Policy-based Emergency Bio-data Transmission Architecture for Smart Healthcare Service

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Keywords: Smart Healthcare, e-Healthcare, IEEE 11073, HL7, Policy-based Medical Service.

Abstract: In this paper, we propose a policy-based emergency bio-data transmission architecture for smart healthcare service. Using the proposed service architecture, the medical staff or doctors can monitor the emergency bio-data of remote patients in accordance with policy. The proposed system consists of three tiers: measurement tier of bio-data of patients, policy-based transmission tier of bio-data of patients, and message conversion tier between IEEE 11073 PHD (Personal Health Device) message and HL7 CDA (Clinical Document Architecture). Bio-data of patients are monitored by an IEEE 11073 PHD agent such as a pulse oximeter, glucose meter, etc., and it is transmitted to IEEE 11073 PHD manager. The manager diagnoses the bio-data information in accordance with policy. The manager software can be installed in either a smartphone or PC where it transmits the bio-data information to the UMS (Urgency Management Server). The UMS converts the IEEE 11073 PHD message to a HL7 CDA standard message, after which it sends the converted HL7 CDA message to the medical staff or medical system. Finally, the medical staff can perform diagnoses using the patient bio-data information. Details of the proposed system architecture are discussed.

1 INTRODUCTION

Mobile, wireless, pervasive computing, and communication environments are changing the way medical staff interact with their patients and the elderly. By employing self-organized wireless physiological-monitoring hardware/software systems, continuous patient monitoring can be used to assure timely intervention by a healthcare practitioner or physician. For example, cardiac patients wearing ECG (Electrocardiogram) sensor systems can be monitored remotely without visiting the hospital. Healthcare sensor systems are required to be connected directly or indirectly to the Internet at all times (Hung, 2009).

Moreover, physiological records are collected over a long period of time in order to allow accurate diagnoses and correct treatment by physicians. However, developing a pervasive sensor network for healthcare has numerous challenges, including conformation of wireless healthcare sensor systems to the human body, integration of different wireless networks with various transmission techniques, and development of healthcare applications over these types of networks. Hung (Hung, 2009) proposed a healthcare monitoring architecture coupled with wearable sensor systems and an environmental sensor network for monitoring elderly or chronic patients in their residences.

Patient-related bio-data such as weight, ECG, EEG (Electroencephalography), SpO2 (oxygen Saturation), etc. measured by sensors in, over, on, and around the patient are delivered to the surgeon, who checks the health status of the patient. In the delivery of patient-related data, international standards such as IEEE 11073 PHD, HL7 (Health Level 7) CDA, etc. are used.

IEEE 11073 PHD (Personal Health Device) standards are a group of standards that address the interoperability of PHDs, such as weighing scales, blood pressure monitors, blood glucose monitors, and the like (IEEE 11073-20601, 2008). IEEE 11073 PHD focused on ubiquitous environments, implementing high quality sensors, supporting wireless technologies such as Bluetooth or Zigbee, and providing faster and more reliable communication network resources. Further, IEEE 11073 PHD standards are adequate for homecare challenge and might be the best-positioned international standards to reach this goal.

HL7 is a messaging standard for exchanging medical information and is becoming a world

Nah J., Chun S. and Park J..
Policy-based Emergency Bio-data Transmission Architecture for Smart Healthcare Service.
DOI: 10.5220/0004194501670173
In *Proceedings of the International Conference on Health Informatics* (HEALTHINF-2013), pages 167-173
ISBN: 978-989-8565-37-2

standard (HL7, 2012). HL7 Version 2.5.1 Messaging Standard has a defined syntax for information representation of segments, data types, flags, and mapped fields.

There have been numerous attempts to apply international standards for healthcare system development (Huang, 2009) (Kim, 2010) (Trigo, 2009) (Yao, 2005). Previously, the relationships between the ISO/IEEE 11073 (usually referenced as x73) PHD model for ECG devices and the fields of the SCP-ECG standard (European Standard EN1063) were investigated (Trigo, 2009). Yao et al., (Yao, 2005) employed the IEEE/ISO 11073 and Bluetooth standards to achieve device auto-association, interoperability, and simple reconfigurability. Huang (Huang, 2009) proposed a healthcare monitoring architecture that uses wearable sensor systems and an environmental sensor network for monitoring elderly or chronic patients in their residences. They proposed a hierarchical network architecture that measures patient-related data and accesses the Internet through GPRS/3G/WiFi.

Kim et al., (Kim, 2010) proposed the integration of the IEEE 1451 and HL7 standards for exchanging information obtained from patients' sensors. In their proposed structure of the healthcare system, medical staff can access the mobile device of a patient by using the IEEE 1451 and HL7 standards.

In most healthcare monitoring systems, emergency judgement of patient bio-data is carried out only by the medical staff. For this, the bio-data should be transmitted continuously to medical staff at a remote location. It is difficult for medical staff to monitor great number of people since their numbers are limited.

In this paper, in order to overcome the above-mentioned problem, we propose a policy-based emergency bio-data transmission architecture for a smart healthcare service. Through the proposed service architecture, medical staff can monitor the emergency bio-data of remote patients quickly and accurately. The proposed system consists of three tiers: measurement tier of bio-data of patients, policy-based transmission tier of bio-data of patients, and message conversion tier between IEEE 11073 PHD message and HL7 CDA. More specifically, patient bio-data are measured by an IEEE 11073 PHD agent such as a pulse oximeter, glucose meter, etc., after which the data are transmitted to an IEEE 11073 PHD manager such as a smart mobile device. The manager software diagnoses the bio-data information in accordance with policy, and it transmits the bio-data information to the UMS (Urgency Management Server). The UMS then converts the IEEE 11073 PHD message to a HL7 CDA standard message, after which it sends the converted HL7 CDA message to the medical staff or medical system. Finally, the patient bio-data information is diagnosed by the medical staff.

The rest of the article can be described as follows. In Section 2, we describe the general service architecture of the patient monitoring system. In Section 3, we propose the system structure of the policy-based patient monitoring service with policy-based emergency management for healthcare service. In Section 4, we implement the proposed system and evaluate its performance. Finally, the conclusion follows in Section 5.

2 GENERAL SERVICE ARCHITECTURE OF PATIENT MOBITORING SYSTEM FOR HEALTHCARE SERVICE

The general service architecture of the patient monitoring system for healthcare service (Pantelopoulos, 2010); (Li, 2010); (Huang, 2009) consists of a mobile device, a central management server, database, and hospital monitoring system. Each component performs its function as follows. The mobile node measures the patient-related data, which are transmitted from the wireless sensors. The central management server then collects the patient-related data from the mobile device and relays the data to the hospital monitoring system. The patient-related data are then stored in the database such as EHR/PHR (Electronic Health Record/Personal Health Record). Next, the hospital monitoring system receives the patient-related data from the central management server. The surgeon in the hospital system then judges whether or not the data are emergency-data or patient-related as well as checks the health condition of the patient. If it is determined from the data that the health condition of the patient is associated with emergency, the surgeon calls an ambulance for timely treatment.

To reliably transmit the bio-data information in the healthcare system, there are several technologies and international standards, such as IEEE 11073 PHD, HL7, DICOM, etc. More specifically, a sensor (called agent in IEEE 11073 PHD) and mobile device (manager, IEEE 11073 PHD standards) are used. The IEEE 11073 standard is a family of standards intended to interconnect and interoperate medical devices (IEEE 11073 agent and manager) with each other.

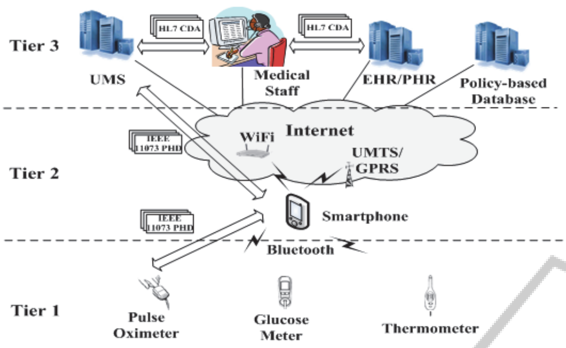

Figure 1: Architecture of policy-based urgency patient monitoring system.

3 PROPOSED POLICY-BASED PATIENT MONORING SYSTEM WITH HENDLING EMERGENCY-PATIENT

3.1 Structure of Policy-based Patient Monitoring System

Figure 1 shows the architecture of the policy-based patient monitoring system. The proposed system consists of an IEEE 11073 agent such as a pulse oximeter, glucose meter, etc., an IEEE 11073 manager such as a smartphone or tablet PC, policy-based database, UMS (Urgency Management Server), medical staff, and EHR/PHR database.

IEEE 11073 agent and manager are equipped with the IEEE 11073 PHD standard protocol stack. The policy-based database stores a variety of critical bio-data information. The IEEE 11073 manager judges whether or not bio-data information is urgent or not by investigating the critical bio-data information from the policy-based database. EHR/PHR stores the personal bio-data information, which is received by the UMS. The UMS performs message conversion between the IEEE 11073 PHD and HL7 CDA standards.

The proposed healthcare service architecture consists of three tiers. Tier 1 measures and delivers the bio-information in accordance with the IEEE 11073-20601 standard. IEEE 11073 agent and manager exchange the bio-data information through the wired/wireless network interface, such as WPAN (Wireless Personal Area Network), LAN (Local Area Network), WLAN (Wireless Area Network), etc.

Tier 2 performs monitoring of bio-data from IEEE 11073 PHD agent(s) and performs filtration/aggregation of the bio-data. It then assesses urgency by referring to the policy database information. If urgency is detected, a manager sends an urgent message to the UMS.

In tier 3, the UMS performs conversion from IEEE 11073 PHD message format to HL7 CDA message format to enable medical staff to check the personal bio-data. The medical staff then makes a decision regarding the urgent situation. If the medical staff declare an emergency based on the bio-data, an urgent message is created and sent to the UMS for monitoring and gathering of the bio-data information on a certain patient. The bio-data transmitted from IEEE 11073 PHD agent arrives in the medical system through the UMS.

3.2 Structure of Urgency Management Server

Figure 2 shows the architecture of the UMS. The UMS is located between the IEEE 11073 agent and medical staff, and it converts IEEE 11073 PHD message format to HL7 CDA message format or from HL7 CDA message format to IEEE 11073 PHD message format to monitor the personal bio-data information. The UMS also converts the gathered bio-data to CDA document format.

The UMS is comprised of the IEEE 11073 manager, CDA Factory, HL7 v2.x Converter. The HL7 v2.x Converter converts the received bio-information to the HL7 message through the IEEE 11073 manager. It also analyses HL7 message received from the remote site to the bio-information monitoring application. HL7 is comprised of the MSH (Message Header Segment), EVN (Trigger Event), PID (Patient Identification Segment), OBR (Observation Request Segment), or essential Segment of the OBX (Observation Result Segment). The request for the bio-information is specified in OBR field, and the bio-information received from the IEEE 11073 agent is transmitted to the OBX field. The HL7v2.x Converter is comprised of Metafile Handler and HL7 Message Converter.

The Metafile Handler analyses the meta data in the HL7v2.x message and verifies the meta information. The HL7 Message Converter parses the HLT message received from bio-information monitoring application at the remote site, after whichi t requests the bio-information to the IEEE 11073 manager. Data mapping between the IEEE 11073 manager and HL7v2.x Converter is perfor-

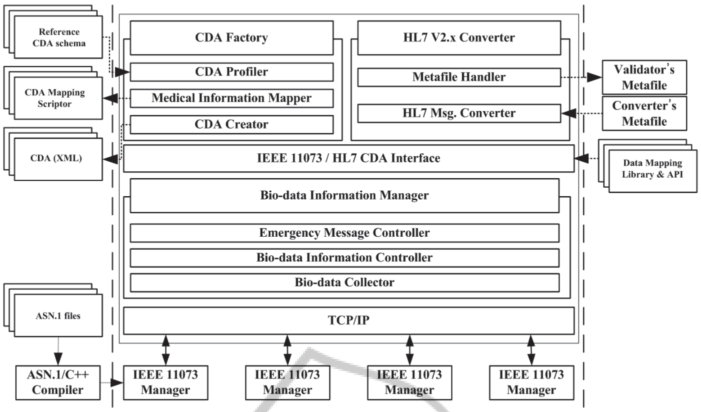

Figure 2: Structure of urgency management server.

Table 1: Service policy management for emergency healthcare monitoring service.

Policy		Description
Emergency Service SetUp	Setting	Setting of emergency bio-data types, patient's information, emergency level
	Info	Information describing emergency service
	Time	Define starts and stop times for emergency service
Patient Management	PatientInformation_SetUp	Delivery of patient individual information for medical information generation
	PatientBioData_SetUp	Delivery of each patient specific bio-data for disorder judge
	BioDataType_SetUp	Delivery of bio-data type, detection time, and medical device ID
Disease Management Emergency Management	DisordersChecker_Status	Delivery of DisordersChecker status such as currently operation status or configuration of disorders checker
	DisorderChecker_SetUp	Request ready for DisordersChecker for close examination for received bio-data from IEEE 11073 manager
	CriticalValuePreset_SetUp	Delivery preset critical value of each bio-data for preliminary examination at IEEE 11073 manager
	Emergency_Creation	Declare emergency situation and request preparation for emergency communication through hot line
	EmergencyCommander_SetUp	Delivery of information for emergency communication such as medicaldevice ID and patient individual information
	EmergencyBioData_SetUp	Delivery of bio-data information such as detected time, type and detected bio-data
	HotLine_SetUp	Delivery emergency information and request preparation for hot line which communicate with physician for transmission emergency data. The hot line means that only emergency patient can transmit bio-data to physician. When the hot line is operating other medical devices stop data transmission.
Protocol Conversion Mgt.	ManagerStatus_SetUp	Delivery manager status such as current list of connected agents
	IEEE11073Analyzer_SetUp	Delivery IEEE 11073 bio-data and request ready for mapping to HL7 message
	HL7Message_Creation	Delivery bio-data, medical device ID, patient information for generation HL 7 message

med through the IEEE 11073/ HL7 CDA Interface. Data mapping information conforms to standard protocol.

CDA Factory of the IEEE 11073/HL7 protocol conversion gateway produces a HL7 CDA document that includes the bio-information collected in IEEE 11073. CDA documentation contains all information related to treatment of the bio-information or patient, and it is structured in the XML format of RIM (Reference Information Model) of the HL7 (Dolin, 2005). The object information for comprising CDA is comprised of Act, Participation, Entity, Role, and ActRelationship.

CDA Factory is comprised of a CDA Profiler, Medical Information Mapper, and CDA Creator. CDA Profiler verifies the inputted CDA document or outputted CDA document. The Medical Information Mapper performs mapping of the bio-information and meta information received from the HL7 v2.x Converter or IEEE 11073 manager to RIM

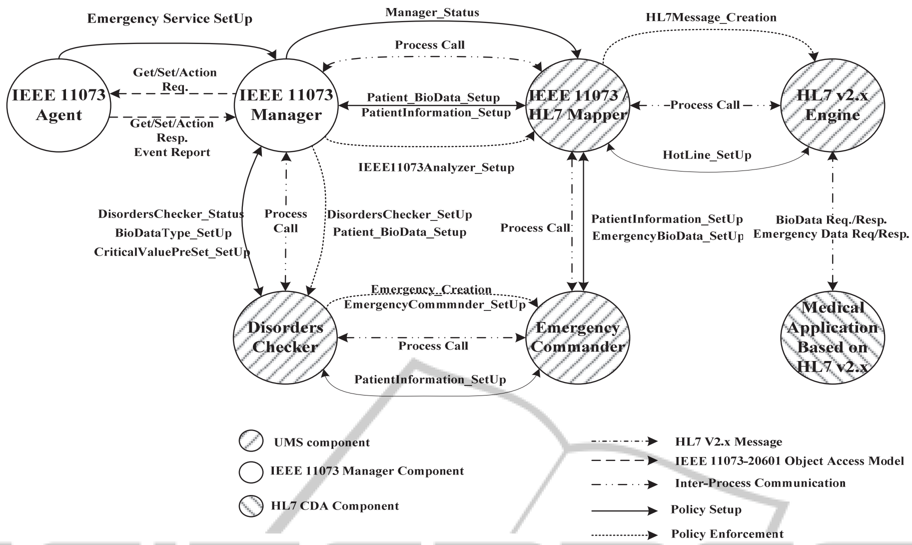

Figure 3: Message flow diagram for policy-based urgency service management.

base class of the CDA document structure. The CDA document is produced based on the CDA template prepared in the CDA Profiler. According to the IEEE 11073 agent, several CDA templates are generated that collects the bio-data information from the IEEE 11073 agent. The generated CDA document is verified again in the CDA Profiler.

The bio-data Information Manager consists of an Emergency Notifier, Data Aggregation, and Data Filtering. The Information manager makes an emergency decision, which is received from the sensor. If an emergency situation is detected, an emergency notification message is created and transmitted to the UMS. The bio-data Collector finally transmits the bio-data information from the UMS to the IEEE 11073 PHD manager. The received bio-data information converts HL7 CDA message format in accordance with the policy information.

3.3 Message Flow Diagram for Policy-based Emergency Service Management

In this section, we describe the structure of policy-based urgency service management for emergency patients that suffer from physical trauma, etc. The policy database is composed of patient management, disease management, and emergency management. The transmission of the bio-data information can be managed through these management functions.

Table 1 indicates service policy management for the emergency healthcare monitoring service. UMS judges whether or not the bio-data information warrants an emergency in accordance with the policy information. If an emergency situation is detected, the UMS sends an emergency notification message to the medical staff. Upon receiving the notification message, the medical staff sends an emergency response message to obtain certain personal bio-data information. Then, the UMS sends the requested bio-data information and stops transmission of other non-urgent bio-data information in order to quickly and reliably transmit the requested bio-data information.

Figure 3 shows the message flow diagram for the policy-based emergency service management. In Figure 3, the patient who needs emergency service, requests the emergency service setup to the IEEE 11073 manager. The emergency service setup request message requested from the IEEE 11073 agent to IEEE 11073 manager does not conform to the IEEE 11073 PHD standard. Thus, we added additional message signalling of data conversion.

In response to this request, the IEEE 11073 manager compares the bio-data of the patient, which are received from the IEEE 11073 agent, and sets the critical value repository. By checking the critical value, the UMS refers to the DisordersChecker SetUp policy for operation of the DisordersChecker. If the critical value exceeds the preset value for determining the emergency bio-data, the IEEE 11073 manager refers to Patient_BioData_SetUp and BioDataType_SetUp policy.

4 PERFORMANCE EVALUATION

4.1 Implementation Environment

Figure 4 shows the implementation environment for policy-based healthcare monitoring. We used two types of sensors; ECG sensor and SpO2. We used an HBE-ZigbeX2 device provided by the HANBACK Company in Korea.

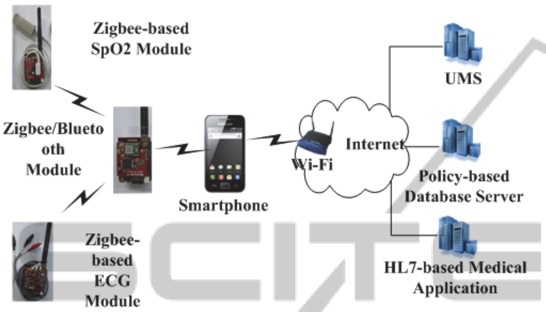

Figure 4: System environment for policy-based healthcare monitoring.

- Server : IBM Server
- Mobile device : smartphone
- Type of sensor (product standard): Bluetooth module (HBE-ZigbeX2-Bluetooth), SpO2 (HBE-ZigbeX2-Spo2), ECG sensor module
- Development language : visual C, MFC

The bio-data information (SpO2 and ECG) is measured and transmitted according to IEEE 11073-10404 (11073-10404, 2008) and 11073 to 10406 (11073, 2008) standards.

4.2 Policy-based Healthcare Monitoring System Scenario

The system operation scenario is as follows: two types of bio-data information, i.e., SpO2 and ECG are measured by the ZigBee-based SpO2 measurement module and ZigBee-based ECG measurement module, respectively. Measured bio-data are transmitted to a smartphone through ZigBee communication and Bluetooth communication. A smartphone requests the critical policy information with regard to SpO2 and ECG to a policy-based database server. Then, the smartphone monitors the bio-data information.

If the measured bio-data information incurs critical urgency conditions, the smartphone sends an emergency notification message to the UMS. Then, the UMS sends an emergency notification message to the HL7-based medical application after its message is converted to HL7 CDA format. The HL7-based medical application requests the measured certain bio-data on a smartphone via the UMS. Finally, the measured bio-data on the Zigbee-based module arrives in the HL7-based medical application.

Figure 5: Display view on smartphone.

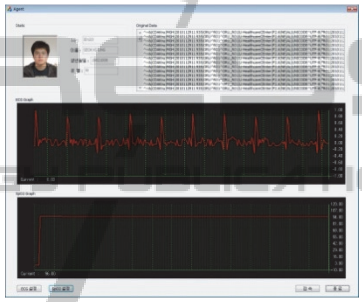

Figure 6: Display view of HL7-based medical application.

4.3 Implementation Results

Figure 5-Figure 8 show the implementation results of the policy-based urgency healthcare monitoring system. Figure 5 shows an ECG graph and SpO2 graph on a smartphone. The bio-data information in these graphs is received by the Zigbee-based ECG and SpO2 measurement modules in real-time in IEEE 11073 message format. The bio-data information is monitored, and the urgency status of the data is determined.

Figure 6 shows the HL7-based medical application. ECG and SpO2 bio-data in the HL7-based medical application are received from the UMS in HL7 CDA message format.

Figure 7 and Figure 8 show the emergency notification message that is received from the HL7-based medical application in the UMS along with the emergency notification message that is received from the UMS in the HL7-based medical application, respectively. This emergency message is generated by the HL7 v2.1 engine.

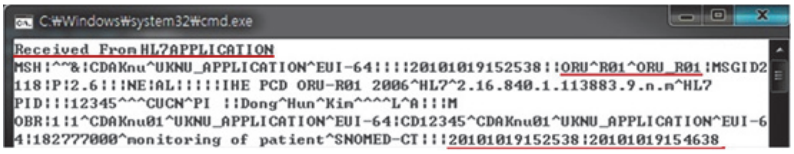

Figure 7: Emergency notification message received from HL7-based medical application in UMS.

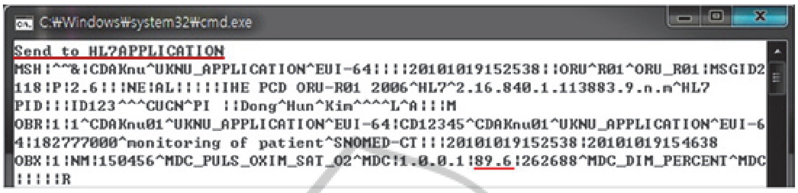

Figure 8: Emergency notification message received from UMS in HL7-based medical application.

5 CONCLUSIONS

In this paper, we presented a policy-based emergency bio-data transmission architecture for smart healthcare service. Since various healthcare standards have been researched by international standard organizations such as IETF, ISO, Continua, HL7, etc., these international standards should be interworked. For this, we designed an interworking architecture of the IEEE 11073 PHD and HL7 CDA standards. In addition, we presented a policy-based transmission architecture in order to increase the reliability of transmission. The details of the proposed system architecture have been implemented.

ACKNOWLEDGEMENTS

This research was supported by the MKE (The Ministry of Knowledge Economy), Korea, under the ITRC (Information Technology Research Center) support program supervised by the NIPA (National IT Industry Promotion Agency) (NIPA-2012-(C1090-1121-0002)), second stage BK21 Project and Kyungpook National University Research Fund.

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