Construction of a Medication Reminder Synchronization System Based on Data Synchronization

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Abstract

This paper proposes a medication reminder synchronization system that consists of medication reminder agents installed in medication reminders and a medication reminder manager installed in a medication server. The medication reminder synchronization system provides a patient with medications as prescribed by medical staff. In addition, medical staff can remotely send messages to the system in order to change the medication schedules or device configuration settings embedded in the medication reminder. The proposed system supports the OMA (open mobile alliance) DS (data synchronization) protocol, which was originally proposed as a DS standard protocol that synchronizes data between mobile devices and a central server. In this study, the OMA DS protocol is redefined and extended to transmit the patient's medication status data and the device configuration data.

Keywords*: Medication reminder, OMA DS, Data synchronization, Medication adherence*

1. Introduction

Recently, disease management has attracted considerable attention with the rapid growth of the elderly population. Many experts believe that ubiquitous healthcare (u-healthcare) technologies can reduce the cost of disease management because these technologies make it possible to check the status of a patient remotely and continuously. Devices such as medication reminders (or medication dispensers) have been developed on the basis of u-healthcare technology. A medication reminder is a personal health device (PHD) that dispenses medications as prescribed.

Medication adherence, which refers to the degree or extent to which a patient takes the right medication at the right time according to a doctor's prescription, has recently emerged as a serious issue because many studies have reported that non-adherence may critically affect the patient, thereby raising medical costs. Therefore, medical and pharrmacy staff should monitor the medication adherence of patients. Owing to these factors, medication adherence requires further investigation. Medication reminders can be very helpful in preventing medication dispensing errors, including misdosing. These devices prompt patients to take the prescribed medications at the right time while providing them with the correct dosage [1].

Most medication reminders are stand-alone devices. Some advanced medication reminders have functions for communication so that they can alert remote medical staff in the event of misdosing. However, when the prescriptions for a patient are modified, the new prescriptions have to be entered into the medication reminder manually, which requires the medical staff to

travel to the patient's home. Similarly, a manager cannot configure new settings for a medication reminder remotely.

In this paper, we propose a medication reminder synchronization system that provides a patient with medications as prescribed by medical staff. In addition, medical staff can remotely send messages to the system in order to change the medication schedules or device configuration settings. The proposed system supports the OMA (open mobile alliance) DS (data synchronization) protocol [2, 3]. The OMA DS protocol was originally proposed as a DS standard protocol that synchronizes data between mobile devices and a central server. In this study, the OMA DS protocol is redefined and extended to transmit the patient's medication status data and the device configuration data.

The remainder of this paper is organized as follows. Section 2 discusses related studies, and Section 3 explains the data and file formats employed by the proposed system. Section 4 describes the proposed system in detail, and Section 5 presents the implementation results. Finally, Section 6 states our conclusions and discusses the directions for future research.

2. Related Work

MyMediHealth [4] is a medication reminder system for children. It runs on mobile devices such as smart phones, providing user interfaces for configuring medication schedules and user alerts for reminding users about the time and type of medication according to the configured medication schedule. Some systems use sensors, radio-frequency identification (RFID), or motion detection technologies to ensure that patients actually take their medications [5, 6, 7].

The OMA DM (device management) protocol [8] was used to remotely manage a smart medication dispenser [9]. This protocol was originally proposed as a standard communication protocol for mobile device management. The medication schedule configured in the dispenser is updated remotely, and the system settings, software, and errors are managed remotely by medical staff. An advanced pulse oximetry system for remote monitoring and management was built using the ISO/IEEE 11073 protocol [10, 11], which was proposed as a standard communication protocol for interoperability between various personal healthcare devices; this system measures a patient's hemoglobin oxygenation and transmits the data to a personal monitoring server. Subsequently, the personal monitoring server analyzes the received data and displays the results to the patient. Furthermore, for device management purposes, operational errors that occur in the pulse oximeter are reported to the personal monitoring server, and the system configurations of the pulse oximeter, such as thresholds and measurement targets, are modified by the server [12].

3. Data and File Formats

The OMA DS protocol uses file formats such as vCard and vCalendar to describe data objects to be synchronized [3]. In this paper, the vCard file format is redefined to describe data objects such as the medication data of a patient and configuration data of the device (medication reminder). Table 1 shows the patient's medication data (MedicationInfoUser) described in the vCard-based format. Every OMA DS message is transmitted in XML; Figure 1 shows a part of the XML messages for the MedicationInfoUser data. Table 2 and Figure 2 show the configuration data of the device and a part of the XML messages for the MedicationInfoDevice data, respectively.

Table 1. MedicationInfoUser

Data Name	Data Type	Comments
Name	String	Patient name
Wait	Digit	Waiting time for alarm (0: 10min, 1: 20min, 3: 30min)
SMS;Guardian1	String	Phone number of guardian 1 (SMS contact info. in case of mis-dosing)
SMS;Guardian2	String	Phone number of guardian 2
SMS;Patient	String	Phone number of patient
SMS;Admin1	String	Phone number of manager 1
SMS;Admin2	String	Phone number of manager 2
Outgoing	Boolean	Whether medication is permitted while going out
Take	Digit	Medication schedule (yyhhmm)
Taken	Digit	Information on medication taken as scheduled
Taken_Times	Digit	Number of medications taken
Alarmed_Times	Digit	Number of medications set in the device in advance
DVC	Digit	Device number

```
<![CDATA[BEGIN:MedicinInfoUser
        VERSION:1.0
        Name:Lim SeungHyeon
        Wait:1122
        SMS:Guardian1:01095911080
        SMS:Guardian2:01095911080
        SMS:Patient:01020500912
        SMS:Admin1:01032011642
        SMS:Admin2:01032011642
        Outgoing:1
        Take:00900216003162441628
        Taken:11111
        TAKEN_TIMES:72
        ALARMED_TIMES:101
END:VCARD]]>
```

Figure 1. Part of an XML Message for the MedicationInfoUser Data

Table 2. MedicationInfoDevice

Data Name	Data Type	Comments
Language	String	Language displayed on the screen of the device
Emergency	String	Emergency phone number
CDMA_GSM	String	Cellular phone number attached to the device
PSTN;Home	String	Home phone number of the patient
PSTN;Manager	String	Home phone number of the manager
Date	String	Local date
Notice	String	Notification messages displayed on the screen of the device

```
![CDATA[BEGIN:MedicinInfoSysConf
VERSION:1.0
LANGUAGE:K
INTERVAL:1
EMERGENCY:119
CDMA_GSM:015321282
PSTN:Home:05312345678
PSTN:Manager:07043218765
DATE:0
NOTICE:방문요망
END:VCARD]]
```

Figure 2. Part of an XML Message for the MedicationInfoDevice Data

4. Medication Reminder Synchronization System

The proposed medication reminder synchronization system transmits OMA DS-based messages containing the patient's medication data and the device configuration data to a remote manager/medical staff. It also synchronizes data (including medication schedules) modified/generated by these personnel in the medication server. Figure 3 shows an overview of the OMA DS-based medication reminder synchronization system.

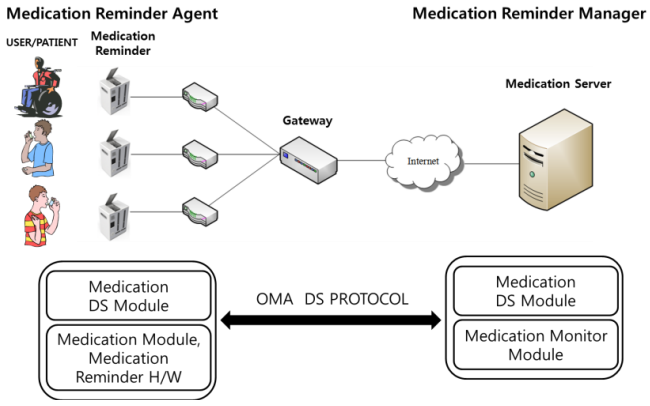

Figure 3. Overview of the OMA DS-based Medication Reminder Synchronization System

A medication reminder agent embedded in the medication reminder at the patient's home gathers information on the medication status and device status; then, it generates OMA DS-based messages. Using the OMA DS protocol, the agent sends messages to the medication reminder manager, which is installed on a medication server at a hospital or other medical facility. Managers/medical staff can access the server to determine the performance of the medication reminder and the medication adherence of the patient. When managers/medical staff want to provide new medication schedules according to new prescriptions, or want to modify the configuration data of the medication reminder, they send the appropriate messages to the remote medication agent. Upon receiving these messages, the agent updates the medication schedules and configuration data of the medication reminder. Figure 4 illustrates the message transmission process for the proposed system.

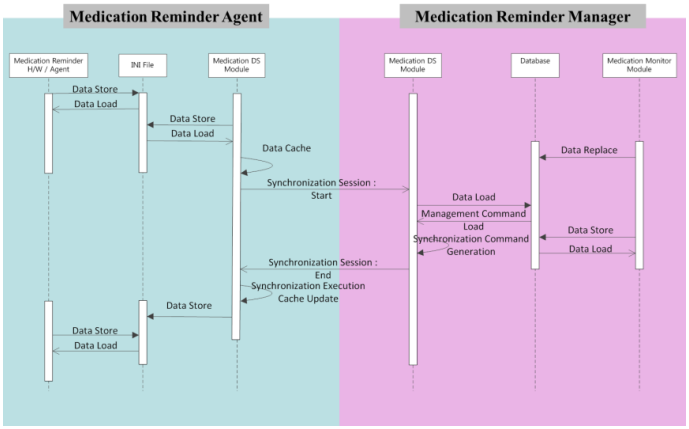

Figure 4. Message Transmission Process

4.1 Medication Reminder Agent

Figure 5 shows the structure of a medication reminder agent, which consists of a medication DS module and a medication module.

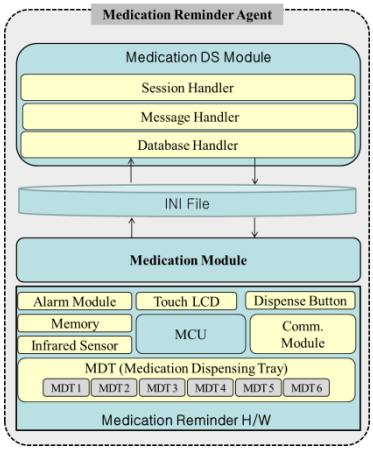

Figure 5. Structure of a Medication Reminder Agent

- Medication DS module: It communicates with a remote DS manager for data synchronization between a medication reminder and a medication server. It consists of a session handler, message handler, and database handler. The session handler opens/closes a TCP session between the medication DS module (of the medication reminder agent) and the medication DS module (of the medication reminder manager). The message handler generates OMA DS-based messages including the information accessed by the database handler from the INI file. Further, the session handler sends these messages to the medication reminder manager. The session handler receives OMA DS-based messages from the medication reminder manager, and then, the message handler analyzes the messages to extract information such as the new medication schedules and device configuration settings. Finally, the database handler stores the information in the INI file. If the messages contain OMA DS-based management commands, the message handler starts executing these commands to store the execution results in the INI file.
- Medication module: It provides the interface between the medication reminder hardware and the patient. It prompts the patient to take his/her medication according to the medication schedule, and it triggers the medication reminder hardware to provide medications to the patient. In addition, it gathers information on the medication status of the patient and hardware errors, and it stores this information in the INI file.
- INI file: It contains current information on the patient status, medication status, hardware errors, and configuration settings of the medication reminder.

4.2 Medication Reminder Manager

Figure 6 shows the structure of the medication reminder manager installed in the medication server. Managers/medical staff can remotely access the server to check the patient's medication status and manage the medication reminder.

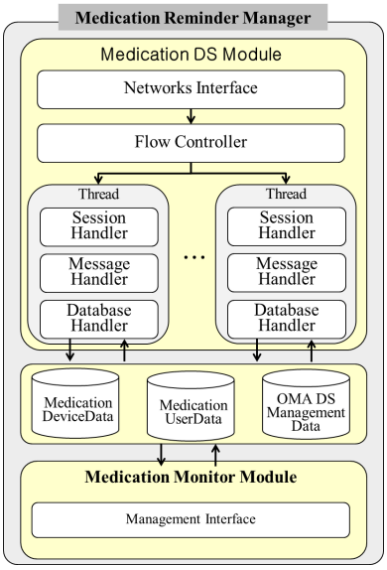

Figure 6. Structure of a Medication Reminder Manager

- Network interface: It represents the TCP/IP communication hardware.
- Flow controller: It monitors the medication reminder manager and creates an independent thread for every new connection with the medication reminder agent.
- Session handler: It opens/closes a TCP session between the medication reminder manager and the medication reminder agent. A session handler exists for every medication reminder agent.
- Message handler: It analyzes the OMA DS-based messages sent by the medication reminder agent in order to extract information on the patient's medication status and hardware errors. It also builds OMA DS-based messages that are sent to the medication reminder agent when the manager/medical staff wants to send new medication schedules and/or update the device configuration settings.
- Database handler: It reads/writes the appropriate information from/to the medication server database. Some examples of the information are the patient's medication status/schedule and the configuration settings of the medication reminder.
- Medication monitor: It enables the managers and medical staff to monitor the medication status of a patient and provide new medication schedules and OMA DS-based management commands.

The data synchronization protocol between the medication reminder manager and the medication reminder agent developed in this study supports the OMA DS standards. Figure 7 illustrates OMA DS-based message flow for the protocol.

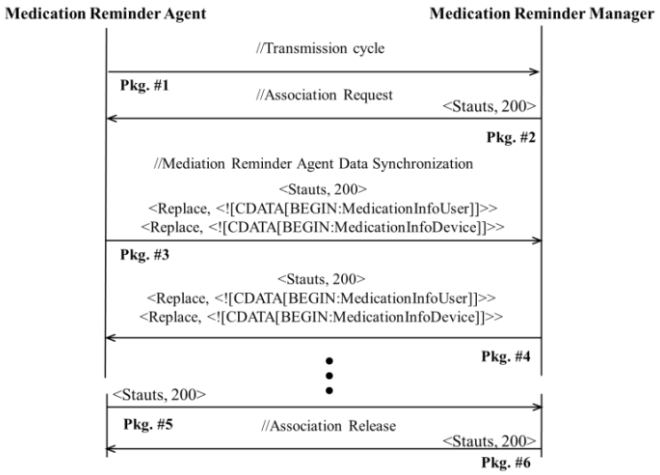

Figure 7. OMA DS-based Message Flow for the Medication Reminder Synchronization System

According to the OMA DS standard protocol, six types of packages are used in one session. Package #1 and Package #2 are used to open a session, whereas Package #5 and Package #6 are used to close it. Package #3 and Package #4 are used for data synchronization operations between the medication reminder agent and the medication reminder manager. Package #3 and Package #4 can be transmitted multiple times. In this study, Package #3 and Package #4 are redefined and extended to contain data such as MedicationInfoUser and MedicationInfoDevice for the proposed system. The OMA DS standard protocol also differs from the proposed system in that the former uses synchronization commands such as Add, Delete, and REPLACE, whereas the latter uses only the REPLACE command. This is because most of the patient's medication data and device configuration data should not be modified.

- Package #1: A medication agent initiates a session by sending its encrypted ID and password to the medication reminder manager. The agent may send an ALERT command in order to transmit the most recent data synchronization time to the manager.
- Package #2: The medication reminder manager sends the following to the medication reminder agent: the authentication result, the response ("STATUS") of the ALERT command, and the sync mode (i.e., slow sync or two-way sync). These will be used during the session.
- Package #3: Using the REPLACE command, the medication reminder agent sends the data items to be synchronized according to the selected sync mode, to the manager.
- Package #4: The database handler of the medication manager performs a data synchronization operation using the data received by the manager from the agent. Then, the manager builds an OMA DS-based message, which contains the synchronization data items and the response ("STATUS") of the data

synchronization operation, and sends the message to the agent using the REPLACE command. In this study, among the various DS commands of the OMA DS protocol, only the REPLACE command is used for synchronization.

- Package #5: When the medication agent does not have any more data items to be synchronized, it sends Package #5 to indicate that it wants to close the session.
- Package #6: By sending Package #6, the manager agrees to close the session.

5. Implementation of the Medication Reminder Synchronization System

The display screen of the proposed medication reminder system is shown in Figure 8. Figure 8(a) shows the medication schedule for this patient (9:00 AM, 1:00 PM, 06:30 PM, and 10:30 PM). As shown in Figure 8(b), the medical staff may change the medication schedule via the medication server to 9:00 AM, 12:30 PM, 07:00 PM, and 11:00 PM. Subsequently, the medication reminder manager at the server is invoked to perform data synchronization with the medication reminder agent associated with it. Figure 8(c) shows the result of the data synchronization operation.

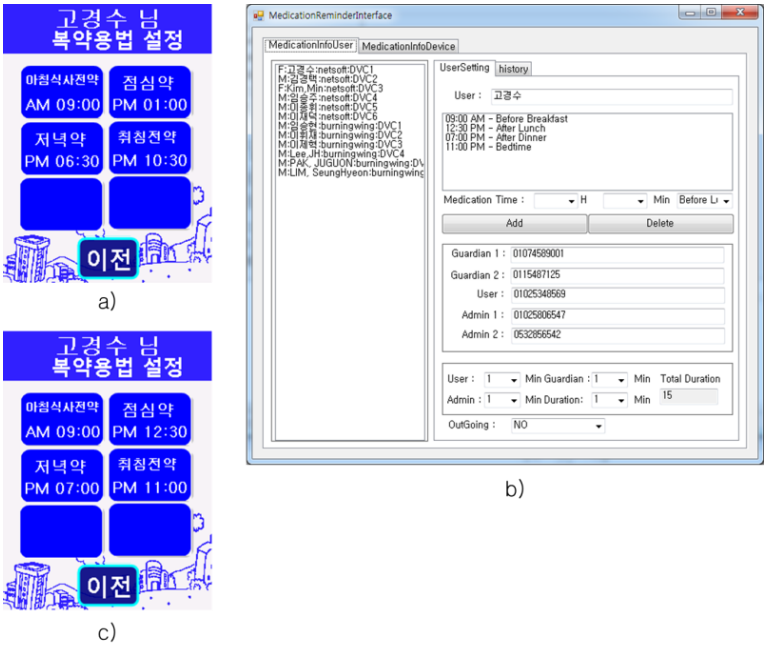

Figure 8. Display Screen of the Medication Reminder System

Figure 9 shows the sizes of the messages transmitted with the increase in MedicationInfoUser data. The medication reminder hardware used in this study supports up to six patients simultaneously. A two-way synchronization mode is used to plot the graph.

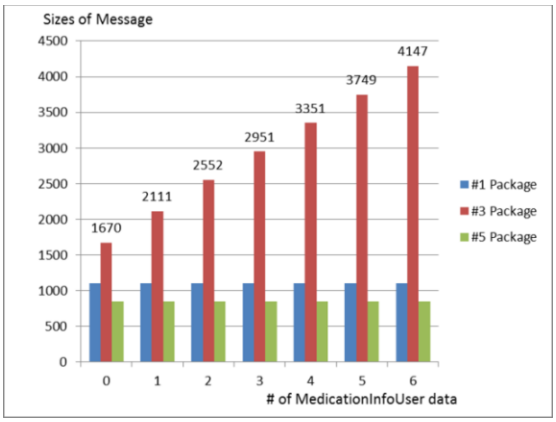

Figure 9. Sizes of Messages Transmitted

6. Conclusion and Future Works

In this paper, we proposed a medication reminder synchronization system that provides a patient with medications as prescribed by medical staff. In addition, medical staff can remotely send messages to the system in order to change the medication schedules or device configuration settings embedded in the medication reminder. The system supports the OMA DS protocol, which was originally proposed as a DS standard protocol that synchronizes data between mobile devices and a central server. In this study, the OMA DS protocol was redefined and extended to transmit the patient's medication status data and the device configuration data.

The medication server was easily constructed owing to the availability of an OMA DS server based on the Funambol server [13], constructed for synchronizing mobile terminals in a previous study [14]. In other words, the addition of an interface between the medication reminder manager and the server was adequate for constructing the medication monitoring server.

In the future, various communication-encoding methods will be studied to identify the most efficient encoding method for the medication reminder synchronization system. In addition, an efficient message transmission mechanism or system structure will be studied to address cases involving a large number of medication reminders.

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