HEALTHINFO 2016

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HEALTHINFO 2016

Forward

The First International Conference on Informatics and Assistive Technologies for Health-Care, Medical Support and Wellbeing (HEALTHINFO 2016), held on August 21 - 25, 2016 in Rome, Italy, tackles with particular aspects belonging to health informatics systems, health information, health informatics data, health informatics technologies, clinical practice and training, and wellbeing informatics in terms of existing and needed solutions.

The progress in society and technology regarding the application of systems approaches information and data processing principles, modeling and information technology, computation and communications solutions led to a substantial improvement of problems in assistive healthcare, public health, and the everyday wellbeing. While achievements are tangible, open issues related to global acceptance, costs models, personalized services, record privacy, and real-time medical actions for citizens' wellbeing are still under scrutiny.

We take here the opportunity to warmly thank all the members of the HEALTHINFO 2016 technical program committee as well as the numerous reviewers. The creation of such a broad and high quality conference program would not have been possible without their involvement. We also kindly thank all the authors that dedicated much of their time and efforts to contribute to the HEALTHINFO 2016. We truly believe that thanks to all these efforts, the final conference program consists of top quality contributions.

This event could also not have been a reality without the support of many individuals, organizations and sponsors. We also gratefully thank the members of the HEALTHINFO 2016 organizing committee for their help in handling the logistics and for their work that is making this professional meeting a success.

We hope the HEALTHINFO 2016 was a successful international forum for the exchange of ideas and results between academia and industry and to promote further progress in health informatics research. We also hope Rome provided a pleasant environment during the conference and everyone saved some time for exploring this beautiful historic city.

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A Cuffless Blood Pressure Monitor for Home Healthcare Systems Monitored by Health Professionals

A cuffless blood pressure monitor

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***Abstract*—We tested a new model of healthcare that involves monitoring physiological parameters to improve team-based healthcare. The system consisted of unobtrusive monitoring, a database, and interventions by health professionals. This report discusses the core technologies used, focusing on those involved in monitoring. An unobtrusive blood pressure (BP) estimation system, and web-based care system, including its database, were designed and tested. BP was estimated with a cuffless BP monitor combined with electrocardiography and photoplethysmography. The mean difference (MD) of estimated SBP and reference SBP was 0.2 ± 5.8 mmHg and the limits of agreement ranged from -11.2 mmHg to 11.6 mmHg. The MD of estimated DBP and reference DBP was 0.4 ± 5.7 mmHg and the limits of agreement ranged from -10.8 mmHg to 11.6 mmHg. The estimated BP was enough accurate compared with the cuff-based BP. The core technologies operated well. The proposed system may prove effective for home-based healthcare. Further studies are needed to evaluate the entire care system.**

Keywords-home healthcare; cuffless blood pressure ; decision making system.

I. INTRODUCTION

It is crucial that the healthcare system becomes more effective so that it can meet the needs of the future ultra-aged society. Hospitals can play an important role in the prevention of diseases, but issues related to the increased demand on medical insurance and the decrease in medical personnel are critical challenges for an aged society. Indeed, physicians and their associates working in small communities must not only provide primary care but also keep up with new medical technology. Long-term care facilities have been established and home-based healthcare services have been recommended to reduce the medical costs associated with caring for the elderly.

In Japan, cardiovascular disease and stroke are the second and third leading causes of mortality, respectively; these conditions have high rates of recurrence [1]. Blood pressure (BP) plays an important role in these conditions. Key lifestyle changes and at-home BP monitoring may help patients to avoid another stroke. Indeed, an occasional BP reading at a health checkup may not be a sufficient basis for effective treatment decisions because BP varies. The use of home BP monitors may help those with high BP to better understand their control over this condition; thus, this population should be encouraged to measure and record their BP and share their BP logs with their doctors [1][2].

Results from randomized trials have suggested home BP telemonitoring (HBPT) as a promising tool for improving BP control of hypertensive patients. Most studies have found significant BP reductions in those using HBPT and HBPT interventions. These approaches have also garnered a high rate of acceptance, helped to improve users' quality of life, and reduced the costs of medical insurance. Although HBPT can be advantageous, older patients tend to be less technologically skilled and may require more user-friendly home healthcare technology. Cuff-based BP monitors are commonly used; however, it can be difficult to properly apply these devices in terms of appropriate fitting and identification of the correct measuring site.

Low-cost wireless monitoring has probably led to more data-sharing between patients and clinics. In addition, HBPT may enhance the quality of data reporting and the ease with which the results are interpreted by doctors. A key contributor to the successful management of BP by HBPT is networking among healthcare providers and consultation between doctors and pharmacists or nurses. This process constitutes a new model of care designed to control BP based on telephone/web services. The effectiveness of this model has been demonstrated in several trials [3].

As feedback from doctors is not immediate and evaluation may be time-consuming and inaccurate, a new model of care called e-BP has been proposed [4][5]. There

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is strong evidence that BP can be controlled using a team-based approach involving health professionals, such as pharmacists and nurses. Indeed, the use of team-based care has increased the proportion of individuals whose BP is under control and has reduced both the systolic and diastolic BP, especially when the team included pharmacists and nurses. Implementation of this multidisciplinary approach will require system-level organizational changes and may be an important element of home-based medical care [6][7].

This study examined a new intervention system based on unobtrusive monitoring. First, we developed a healthcare scenario and core technology, mainly unobtrusive monitors, to create a new model of care. The results of this preliminary study will provide information for reconfiguring the system for further research.

II. METHOD

In this section, the propose system is desribed.

A. Proposed system

Fig. 1 shows an overview of the proposed system. The central concept is the use of a team-based care system consisting of three main parts: unobtrusive monitors, a rule-based expert health management system, and interventions by health professionals. Specifically, BP is monitored unobtrusively by cuffless blood pressure which described more detailed at (B); the BP data are automatically transmitted to a server, and health status is ascertained using a ruled-based expert system, which considers data on the estimated BP in the morning and evening, steps walked, weight, and other factors. The expert system automatically generates alerts based on comparisons with predetermined threshold values. When alerts are issued, a health professional calls the client and conducts a clinical evaluation. Based on the findings, the health professional judges the client's health status and decides whether a visit from a clinician is warranted or if a caregiver should be called. Health professionals manage both chronic conditions and emergency situations. Clients can also monitor their health via a browser.

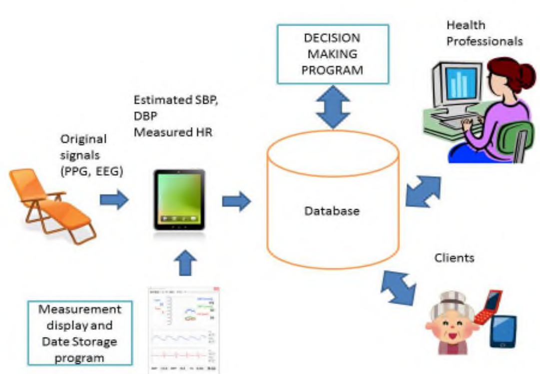

Figure 1. Overview of the system. SBP: systolic blood pressure; DBP: diastolic blood pressure; HR: heart rate; PPG: photoplethysmograph; ECG: electrocardiograph.

B. Design of unobtrusive monitoring

The BP was measured with a cuffless BP monitor, a system that was developed in the 2000s [8] and approved as a standard by the Institute of Electronics and Electrical Engineers (IEEE) in 2014 [9]. BP is related to the stiffness of blood vessels: if the blood vessel is rigid, the velocity of the blood is rapid, while if the blood vessel is soft, the velocity is slow. The pulse transit velocity based on the R wave of the electrocardiograph (ECG) and the associated peak of the pulse wave are related to the BP. If we know the calibrated BP, calibrated systolic blood pressure (SBP_{CAL}), and calibrated pulse transit time (PTT_{CAL}) at SBP_{CAL}, the estimated systolic (SBP_{EST}) and diastolic (DBP_{EST}) blood pressures are defined as

$$SBP_{EST} = SBP_{CAL} - \frac{2}{\gamma PTT_{CAL}} \Delta PTT \quad (\Delta PTT = PTT_{MEAS} - PTT_{CAL}) \tag{1}$$

$$DPB_{EST} = SBP_{CAL} - \frac{2}{\gamma PTT_{CAL}} \Delta PTT - (SBP_{CAL} - DBP_{CAL}) \left(\frac{PTT_{CAL}}{PTT}\right)^2 \tag{2}$$

where γ is the peripheral resistance, and ΔPTT is the difference between the obtained PTT_{MEAS} and PTT_{CAL} [8][10].

The chair-based system consists of an ECG and a photoplethysmograph (PPG). ECG electrodes are placed on both arms of an armchair and a PPG sensor is placed on one arm of the armchair, as shown in Fig. 2. The client gently touches the electrodes and inserts the index finder in the sensor box. Beat-by-beat signals are then collected to estimate SBP and DBP using the above equations. The algorithm for data collection is shown in Fig. 3.

The device was compared with a simultaneous recording with a beat-by-beat BP monitor (Finometer, Finapres Medical Systems, Amsterdam, The Netherlands) based on the unloading method. The distribution of BP readings and long-term data were also compared with readings using a cuff-based BP monitor (HEM 7510C, Omron Healthcare, Inc., Kyoto, Japan).

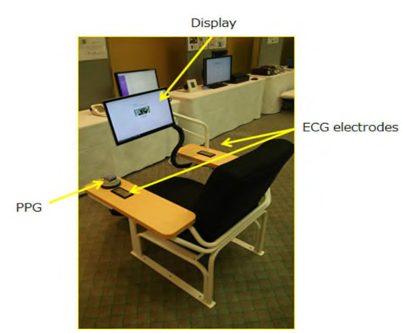

Figure 2. Cuffless blood pressure monitor and chair.

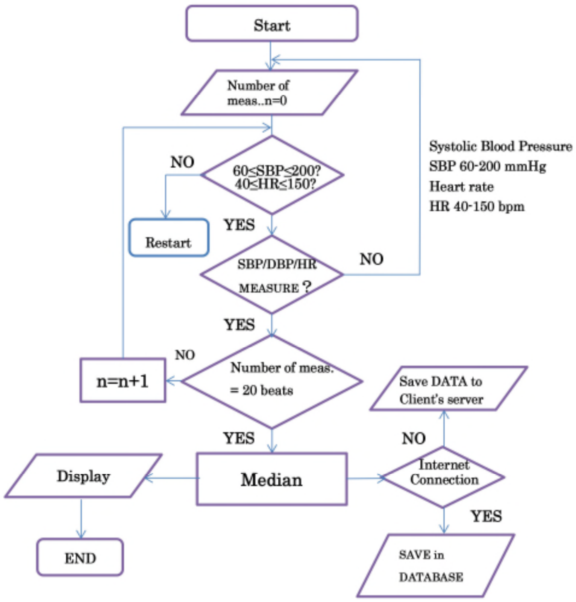

Figure 3. A flow chart of decision making program

The accuracy and validity of the setup were tested in ten normal young males (age, 24.1 ± 5.4 years) who sat in the chair while the BP was measured.

C. Database

A database was created from information obtained from clients, including the estimated BP and heart rate. All data were uploaded to the server, and a health professional checked the continuity of data collection. The database software included an expert system and verified client participation. A health professional was encouraged to monitor the status of clients who did not participate in this system. At the same time, the clients checked their own health status via the Internet.

D. Expert system

A problem-solving expert system is useful for managing the healthcare of individuals. Home monitoring depends on patients measuring their BP regularly, recognizing when readings consistently exceeded the target values, understanding the need for the intensification of treatment, and visiting their physician for review and appropriate management. Therefore, we developed criteria to enable the expert system to generate alerts when values exceeded the predetermined values listed in Table 1. The criteria have been made by guidance of physicians. If the client's health is relatively good, then a message saying "fine" is automatically transmitted to him or her. When alerts are generated, the alerts are sent to a health professional and not to the client, who instead receives a message saying, "Your data are being checked by a health professional who will reply shortly."

TABLE 1 ALERT CONDITIONS OF THE EXPERT SYSTEM.

Items	Conditions
SBP	>160 mmHg
DBP	>95 mmHg
Pulse pressure (SBP – DBP)	>50 mmHg
SBP (morning – night)	>±30 mmHg
Spontaneous SBP	>160 mmHg
Continuous SBP at successive three days	>150 mmHg
Changes in the average SBP over 1 month	>30 mmHg
Heart rate	<40 or >120

SBP: systolic blood pressure; DBP: diastolic blood pressure

E. Intervention by health professionals

After receiving an alert, the health professional calls the client to make relevant clinical inquiries. Initially, information is obtained regarding life-threatening conditions, such as stroke and heart failure. After collecting physiological data and completing the medical inquiries, the health professional decides whether to arrange for a clinician to visit the patient or to contact the patient's caregivers. For our trial runs, we recruited and trained retired register nurses to serve as the health professionals, and the system was tested on healthy subjects.

F. Experimental set-up

Total system was operated for a healthy young male. The subjects sat down the chair and touched the electrode on the chair arm. The experiments were performed two months to check the reliability of expert system as well as the operation of intervention.

III. RESULTS

Results show the accuracy of developed cuffless blood pressure monitor and a preliminary result of a long term recording for daily life.

A. Unobtrusive monitoring of BP

Fig. 4 shows the distribution of the BP values obtained from ten subjects in different environments. The mean difference (MD) of estimated SBP and reference SBP was 0.2 ± 5.8 mmHg and the limits of agreement ranged from -11.2 mmHg to 11.6 mmHg. The MD of estimated DBP and reference DBP was 0.4 ± 5.7 mmHg and the limits of

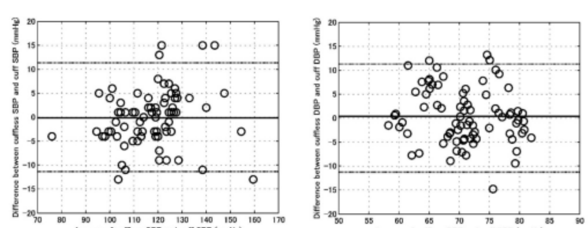

Figure 4. Bland–Altman plots of systolic blood pressure (SBP, left) and diastolic blood pressure (DBP, right).

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agreement ranged from -10.8 mmHg to 11.6 mmHg**.**

B. Database and intervention system

The database stored information on the estimated BP. Figure 5 shows the screen display that a health professional would see. Red indicates outside the normal BP range. When red values were seen on the screen, the health professional contacted the client and asked about various medical conditions before making a decision.

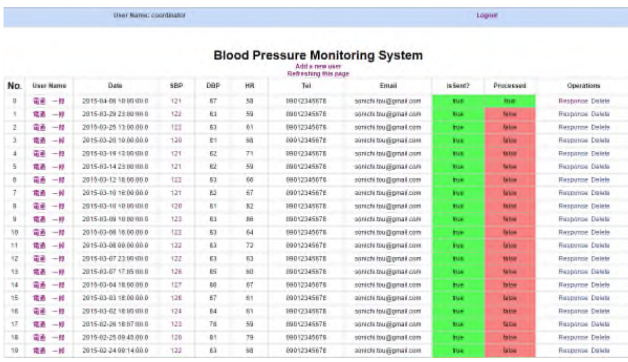

Figure 5. Screen display for the health professional.

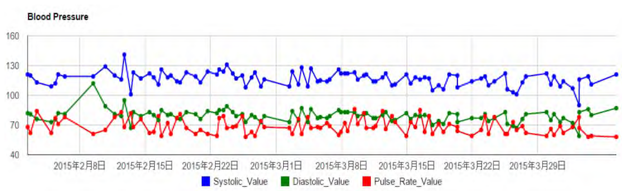

Figure 6. Example of long-term BP recordings.

The success of this intervention was tested using long-term BP monitoring, as shown in Fig. 6.

IV. Discussion

We developed and tested a model to be used as a new healthcare system. The novel elements of this approach are that it involves unobtrusive monitoring and a team-based healthcare system, which operates efficiently due to its simplicity.

Based on our preliminary trial, the following problems remain to be solved. In terms of unobtrusive monitoring, further studies are required to determine how to eliminate unreliable signals caused by motion artifacts or other factors. Cuffless monitoring was performed according to the IEEE standards, and measurements obtained while the client sits in a chair are relatively reliable because they are taken at rest. Although the error was within the standard deviation, the interval of calibration and measurement site warrant additional consideration to increase the accuracy of the measurements.

Furthermore a monitoring device was battery- operated and client safety is satisfied

The effectiveness of an expert system rests on the development of a set of rules that produce clinically relevant alerts that ensure client safety. The existing team-based care depends on physiological data, such as the BP and ECG, but the monitoring depends on the clients. Our system measures physiological parameters without interrupting the daily lives of the clients, and beat-by-beat information is more accurate than spot monitoring.

The innovative aspect of this system is related to the interventions and consultations provided by professional nurses and medical staff. Although physicians may be too busy to review all records, health professionals such as registered nurses can help to diagnose patients and interpret the BP data obtained in the morning and evening. It is also important to provide relevant education for health professionals, including registered nurses, registered dieticians, and pharmacologists, and to identify the experience and skills that should be required of professionals involved in this system.

The final goal should be cost-effective eHealth imitative in daily home healthcare and practice [11] and we collect data of many clients to prove the system.

V. Conculusion

We proposed a team-based healthcare system. The core technologies operated without any trouble. We obtained long-term BP records smoothly and automated decision making system worked to classify either normal or abnormal values. The next step will involve testing the entire system in a home-based healthcare setting. In addition, other cardiovascular parameters such as ECG and respiratory rate should add for better description of medical service.

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Architecture for Monitoring Security State of ISO/IEEE 11073 Healthcare User Domain

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***Abstract*— With an increase in concern about one's health, Ubiquitous healthcare (U-health) service industries are getting more and more developed. Because the health data is very important one, security should be essentially applied to healthcare area. This paper proposes a healthcare security architecture, which can monitor the security state of a healthcare user domain and evaluate its security level. Through the proposed architecture, healthcare providers can determine trust or distrust of health data received from healthcare user domain by checking its security level.**

Keywords-Heahthcare; security state; monitoring; trust;

I. INTRODUCTION

With an increase in concern about one's health, U-health service industries are getting more and more developed. Through U-health service, users can conveniently measure their own health status at home or fitness center without need to go to the hospitals and receive medical services in remote diagnostics.

Continua Health Alliance (CHA), an international healthcare organization, has proposed an end-to-end healthcare architecture for enabling end-to-end connectivity of devices and services for personal health management and healthcare delivery and for providing interoperability among various kinds of healthcare devices [1]. The Continua healthcare architecture consists of a healthcare user domain where the health data (i.e., bio-data) of users is measured through personal healthcare devices and a healthcare provider domain where the health status of users is diagnosed by analyzing the health data.

Because health data is very important and sensitive one, security should be essentially applied to healthcare area. Accordingly, the CHA uses security standards such as TLS to protect health data in the healthcare provider domain. To protect health data in the healthcare user domain, the CHA employs link layer security standards. Because the link layer security standards do not sufficiently support security requirements of healthcare service, there has been research for applying security function to the ISO/IEEE 11073 protocol which is a health data transport protocol [2]-[4].

Even if the healthcare architecture considers security function, there is a problem that healthcare providers cannot determine trust or distrust of the health data received from a healthcare user domain because they have no information about how the health data has been handled in the user domain.

To address the health data trustworthiness issue, this paper proposes a healthcare security architecture, which can monitor the security state of a healthcare user domain and evaluate its security level. Through the proposed architecture, healthcare providers can determine trust or distrust of health data received from a healthcare user domain by checking its security level.

II. HEALTHCARE END-TO-END ARCHITECTURE

Fig. 1 shows the healthcare end-to-end architecture which has been proposed by CHA. The architecture defines a Personal Healthcare Device (PHD), Aggregation Manager (AM), Tele-health Service Center (TSC), and Health Records Network (HRN).

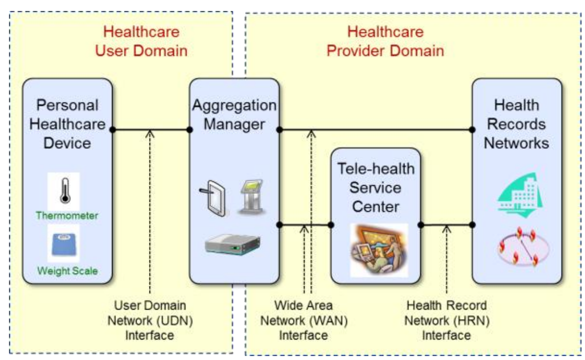

Figure 1. Continua architecture: healthcare end-to-end architecture.

The PHD is a personal device which measures the health status of users. An example of PHDs includes a thermometer, a pulse oximeter, a weight scale, a glucose meter, and so on. The AM is a communication gateway which collects health data from PHDs and transmits them to a TSC or a HRN. An example of AMs includes smart-phone, PC, and so on. The TSC is a healthcare server which provides healthcare service such as a chronic disease management and an old people health care. Finally, the HRN indicates a hospital medical information system such as hospital Enterprise Health Record (HER), physician Electronic Medical Record (EMR), or Personal Health Record (PHR).

In the Continua architecture, there are three kinds of interface: User Domain Network (UDN), WAN and HRN.

The UDN interface is one between PHD and AM. It uses the ISO/IEEE 11073 protocol [5] as data transport protocol. As link layer protocol it employs Bluetooth, BLE, USB, ZigBee, and NFC. The WAN interface is one between AM and TSC or between AM and HRN. It uses the IHE HL7 protocol as data transport protocol. The HRN interface is one between the TSC and the HRN and uses the IHE HL7 protocol [6].

Because health data is very important and sensitive one, security should be essentially applied to healthcare area. Accordingly, the CHA uses security standards such as TLS and IHE (Integrating the Healthcare Enterprise) XDM (Cross-Enterprise Document Media Interchange) to protect health data in the healthcare provider domain. To protect health data in the healthcare user domain, the CHA employs link layer security standards such as Bluetooth health device profile and ZigBee healthcare application profile. The link layer security standards do not sufficiently support security requirements of healthcare service. For example, the link layer security does not support user authentication. To directly protect health data in the healthcare user domain, there has been research for providing security function to the ISO/IEEE 11073 protocol which is a health data transport protocol [2]-[4]. But currently any of those research results has not been accepted as international standard.

Even if the healthcare architecture can protect the health data from cyber-attack by using security function such as confidentiality, integrity, and availability, there is still a health data trustworthiness issue. Namely there is a problem that the healthcare providers cannot determine trust or distrust of the health data received from a healthcare user domain because they have no information about how the health data has been handled in the user domain.

III. SECURITY STATE MONITORING ABOUT HEALTHCARE USER DOMAIN

This section proposes the architecture for security state monitoring and explains in detail about security state data collection and security level evaluation.

A. *Architecture for security state monitoring*

In this paper, we propose five steps in order to determine trust or distrust of the health data received from a healthcare user domain as shown in Fig. 2. The five steps are as follows:

① Raw security state information collection step: collect raw security state information by monitoring PHD and AM, such as communication security state, healthcare protocol state, healthcare environment, and AM security state.

② Abnormal behavior detection step: detect abnormal behavior by analyzing the raw security state information which was collected in the previous step and by using security software installed in the AM.

③ Security state information normalization step: normalize the collected security state information by removing duplicated or useless data. As a result, it is generated security state information about communication security, cyber-attack detection, healthcare environment, and AM security.

④ Security level evaluation step: evaluate the security level of a healthcare user domain by using the security state information acquired through the previous steps.

⑤ Security response step: determine trust or distrust of the health data received from the healthcare user domain. If it is regarded as unreliable data, it is ignored and the communication from its sender is refused.

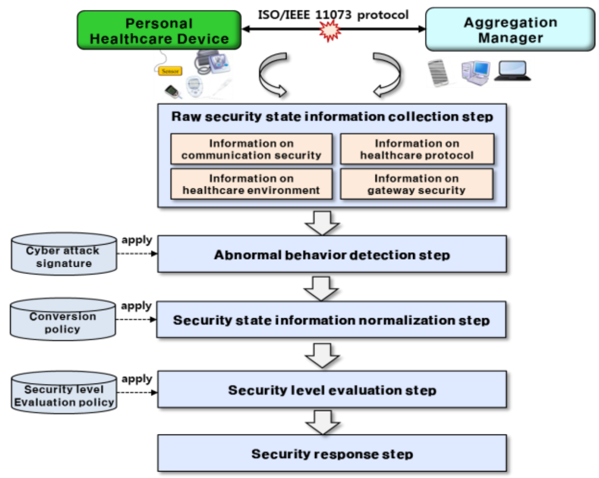

Figure 2. Five steps for determining trust or distrust of health data received from healthcare user domain

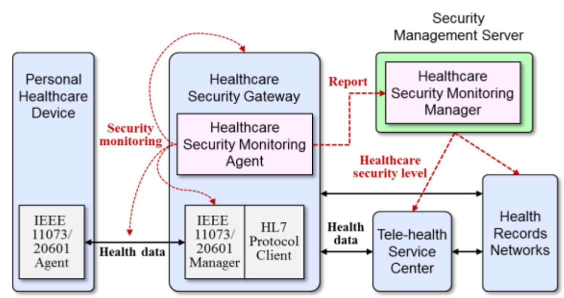

Figure 3. Architecture for security state monitoring about healthcare user domain

Fig. 3 shows architecture for security state monitoring about the healthcare user domain. In the architecture, we propose two core components for security state monitoring: a healthcare security monitoring (HSM) agent and a HSM manager. The HSM agent operates as a component of the AM and the HSM manager resides at a separated system such as security management server.

The HSM agent operates as follows. Firstly, it collects security state information. And then it detects cyber-attacks (e.g., Denial service of attack) by analyzing the collected security state information or by using security software installed in the AM. Finally, it summarizes the collected or analyzed security state information (i.e., communication security state, cyber-attack state, health data collection environment, and AM security state) and reports them to the HSM manager.

The HSM manager operates as follows. First of all, it determines the security level of the healthcare user domain by analyzing the security state information received form the

HSM agent. Lastly, it provides the security level of the healthcare user domain to TRC or HRN so as to help them determine trust or distrust of the health data received from a PHD.

B. Collection of raw security state data

The raw security state data which is collected by the HSM agent is as follow.

- Communication security state: indicates whether or not the communication security mechanisms such as authentication, confidentiality, and integrity are applied to the UDN interface (e.g., ISO/IEEE 11073 over Bluetooth)
- Healthcare protocol state: indicates information about protocol warning/error messages and protocol connection on the UDN interface
- Health data collection environment: indicates information on PHD and AM (e.g. product name and model), whether or not a PHD is shared by people, whether a PHD is installed in open or private area, and so on
- Gateway security state: indicates whether or not security software or chipsets are being performed on the AM, such as a firewall, an anti-virus, a Trust Platform Module (TPM), and so on.

A HSM agent can detect abnormal behavior by analyzing healthcare protocol state information. An example of abnormal behavior includes a denial of service attack which requests communication connections so excessively as to exhaust the computing resources of an AM.

C. Evaluation of security level

If a HSM manager receives security state information about a healthcare user domain, it evaluates the security level of the domain by analyzing the received information based on its own local policy. The following is a simple example of such policy-based security level evaluation algorithm.

① Extract security state attributes from the security state information which is received from the HSM agent

② Convert the value of security state attribute to numeric one. (e.g., if authentication function is supported at the UDN interface, its value is 1. Otherwise its value is 0)

③ Normalize the value of security state attributes by applying different weight to them. The weight value by security state attribute is determined by a user-defined policy

④ Calculate a total security state score of the healthcare user domain by adding all the values of security state attributes

⑤ Finally determine the security level of the healthcare user domain by using the security state score. The relation between security state score and security level is set by a user-defined policy.

In this paper, we define four kinds of security level: Safety, Watch, Warning, and Risk. The security level is determined by a user-defined policy. An example of such policy is described in Table. 1. According to Table 1, if all the security state of a healthcare user domain is perfect, then its security level becomes 'Safety'. If the security state is good in the communication security but bad in the gateway security or the cyber-attack, then its security level becomes 'Watch'. If the security state is bad in the communication security, then its security level becomes 'Warning'. Finally if all the security state is bad, then its security level is 'Risk'.

TABLE I. AN EXAMPLE OF USER-DEFINED POLICY FOR DETERMINING SECURITY LEVEL

security state information \ security level		Safety	Watch	Warning	RISK
Communication security	Authentication	O	O	X	X
	Encryption	O	O	X	X
	Integrity	O	O	X	X
Gateway security	Firewall	O	X	O	X
	Anti-virus	O	X	O	X
	File encryption	△	△	△	△
	TPM	△	△	△	△
Cyber-attack	No DoS	O	X	O	X
	Virus detected	O	X	O	X

△ : don't care

IV. CONCULSION AND FUTURE WORK

In this paper, we have proposed a healthcare security architecture which can monitor the security state of a healthcare user domain and evaluate its security level. Our architecture can help healthcare providers determine trust or distrust of health data received from the healthcare user domain by checking its security level. Our future work is to implement and verify the proposed architecture.

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