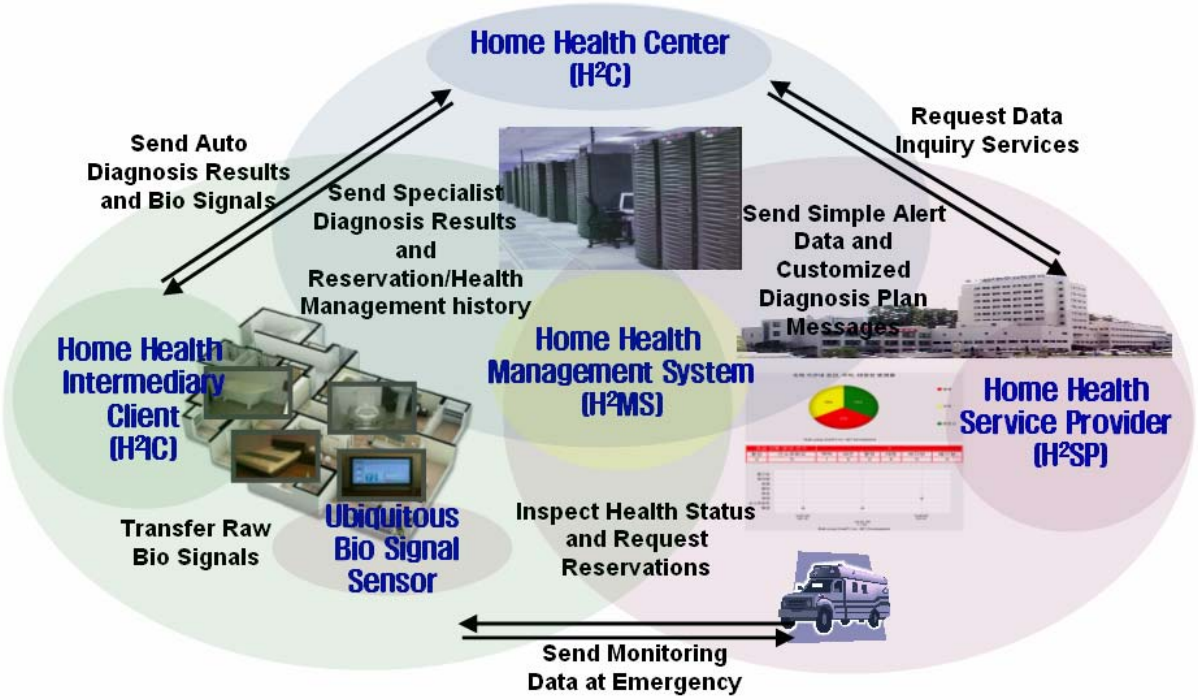


Figure 1. Organization of H2MS and a brief function of the subsystems

However, that industrialization of the Home Health Management System stays in early states because of legal limitations, administrative problems of the charge for medical treatment, and lack of unrestricted real-time monitoring sensor techniques. Although, new business models are proposed by several research centers and institutes of all classes for the Home Health Service. The most popular model is a lasting monitoring to manage health, an early detection of diseases and a rapid service for an emergency situation.

In this paper, we will introduce ubiquitous communication based H^2MS (Home Health Management System) with early warning report service, and explain an overall organization of the system, a detail function of subsystem, and reactive work process for abnormal status in patient.

This paper is organized as follows. System configurations, major functions, and features will be discussed. It will present features about a ubiquitous bio-signal sensor based on the merged-sensor of four types and bio-signal processing. Then, we will focus functions and features of the subsystems of H2MS, and finally reach conclusions.

2. System Design

2.1. Purpose of the System Model

H^2MS is aimed at home healthcare service model with a low costs and a large number of supplies by reducing of expensiveness prescriptions of doctors. This system is developed for prevention and early detection of disease, and for prognosis managements and health improvements based on complex sensors. It is a custom-made service for privates.

This part, we will look around the whole organization and main function of H^2MS, and explain the detecting bio-signal base on ubiquitous sensors. In addition, we will be known about the lower part system based on workflow which is based on server/client model.

2.2. System Organization and the main function

H^2MS is divided into four subsystems such as Fig. 1. They are Ubiquitous bio-signal sensor, Home Health Intermediary Client (H^2IC), Home Health Center (H^2C), Home Health Service Provider (H^2SP). H^2MS is divided by physical and network environments and functions. As you will see on Fig. 1, these subsystems performed their own work independently and each part is mutual complemented. The main target person is a chronic disease and the elderly. But it will be helpful

Table 1. Summary of ubiquitous bio-signal sensors

Sensor Type	Types of Acquisition signal	Applied µ-Controller	AD Resolution	Sampling Rate	Signal BW	remarks	Type
Bed type	ECG(1-channel)	MSP430F149	12bits	300Hz	0.05~80Hz	EDR extrac.	Wave
Lavatory type	ECG(1-channel)	Atmega8	8bits	300Hz	0.05~80Hz		Wave
	NIBP	Atmega128(main)	8bits	300Hz	DC~20Hz		Numeric
	SpO_2	MSP430F155	7bits	-	DC~50Hz		Wave
	Temperature	Atmega128(main)	8bits	-	DC~50Hz	manual	Numeric
	Diabetes	Atmega128(main)	8bits	-	DC~50Hz	manual	Numeric
	Body Fat	Atmega8	8bits	300Hz	>150KHz		Numeric
Bathtub type	ECG(1-channel)	Atmega8	8bits	300Hz	0.05~80Hz		Wave
Holter type	ECG(3-channel)	MSP430F149	12bits	240Hz	0.05~80Hz	V-lead	Wave
	Activity Signal		12bits	240Hz	DC~60Hz	2-axis	Wave

for improving patients and healthy person, too. Because it will give accumulative health information to medical experts such as doctor. The aims of this system are early warning/detection on the illness and proper managements on the emergency.

2.2.1. Detector bio-signals based on complex sensors. This detector can detect bio signal from people in everyday life. It is different from common detector that is inconvenient for the people because people have to waste their time for detection. This detector doesn't waste people's time. Because it is operated in daily life environment. People don't recognize their detection. There are four kind of detector, such as bed type, lavatory type, bathtub type, and holter type. They detect some parameters such as heart rate, blood pressure, oxy saturation, body fat, body temperature, diabetes.

2.2.2. Home Health Intermediary Client (H^2IC). H^2IC's main function is mediation that mediates between bio-signals and user's information. And it stores and manages mediation's data. If bio-signals are sent to Home Health Center's server in real time, it will cause network traffic. So H^2IC uses auto diagnosis algorithm. This method prevents network traffic, because bio-signals are sent only in unusual case occurs, but normal case occurs, H^2IC sent simple xml message to H^2C server. In addition, if emergency occurs, H^2IC sends client's data to contractual hospital and emergency center (e.g. 119 in Korea). It can make client inquire their accumulated health history and proper expert's prescription, or their visit/reservation on the hospital and emergency center.

2.2.3. Home Health Center (H^2C). This part charges a managing a great number of data sent from H^2IC and H^2SP. And it sends data to database system. Its main function is connecting to DB (database), and inquiring/searching/storing data. Monitoring and sending message to emergency center or hospital are important duties. H^2C is based on web and application. It monitors H^2IC's data in real time. And according to the auto diagnosis algorithm, proper prescriptions and managements will be offered to the clients. (This prescription is accepted by medical experts from H^2SP)

2.2.4. Home Health Service Provider (H^2SP). This part is regarded as a hospital services. In other words, H^2SP is the place that medical experts work on. When above abnormal stage occurs, according to the auto diagnosis algorithm, H^2IC sends proper prescription and bio-signal data to H^2C. And experts reach and get to the client's information on H^2C within his right. And the expert prescribes for the patient, and sends it to H^2C. And finally it is sent to the client (H^2IC). H^2SP is permitted to get client's history and data/information within its right. Usually H^2SP offers prescription using SMS/E-Mail.

3. Ubiquitous bio-signal sensors

The most important features of ubiquitous bio-signal sensors for home healthcare are unconsciousness and noninvasiveness. In here, we are first going to giving a full detail of types and corresponding features on ubiquitous bio-signal sensor developed in this study, then going to describing behaviors of each detectors.

3.1. Design Characteristics of ubiquitous bio-signal sensor

(a) (b)

Figure 2. Conductive textile (a) and the scenery of ECG acquisition in bed (b)

We installed ubiquitous bio-signal sensor to bedroom and bathroom where residents spend their everyday life mostly and regularly. We developed a bed-typed bio-signal sensor using conductive textiles so whole system did not need both conventional electrodes and lead cables for acquiring ECG signal. For detecting bio-signal in bathroom, a lavatory-typed and a bathtub-typed detector was developed and installed respectively. ECG, NIBP, body fat, SpO2 and weight can be measured by using a lavatory-typed detector. Also a bathtub-typed detector measures single channel ECG acquired by non-contact action. In addition to location fixing devices, we developed holter-typed bio-signal sensor which was used for mobile circumstances within the house.

Table 1 shows microcontrollers used in each sensor and significant features of bio-signals. All kinds of data measured from ubiquitous bio-signal sensors in each sector at home were designed to transfer into a Home Health Intermediary Client (H^2IC) through Bluetooth network which is one of the near field communication (NFC) schemes.

3.2. Operational Features of the Ubiquitous Bio-signal Sensors

3.2.1 Bed type Sensor. A bed-typed bio-signal sensor measures ECG with two electrodes made of conductive textile in order to minimize the restriction on users. It also extracts ECG-Derived Respiration (EDR) signal from the obtained ECG. To measure the ECG conventionally, electrodes with adhesive electrolyte are normally used. Such electrodes and cables might make users feel stressed. The conductive textile can realize long-term ECG measurement without any inconvenience while sleeping. Fig. 2 shows the conductive textile used in this study and the scenery of ECG acquisition in bed.

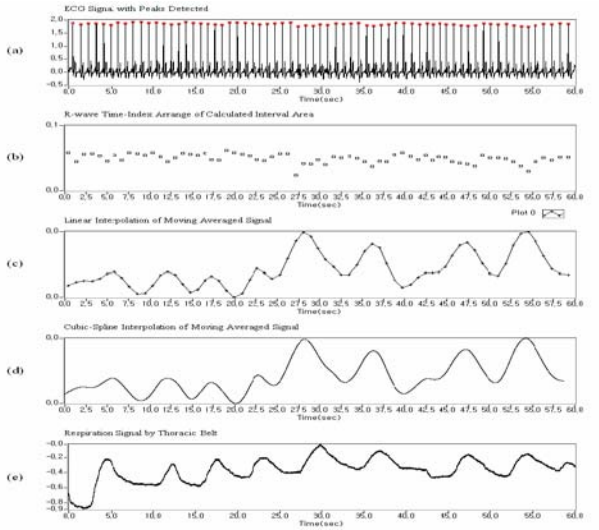
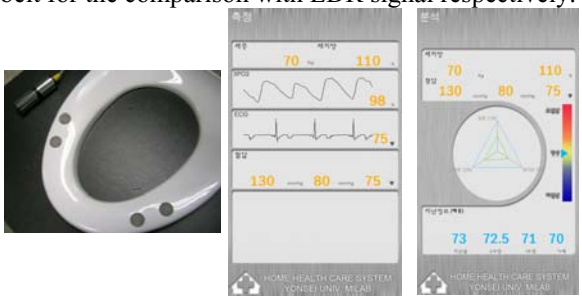


Figure 3. Representation of the process on extracting EDR and the comparison with respiration signal using thoracic belt. (a) ECG signal with peaks detected. (b) R-wave time-index arrangement of calculated interval area. (c) linear interpolation of moving averaged signal. (d) cubic-spline interpolation of moving averaged signal. (e) respiration signal using thoracic belt.

When using the conductive textile as an electrode, there are three major types of electrode arrangements recommended in general. The first type consists of pillow electrode, lower limb electrode on the seat and isolated electrode beneath the seat as Ishijima published [3]. The second one has three electrodes for head, body and leg to measure ECG and respiration as Ishijima also used [4-6]. The last one forms the basic setting with three input ECGs by arranging electrodes on both shoulders and legs [7]. These arrangements are designed to minimized noise by operating the driving circuit on the right leg(RL) or grounding the amplifier and the human body. Nevertheless, there are some disadvantages in that three electrodes are required, and especially subjects have to take off their upper clothes in the second and third case. In this study, we designed the system using only pillow and leg electrodes, that is, this system does not need RL drive circuit. Furthermore, EDR signal can be obtained without adding any components. EDR is extracted using the notion that the change in intrathoracic impedance by respiration influences the ECG signal [8-10]. Fig. 3 represents ECG signal with peaks detected, R-wave time index arrangement of calculated interval area, linear and cubic spline interpolation of moving

averaged signal, and respiration signal using thoracic belt for the comparison with EDR signal respectively.



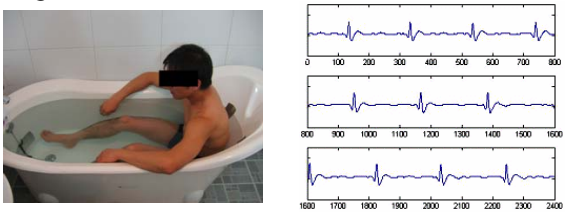
(a) (b) (c)

Figure 4. A lavatory-typed detector. (a) Three pairs of electrodes included in seat and grip. (b) An example of display on measurement in LCD. (c) An example of display on analysis in LCD

3.2.2. Description of a lavatory-typed Detector. We developed a lavatory-typed detector as it is used regularly and frequently. It is possible to acquire various information of user's health condition by measuring ECG, blood pressure, body temperature, blood sugar, SpO2, and body fat mass. Also users themselves can check the results of measurement through a LCD monitor hanged beside the lavatory. This system provides voice assistant function for user's convenient as well. Single channel ECG and body fat mass were measured by means of two pairs of electrodes in the lavatory seat and a pair of electrodes in the grip. The seat and grip are contacted user's thighs and right hand respectively. Another physiological signals, SpO2 and blood pressure are detected from a index finger in right hand side. Fig. 4 illustrates the lavatory seat and the grip including electrodes and some of screen displays which are appeared in LCD monitor.

Users can feedback not only the current measuring result but also the past data so that trend of variation on their health condition would be monitored by themselves. Measurements of body temperature and blood sugar are carried out by separate devices outside a lavatory system, but measured data from them are sent to a lavatory typed detector and saved for transferring H^2IC.

3.2.3 Description of a bathtub-typed Detector. There is a high risk of sudden death especially for the elderly having bath in bathtub because of sudden extend or shrink of blood vessels. Thus, if it is possible to detect continuous ECG signal in the bathtub during a bath, we can cope with those of accidents. Therefore, we designed a bathtub-typed detector. It is able to acquire single channel ECG via 3 stainless electrodes attached

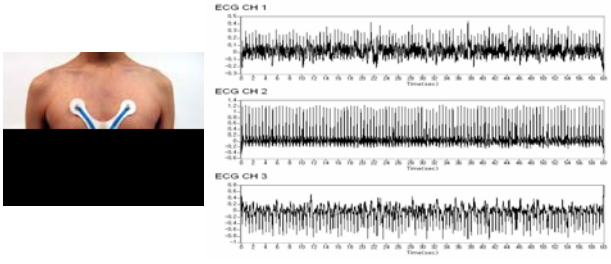


(a) (b)

Figure. 5. The scenery of data acquisition in the bathtub attached electrodes and ECG signal acquired during a bath. (a) an user and stainless electrodes in bathtub. (b) ECG signal acquired during a bath

in bathtub. ECG signal from the bathtub does not affect its quality even if user's skin is out of contact with electrodes. In order to reduce motion artefact, band-pass filter which has very narrow bandwidth is used, consequently, QRS complex of ECG measured are able to detect reliably. An illustration of bath in the bathtub attached electrodes and ECG signal from the detector represent in figure 5.

3.2.4. Description of a holter-typed Detector. As was pointed out earlier, the bed-typed, lavatory-typed and bathtub-typed bio-signal detectors have a function of acquisition of only single channel ECG signal, so that minimal constraint is imposed upon user. However most of patients with an advanced heart disease must be checked their cardiac condition through a medical examination on V-leads which are called precordial leads. In spite of measuring V-leads, attachment of electrodes in appropriate places on skin is not easy for general people. Accordingly, we developed a holter-typed detector which is easy to use under movement condition whether users are in indoor activity or outdoor activity. The holter-typed detector can acquire 3 channel ECG signals and 2 channel activity signal by using accelerometers. Fig. 6 shows the appearance of this detector attaching and 3 channel ECG signals obtained from it while user was in activity.



(a) (b)

Figure 6. The appearance of a holter-typed detector and 3 channel ECG signals. (a) a holter-typed detector

attached to user. (b) 3 channel ECG signals obtained in activity.

(b) back of circuit board

Table 5. Comparison of key features of complementary protocols

Features	IEEE 802.11b	ZigBee	Bluetooth
Power Profile	Hours	Years	Days
Complexity	Very Complex	Simple	Complex
Nodes/Master	32	64,000	7
Latency	Enumeration upto 3sec	Enumeration upto 30ms	Enumeration upto 10sec
Range	100m	70-300m	10m-100m
Extendability	Possible	Yes	No
Data Rate	11Mbps	250kbps	3Mbps/1Mbps
Security	Authentication Service Set ID(SSID)	128bit AES and application Layer User Defined	64bit, 128bit
Audio Connection	NO	No	Yes

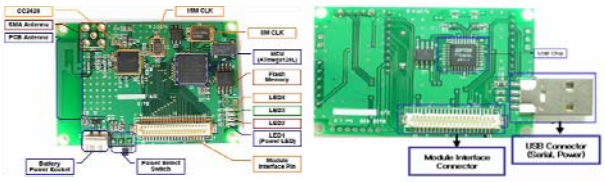
All kinds of bio-signal sensors developed in this research are designed to satisfy international standard of medical devices presented in IEC60601-1. For particular requirements on safety and performance, we referred to IEC60601-2-27 which is regulatory guidance for patient monitoring system.

4. H2MS Communication System

4.1. Home Health Intermediary Client (H^2IC)

Home Health Intermediary Client (H^2IC) performs various roles such as saving, processing and screening physiological data obtained by multi-sensor based ubiquitous bio-signal sensor which were installed in each location at home. It also plays a role in transferring specified data to Home Health Centre (H^2C). Moreover, H^2IC has a reservation function between users and their assigned hospital with a user-friendly interface.

From now, we will review our processing method for communication between various types of detectors and H^2IC, XML conversion procedures for bio-signal data, and GUI management capabilities.



(a) (b)

Figure 7. Zigbee module sensor circuit board (a) front,

4.1.1. Data Transmission from ubiquitous bio-signal sensor to H2IC.

Data collected from each section of the house and from holter-typed detectors are designed to transmit to H^2IC in real-time. Fixed type of detectors, that is, a bed type, a lavatory type, and a bathtub type, adopted Bluetooth class I as a wireless communication component. Meanwhile, Class II of Bluetooth was adopted for holter-typed detector as a result of the consideration on power consumption. In the case of a holter-typed detector, it transmits acquired data directly to H^2IC if the user stays at home or transmits to the PDA owned by user if she or he is out of the house. The data stored in PDA will be transmitted to H^2IC when user comes back to home.

The construction of Bluetooth network used within the house is 1:n structure called Piconet. In the same Piconet, the master device controls wireless communication to prevent the cross among the slaves. Comparison of key features of complementary protocols in NFC including Bluetooth is shown in table 5. In this research, Bluetooth protocol that has middle class complexity was chosen as the reason that not many nods should be needed and relatively large size of data should be transmitted.

4.2. Home Healthcare Server (H^2C)

Home Healthcare Center is mainly comprised of handling event messages that sent in real-time data via the H^2IC group to home healthcare center. Home Healthcare Center contains a method of handling message, sending managed health information to client and providing business logic of emergency situation. After processing and saving data, home healthcare

system provided data searching service for H^{2}IC and H^{2}SP and reservation service for client.

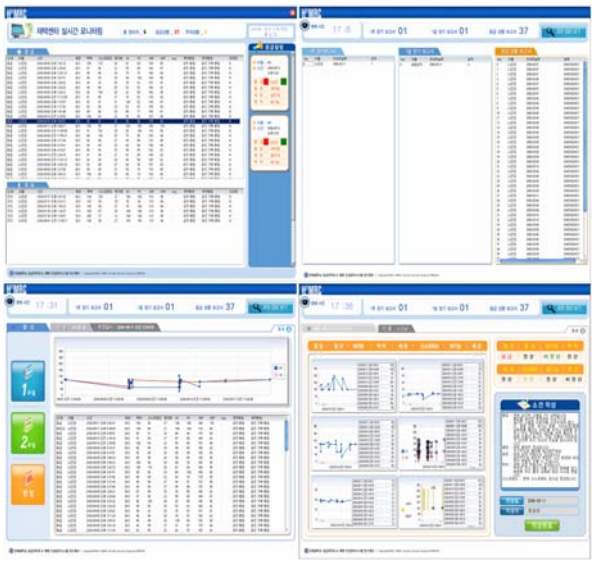


Figure 8. Displays of real-time monitoring in H^{2}C and H^{2}SP: (top-left/right) real-time monitoring in H^{2}C, (bottom-left) checking real-time heath status in H^{2}SP, (bottom-right) real-time regular/emergency reporting program in H^{2}SP

4.2.1. Event Message and Row data transmission with e-security. Row data are transmitted between applications over a secure HTTP link. These messages are modeled using XML. We design the system that H^{2}IC transfer XML event message and Row data to H^{2}C interactively using Internet service. Network based IPSEC(IP Security) or tunneling make a excessive load. Make up these weak points, messages are developed e-security using Encryption/Signature of XML event message. E-security algorithm is symmetric key based Rijndael algorithm. XML Signature base Public Key Infrastructure(PIK) which provided W3C are used this Authentication algorithm. Considering network loads, system performance, system didn't choice symmetric key based Key Distribution Center(KDC)[14-15]. The event message from the holter monitor which convert to XML event message using Encryption and Signature. The holter ECG row data only have Encryption process. As a performance result shows transport a event message per 1 sec occur network loads. A packet needs at least 2 sec. Transmitted wave data's segment range can control by health workers according as clients' health level.

4.2.2. Design business login and Monitoring. Sending a event message form multi agent, the data can lose and damage by network transmission error and system malfunction. The Orchestration function of Biztalk server is used for watching and managed scheduling level of event message. This managed efficiently transmitted event message and transaction function of file system. Transmitted wave typed vital signal needs the effective test. When transmitted vital signal contains a noise signal or customer can not receive their health responding cause of an electrode contact poorly, the system send a checking message. The system contains a dll type or code based filtering logic that checks transmitted vital signal errors.

4.3. Home Healthcare Service Provider (H^{2}SP)

When H^{2}SP catch 'Emergency' event message form some H^{2}IC, this apply to a business rule. First, HTN based customized health management scheduling process,

Second, vital signal processing and event messages are received from emergency responding system which is analyzed by health experts. Early responding system in Emergency responding system which is modeled the emergency center of wonju christian hospital at yonsei university. This model is adapted to emergency responding system. H^{2}SP provide the interface which send regular report(2weeks, 4weeks) and event report including diagnosis of vital signal and their views. Health experts make the accumulated vital signal on report. This verse provide the emergency responding system modeling at H^{2}SP and explain the system interface which is searching or advising a health management result at H^{2}IC, H^{2}C and H^{2}SP.

4.3.1. Emergency situation responding system. According event sate diagram, Fig.8 shows Emergency, Alert responding model. Design Emergency situation responding model which is early warning and taking patient to hospital/taking first aids induction.

- Emergency: To detect an acute disease, a blood pressure, a pulse, a electro-cardiogram , a blood sugar level, oxygen saturation are used. When one of the parameters indicates emergency level, customer's terminal provide pop-up of event message which contains a alert message and a automatic diagnoses script. Moreover these message and diagnoses are provided internet services and FAX. H^{2}C sends a text message to a user and user's relations. The nearest a emergency center receive a emergency condition report automatically. The H^{2}IC of a contract receive

with user's emergency result and provide a health level and current state and medical history. Also send a text message to user's doctor for preparing the hospital visit.

Figure 9. The screen shows that Event message/ Result of diagnosis based on web environment

- Display real time regular/event state report.
- acquisition data base customized user health management report.
- analyzing user's health tendency (health parameter tendency; 1 week/2week/1 month)
- Alert: To detect an acute disease, a blood pressure, a pulse, a electro-cardiogram , a blood sugar level, oxygen saturation are used. When one of the parameters indicates alert level, customer's terminal provides pop-up of event message which contains a alert message and a automatic diagnoses script. Moreover these message and diagnoses are provided internet services and FAX. H^2C sends a text message to a user. The nearest a emergency center receive a emergency condition report automatically. The H^2IC of a contract receive with user's alert result and provide a health level and current state and medical history. User's diagnosis is transferred to user's terminal using internet service or FAX for feedback.

5. Conclusion

This paper shows home healthcare management system based on variable sensors, network technologies and data processing using AI. This system operates in daily life with no recognition. So clients have no restriction on their movements, they only have to do naturally. Their bio-signals are observed and sent to all sorts of parts (H^2C, H^2IC, H^2SP). And clients are given proper prescriptions base on auto diagnosis system. This system is very helpful for chronicity patients, old and feeble persons and healthy people who want to maintain their health. But this system should develop some points such as limitation of kinds of bio-signal and lack of quality of bio-signal. If these weak points are developed, this system will more profitable for human beings.

6. Acknowledgment

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