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Design and Implementation of u-Health System to Support Interoperability with Legacy Non-Standard Medical Devices

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Abstract**: *Although there have been worldwide studies on u-Health services to converge the latest IT technologies into the medical field, there are still limitations to compatibility and interoperability with existing legacy non-standard medical devices. This paper proposes a u-Health system architecture to utilize legacy non-standard medical devices for standard u-Healthcare services by adding a codec and algorithms to IEEE 11073 agent. The proposed agent located between medical devices and mobile manager encodes non-standard data of legacy devices to IEEE 11073 standard data format and decodes vice versa using the developed codec and algorithms, which makes it possible to support data compatibility and interoperability between u-Health standard systems and non-standard systems. The proposed system is implemented by using Intel Edison board and android-based smartphone to verify performance and effectiveness of the proposed system. The implementation results show that legacy non-standard medical devices can be utilized for the u-Health standard services based on the IEEE 11073 PHD protocol by using the proposed system, which means that the proposed system can contribute to the growth and extension of u-Health services by solving the problem of service limitations caused by existing legacy non-standard devices.***

Index Terms**: *Agent, Interoperability, IEEE 11073, Legacy non-standard medical devices, Mobile manager, u-Health.***

I. INTRODUCTION

Along with the development of IT technology, convergence with IT technology has been attempted in various fields recently. In the medical field, research and development of u-Health services are being actively conducted to support healthcare and medical services anytime, anywhere by combining IT technology. These u-Health services necessarily require interoperability between diverse medical devices and service platforms, which can be made possible by deploying u-Healthcare standards such as IEEE 11073 PHD (Personal Health Device) [1, 2], HL7 (Health Level 7) [3], DICOM [4], etc.

However, many legacy medical devices and systems operated by medical institutions as well as personal health devices often do not support u-health standards, so data compatibility and system interoperability between medical devices or institutions are often not guaranteed, which is an obstacle to the growth of the u-Healthcare industry. Therefore, it is required to support interoperability and backward compatibility between u-Health standard-compliant systems and legacy non-standard medical devices and services.

This paper proposes a u-Health system model and operating algorithms that support interoperability and backward compatibility not only for u-Health standard (IEEE 11073-20601) systems but also for non-standard systems by adding codec module to IEEE 11073 agents. The proposed codec module converts non-standard biometric data into ISO/IEEE 11073 standard data form in the proposed IEEE 11073 agent system. In the proposed system, the IEEE 11073 manager system can exchange standard data with non-standard devices through the agent system. The proposed IEEE 11073 agent and manager system are implemented using Intel Edison board and smartphone based on android OS.

The composition of this paper is as follows. In Section Ⅱ, the ISO/IEEE 11073 PHD standard is described. Section Ⅲ describes the proposed system including its operation algorithms and functions. Section Ⅳ reviews the implementation results of the proposed system and then Section Ⅴ concludes finally.

II. RELATED WORKS

This section describes the ISO/IEEE 11073 which is an international standard for u-Healthcare systems. As shown in Fig. 1, the ISO/IEEE 11073 standard specifies exchanging health information between agent devices and manager devices.

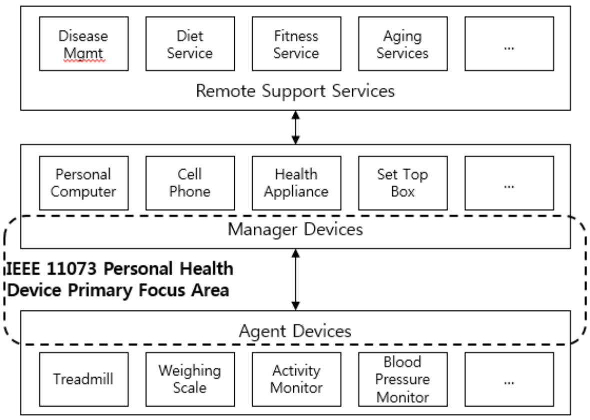

Fig. 1. Personal health device conceptual structure of ISO/IEEE 11073 standard.

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An agent device collects biometric and health data from health/medical devices or sensors, while a manager device manages and monitors sensing data through the agent device. The ISO/IEEE 11073 standard defines 5 to 7 layer's protocols of OSI 7 layers. Transmission technologies such as Bluetooth, Zigbee, etc. may be used for data delivery on the underlying 1 to 4 layers [5-7].

In particular, ISO/IEEE 11073 defines ISO/IEEE 11073-20601, which is a protocol for exchanging data between an agent device and a manager device. Fig. 2 shows the ISO/IEEE 11073-20601 modeling structure which is composed of Domain Information Model (DIM), Service Model, and Communication Model [8-11]. DIM is an object-oriented model that describes device and biometric data and defines the class of the agent. The class attribute is defined as an attribute of the type defined in ASN.1, and the object is adjusted to the attribute. The service model that defines the interaction between the device and the data uses the message format described in ASN.1 [12, 13]. Available services include Event reporting service, Object access service, Association service, and Conversion service. The communication model manages the communication characteristics and the connection state between the manager and the agent device and classifies the connection states of the finite state machine between the two devices into connection, association, operation, and so on.

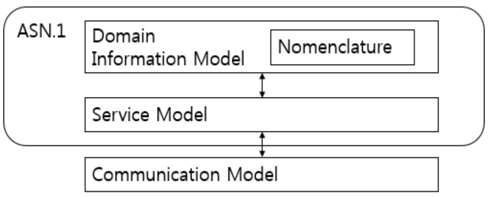

Fig. 2. ISO/IEEE 11073-20601 modeling.

III. THE PROPOSED U-HEALTHCARE SYSTEM FOR LEGACY NON-STANDARD DEVICES

As shown in Fig. 3, the proposed u-Health system architecture is composed of personal health devices, agent device with IEEE 11073 codec, and mobile manager. In particular, the personal health devices include not only IEEE 11073 standard-compliant devices but also legacy non-standard devices or sensors. This section describes the proposed system on the assumption that the personal health devices are legacy non-standard devices.

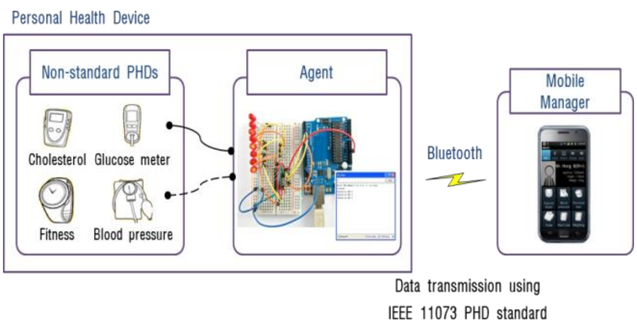

Fig. 3. The proposed u-Health system architecture.

A. u-Health Agent System

The u - health agent system proposed in this paper has a function of converting data received from non-standard health devices into IEEE 11073 standard data by adding a codec module to a general IEEE 11073 PHD agent device.

Fig. 4 shows a message diagram and operating algorithm when the proposed agent system operates both in a client mode and in a server mode, respectively. In the client mode, the agent system first requests the manager to establish a Bluetooth connection and reports PHD's sensed data to the manager without a request form the manager.

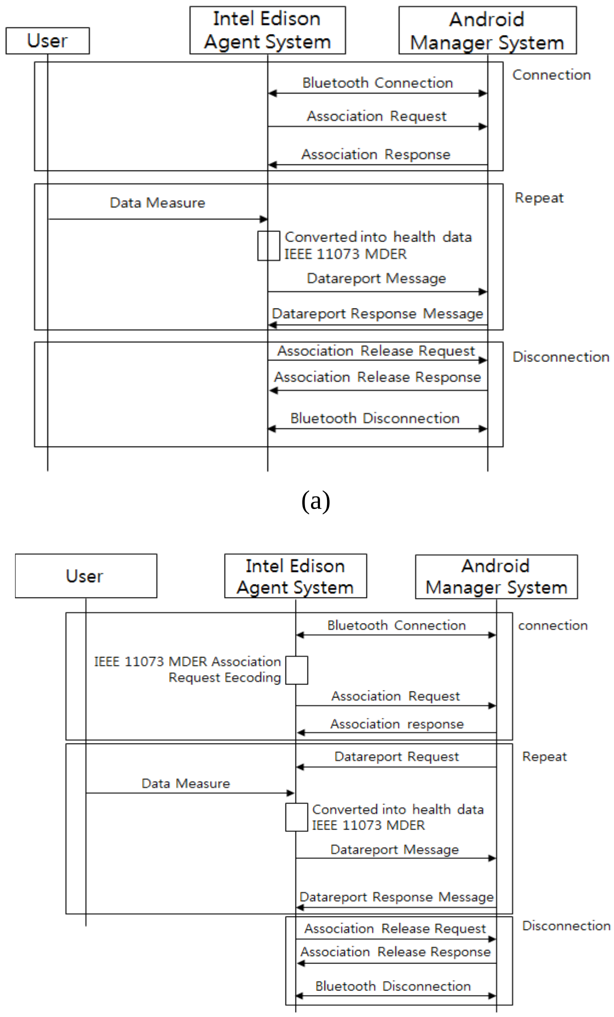

Fig. 4. Message diagram and algorithm of u-Health agent system. (a) Client mode, (b) Server mode.

When the Bluetooth connection is completed, the agent system transmits the Association Request message converted to the IEEE 11073 MDER standard format [14] to the manager system to deliver its own information.

The agent system which is implemented using an open hardware platform - Intel Edison board transmits the biometric data periodically collected from the connected sensors to the manager by using Datareport message encoded to the IEEE 11073 MDER standard format.

Then, it receives a Datareport Response message from the manager system. Data measurement, IEEE 11073 MDER encoding, and data transmission are repeated until the connection between the agent system and the manager system is terminated.

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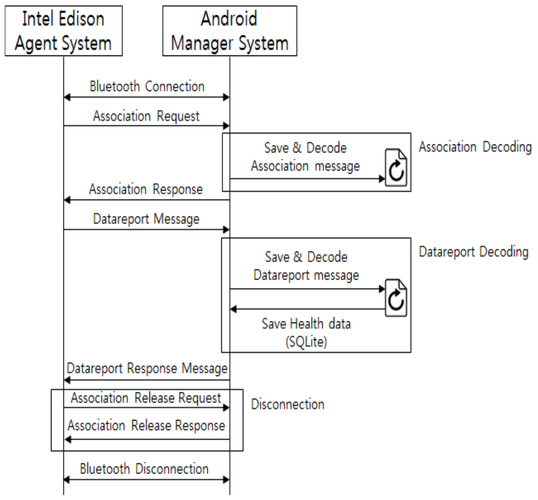
The connection terminating process between two systems begins by sending an Association Release Request message from the agent system to the manager. When the agent system receives the Association Release Response message from the manager, it releases the Bluetooth connection to completely terminate the connection between the two systems.

When the agent operates in the server mode, the manager system attempts to transmit a control command such as Datareport Request to the agent system. At this time, the agent receives a request for Bluetooth connection from the manager. Upon receiving the Datareport Request message from the manager after the association is established, the agent measures the biometric data and transmits the data after converting them into the IEEE 11073 MDER standard format. The agent system can operate both in the client mode and in the server mode at the same time and request the manager to connect first or accept the connection request from the manager.

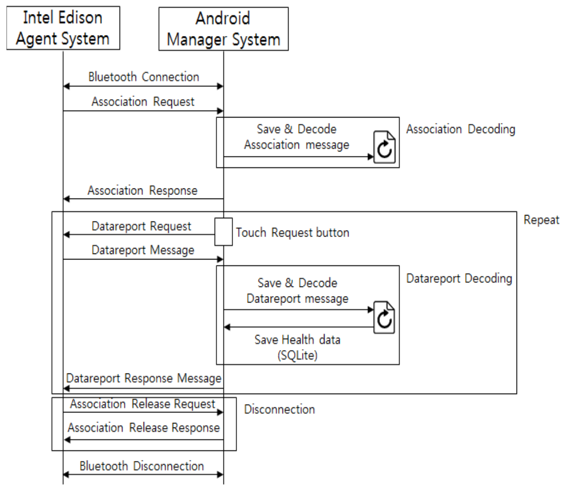
B. u-Health Manager System

In the proposed u - Health system, the manager transmits control commands to the health devices and receives the biometric data measured by the health devices through the agent system. The manager as well as the agent system operates both in client mode and in server mode. Fig. 5 shows message diagram and operating algorithm in each mode.

When the manager system operates in the server mode, it receives Bluetooth connection request and periodic data report from the agent operating in the client mode. After Bluetooth connection is established, the manager receives the Association Request message from the agent and stores the message in the temporary file. And then the manager sends the Association Response message to the agent using the file with the Association decoding process. Once the association is established, data transmission between the manager and the agent system is repeatedly performed through the exchange of a Datareport message and a Datareport Response message. When the manager receives from the agent the Datareport message including the biometric data encoded to the IEEE 11073 MDER standard format, it also saves the Datareport message as a temporary file, extracts only necessary biometric data through a decoding process, stores it in its own database, and transmits a Datareport Response message to the agent system. When the manager receives an Association Release message from the agent to terminate the Bluetooth connection, it sends the Association Release Response message to the agent in response to the Association Release message to completely terminate the connection between the two systems. In the client mode, the manager requests the agent to establish the association by sending the Association Request message and to send the Datareport message by sending the Datareport Request message. Service users of the proposed system can invoke and uses the biometric data stored in the manager database with applications at any time regardless of the operating mode of the manager.



(a)



(b)

Fig. 5. Message diagram and algorithm of u-Health manager system. (a) Server mode, (b) Client mode.

IV. IMPLEMENTATION RESULTS AND REVIEW

A. Non-standard Personal Health Device

In this paper, the Grove-Ear-clip heart rate sensor as shown in Fig. 6 (a) was used as a non-standard personal health device. When an interrupt occurs in the HIGH input signal of Fig. 6 (b), the heart rate is measured once. As shown in Fig. 6 (c), the final heart rate data is decided through the number of interruptions for one minute, and the corresponding measurement value is transmitted to the u-health agent once a minute.

(a)

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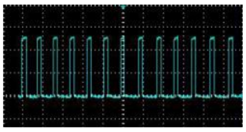
(b)

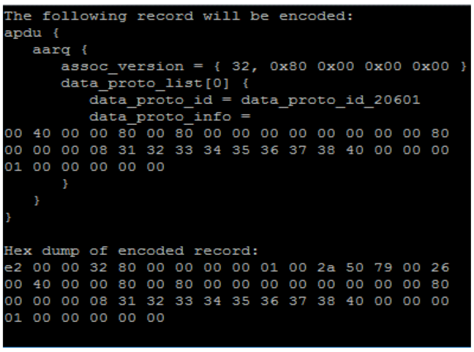


(c)

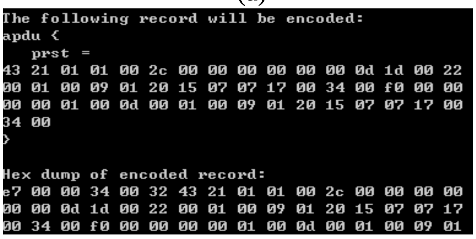
Fig. 6. Measurement of sensor data. (a) Grove-Ear-clip heart rate sensor, (b) interrupt signal, (c) wave pattern of heart rate sensor signal.

B. Implementation of u-Health Agent System

In this paper, the proposed IEEE 11073 agent system was implemented using Intel Edison board which is an open hardware platform and the IEEE 11073 PHD standard was implemented using ASN1C. In particular, a codec was implemented and deployed to the proposed u-Health agent system, which provides the proposed system with a function to convert non-standard biometric data into u - health standard data. In other words, the biometric data measured by the non-standard health device are converted into the MDER standard data format, which is ASN.1 (Abstract Syntax Notation One) coding rule defined in the ISO/IEEE 11073 standard, through the codec of the proposed u-health agent system.



(a)



(b)

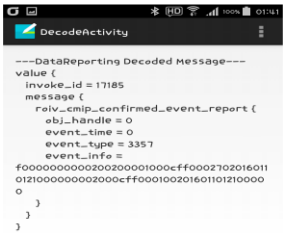
Fig. 7. IEEE 11073 messages at u-Health agent. (a) Encoded Association Request message (b) encoded Datareport message.

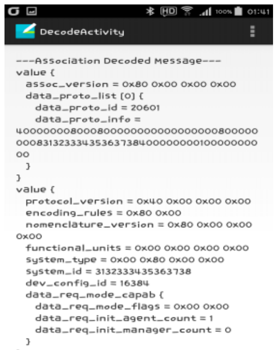
Fig. 7 (a) shows the Association Request message converted to the IEEE 11073 MDER standard data in the implemented agent system. The agent system first transmits an Association Request message after Bluetooth connection, and every time a measurement value is generated once per minute in the heart rate sensor, the measured value is converted into the IEEE 11073 MDER standard format through the newly deployed codec. Fig. 7 (b) shows the encoded data from the original heart rate measurement values to the IEEE 11073 MDER standard data format.

C. Implementation of u-Health Manager System

The proposed u-health manager system is also implemented based on ASN1C like agent system. Fig. 8 (a) shows the IEEE 11073 standard Association and Datareport messages which the agent sent and the manager received. The decoded messages are shown in Fig. 8 (b) and (c).

(a)





(b) (c)

Fig. 8. IEEE 11073 messages at u-Health manager. (a) Received Association and Datareport messages, (b) decoded Association message, (c) decoded Datareport message.

D. Application Interfaces and Experimental Results

Fig. 9 shows the application interface and experimental results implemented in the u-health manager system. Fig. 9 (a) shows the application main menu that runs on the Android-based smartphone that acts as the manager system. The first button is connected to the layout to receive the IEEE 11073-20601 MDER encoded message through Bluetooth communication with the agent system. The second button is connected to the graph layout which extracts and stores the necessary biometric data among the decoded results of the received message and displays them as a graph. The third button is for entering the layout which displays the message received the most recently from the agent system and decoded results on the screen.

Fig. 9 (b) shows the Bluetooth connection status when connected between the agent and manger systems. Fig. 9 (c) shows an activity where an Association message and a Datareport message received from an agent system via Bluetooth are displayed in a status message section in a general ASCII code form. When users select the sub menu shown in Fig. 9 (d), they can go into the graph layout where they can check the grouped biometric data as shown in Fig. 9 (e).

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The graph is an experimental result that recalls the data stored in the database of the manager system (SQLite) and shows it in graphical numerical values. Finally, Fig. 9 (f) shows the decode layout screen, together with sub-menus of the layout. When the first sub menu in Fig. 9 (f) is touched, Fig. 8 (a) display is refreshed. Fig. 8 (a) shows an association message and Datareport message received form the agent system as binary data. With the second and third sub menu touched in Fig. 9 (f), decoded Association and Datareport messages will be displayed, respectively.

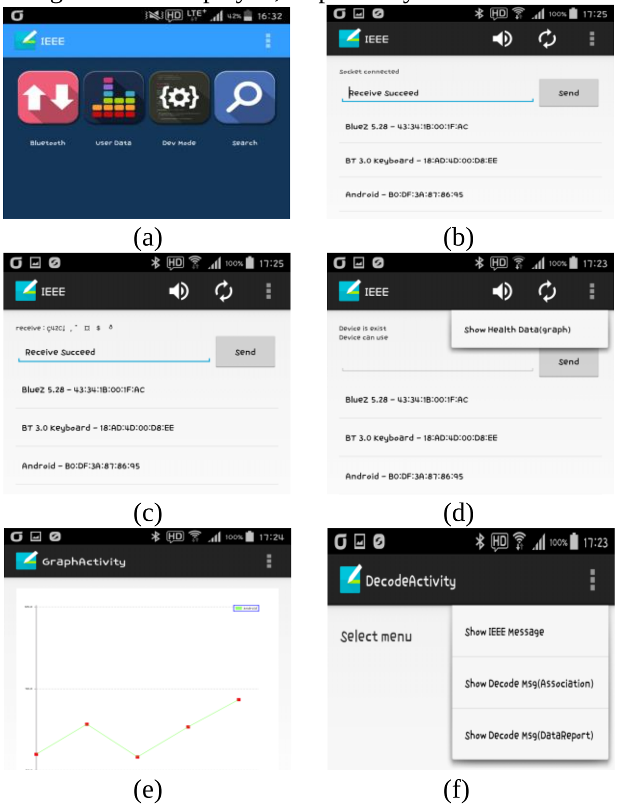

Fig. 9. Application user interfaces of u-Health manager system. (a) Application main layout, (b) connection to agent system, (c) message received from the agent system, (d) dropdown submenu at main layout, (e) grouped health data at graph layout, (f) decode layout.

V. CONCLUSION

This paper proposes a u-Healthcare system architecture to utilize the legacy non-standard medical devices for ISO/IEEE 11073 u-Health standard services by adding a codec and some algorithms to IEEE 11073 agent and manager. The developed codec applied to the agent encodes non-standard data of legacy medical devices to IEEE 11073 standard data format and decodes vice versa, which makes it possible for standard u-Health system to communicate with legacy non-standard devices. This means that the proposed u-Health system supports data compatibility and interoperability between u-Health standard systems and non-standard systems. In this paper, the proposed system was implemented using non-standard health devices, Intel Edison platform, Android OS-based smartphone, etc. to confirm that the existing non-standard health devices can be utilized for the u-health standard services based on the IEEE 11073 PHD protocol. From the implementation results, it is demonstrated that the proposed u-Health system can contribute to the growth of u-Health services by solving the problem of service limitations caused by legacy non-standard health and medical devices.

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