A Prototype Implementation of U-pillbox System

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Abstract—Healthcare has become one of the hot issues in 21st century, not only in computer science and information technology, but also in sociology, medical science and public services management. To provide convenient and efficient healthcare service, u-healthcare (ubiquitous healthcare) systems, which reshape the traditional healthcare systems and enhance e-healthcare (electronic healthcare) systems with awareness of a patient's situation on the basis of advanced network and sensor technology, are proposed recently and will be the next generation of healthcare products. The empathetic u-pillbox system is a heuristic example of u-healthcare systems that emphasizes humanistic healthcare service provision to the elderly. This paper is based on the contours of u-pillbox system, proposed a prototype to inherit its theory, demonstrated a software implementation to realize this idea, and addressed that how the prototype can be extended for potential widely applications such as further healthcare services to elderly users, their family members or other concerned parties.

Keywords—u-pillbox system; u-healthcare; healthcare service oriented prototype

I. INTRODUCTION

Healthcare has become one of the important aspects of 21st century life. It is a hot issue not only in computer science and information technology, but also in medical science, public services management and sociology. In 2010, Economic Cooperation and Development (OECD) published a report of expenditure figures on health in different countries. It said, in the United States, 17.6% of GDP was spent on health, followed by the Netherlands, 12%; the figure in Japan is 9.5% [1]. Lack of medical personnel and dispersion of healthcare data is the reasons of this high expenditure. Among these figures, healthcare expenditure directed at the elderly population makes a big contribution due to the increasingly graying population, Adult offspring lack of time to take after their parents, and high incidence of diseases such cancer, obesity and diabetes due to environment and life style changing are the reasons of this high expenditure. Moreover, these problems will not been solved or even remitted as social developing. The demand for healthcare services, especially the services for elderly, will continue to grow.

A u-healthcare (ubiquitous healthcare) system, which inherited the concept of ubiquitous technology, overcoming the deficiencies of e-healthcare system, which is the first trial of healthcare practice using electronic processes and communication [2], by gathering continuous patients' health situations and the environment that patients exploded to, can meet the requirements of today's healthcare and will be the next generation of healthcare service provision products. U-pillbox system, which described in this paper, is based on the concept of u-healthcare system, focuses on providing medication regimen service which is the basis therapy to the elderly.

There are some medication provision products in the healthcare service market. An electronic pillbox device named uBox-uPhone [3], designed by a MIT research team, can provide the reminder and record service of taking medicine by flashlights and beeps, and sending messages to the caregivers when the box is empty. My Electronic Pillbox [4] provides reminder service by flashlights, beeps, phone calls, text messages and emails. Vitality GlowCaps [5], connected to Internet through AT&T, uploads the medicine taking information to the remote database directly. MedFolio Pillbox [6], empowered with a patent of recognizing pills, storing the brief description and samples of pills in the shell to guide users taking medicine in the right way, is the outstanding products in current medication provision products. Briefly speaking, all of these products can meet the basic requirements of medication taking service by using timely reminder and prevent double-dosing, but have the shortcomings which could cause the break in the regime, such like not actually taking the medicine after picking them out of the box. U-pillbox system is a trail to meet such complicated requirements and overcome the shortcomings of current products in the designed basis of environment awareness and human intention.

In this paper, Section II will describe the prototype of u-pillbox system and show how it works to provide services to the elderly. Section III will explain the prototype implementation and show an empathetic healthcare service scenario in a u-pillbox system environment. Finally, the conclusion is drawn in Section IV.

II. PROTOTYPE OF U-PILLBOX SYSTEM

A. The Contours of U-pillbox System

The prototype described in this paper is based on the contours of the u-pillbox system which proposed in the earlier submitted paper [7]. It is a combination of a Cyber-pillbox system and u-pillbox device working in tandem to provide efficient and high quality care, aimed to overcome the shortcomings of existing systems in ensuring adherence to a medication regime and to bring all parties involved in healthcare of elderly into a closer relationship.

The functions of the u-pillbox system need to be implemented in three steps: (1) data acquisition, (2) data analysis & model enhancement, and (3) active and empathetic service. U-pillbox device collects the environment data, medication taking diary data and human physiological condition data, passes them to the analysis step. Then system provides personalized service through u-pillbox device and other devices or sensors, based on the result of data analysis that combines data from u-pillbox device, from other sensors and from Cloud Data Center. While delivering services, u-pillbox device collects human reaction data so that the whole process form a data circulation that passes data and its analysis output from one step to next. Furthermore, the usage tracks, physical signs and environment or context data will help build the human model clearer and clearer, the healthcare service will become more and more empathetic and personalized.

B. Prototype of U-pillbox System Framework

As showed in Fig. 1, the prototype has three parts to implement healthcare service provision, data acquisition, context awareness and service provision, which map to the three steps in the contours. Data acquisition section manages the device and sensors to collect data from patients. Context awareness, mapped to the data analysis & model enhancement step, analysis the data which collected from data acquisition section and give the result to service provision section to guide sensors and devices reacting to the patients.

C. Data Acquistion

Understanding human and being aware of the environment is the key to build this empathetic healthcare system. The data collected from this section are mainly from three parts: u-pillbox device, human physical signs sensing and environment sensing.

1) U-pillbox device

U-pillbox device is the main sensor unit of collecting data

from users and environment in the u-pillbox system. It has the following functions:

a) Function of storing 7 days pills.

b) Function of medication taking reminder:

• Reminding the user to take medication on time by flashlights, music or voice prompt according to the preferences and guidance that is provided by doctors, caregivers, family members, or from further data analysis results.

• If the user takes medicine on time, record the time and pills information.

• If the user don't take medicine on time and ignores the reminder, record the ignoring information and reminding the user after 2 seconds.

• If the user ignores the reminder 5 times, stop further reminding and send the messages to his or her doctors, caregivers and family members.

c) Function of recording human physiological condition and enviroment information.

d) Function of voice prompt in the whole system, "speak out" messages on behalf of other "dumb" sensors.

e) Function of providing complicated healthcare service by working with other sensors.

The u-pillbox device should have all the functions of existing pillbox products and overcome the shortcomings of them, which means it has the functions of better timely reminder and other extended healthcare services. Therefore, the u-pillbox device needs to collect more data not only about medication taking. Small admeasuring apparatuses for measuring physical signs, such as thermometer, blood glucose meter, pulse ox meter, etc., are commonly used in healthcare of the elderly and can be embedded into the u-pillbox device.
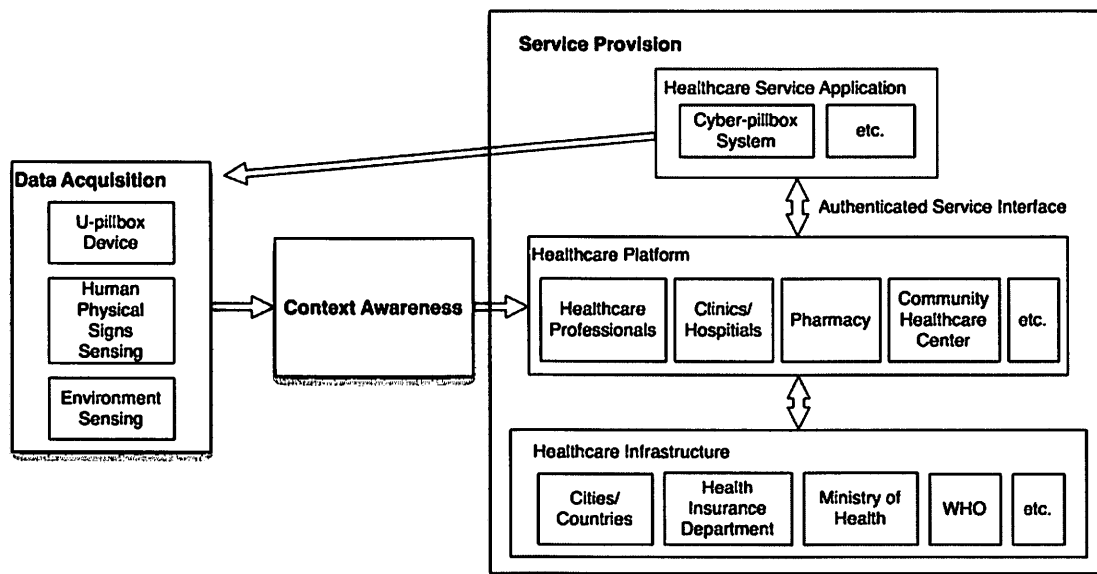

Fig. 1. Prototype architecture of the u-pillbox system

Collecting the information of environment or context persons are exposed to, such as temperature, humidity, illumination, air pressure and so on, is useful to find more impact factors for treatment and health because they can affect patients' physical and mental health. Due to the size limitation of u-pillbox device, it can't be embedded in many sensors. But it can have an interface so that other devices or sensors can share data with it and transmit data to the healthcare database for further analysis.

2) Human physical signs sensing and environment sensing

The physical signs such as blood pressure and heartbeat, which the data need to touch the body for a while to collect, are the crucial indexes of patients' health situations. There are some research topics about creating wearable sensors and sensing fiber for healthcare to make the measurement simple and convenient [8]. All the sensors and devices around the body can form a body sensor network (BSN) through network, which means using related technologies to develop pervasive sensing, enable ubiquitous, pervasive and remote health monitoring of physical, physiological, and biochemical parameters [9].

The u-pillbox device has the function of collecting environment or context information that the patients are exposed to, but it is not enough. It needs to understand the users through the activity awareness, location service and so on, to provide empathetic and active healthcare service. Moreover, from [10], sensors deployed to monitor the household appliances, beds, toilet/showers and so on can assist to get the information of person's current location and activity. These kinds of information can be used to generate person's activity pattern so as to detect abnormal activity.

Therefore, combining all the technology together and working together with other equipment, the u-pillbox can have much more functions than simply giving medicine reminders.

D. Context Awareness

Ubiquitous and pervasive sensing in the data acquisition section can collect huge amount of data. How to analysis them and find knowledge becomes another challenge. It is difficult to process such large quantities of data using traditional data processing applications within tolerable elapsed time, due to limitations in storage, computing and visualization. Therefore, this problem needs to be solved by large scale distributed computing. As a development of parallel computing, distributed computing and grid computing, cloud computing could be a solution to complete this task. The methods which proposed in the contours of the u-pillbox system is an effective processing unit to analysis the huge amount of data and get the results to guide service provision, especially the human model, which generated after the data analysis, will become more and more clear while the whole processing, and become a virtual "mirror" to the users which is also a cyber individual (Cyber-I) [11] model of the users.

E. Service Provision Framework

As Fig. 1 shows, service provision framework that is deployed in the prototype of the u-pillbox system has three layers to implement healthcare service provision: healthcare infrastructure, healthcare platform and healthcare service application.

1) Healthcare infrastructure

The healthcare system infrastructure is the hardware and information foundation for providing health services to the upper layers. The armamentarium and fundamental equipment from cities, countries, health insurance department, ministry of health, WHO, etc. can connect together and open a user interface to the outside through a healthcare infrastructure master which is a global organization gathering all the information together. If a service from upper layer needs to know the detail information about a piece of equipment, it can search on the healthcare infrastructure master first and then get the address to access the equipment directly. The connected organization in this layer also provides the information about rules, certifications, healthcare related criterions, laws and so on. They are somehow hard criteria and changed a litter in recent years. When the upper layer finds that it is not suitable for the current situation, it can submit a changing advice to the master and let the correlative organization to consider.

2) Healthcare platform

All the participants in healthcare platform layer provide various healthcare services. In the prototype of the u-pillbox system, a service building architecture named Healthcare Service-oriented Architecture (HSOA) is used to organize these services and make full use of them in a convenient way. It is inspired by one of the hot architecture theory that used in designing enterprise software currently, named Service-oriented Architecture (SOA). Healthcare service provision has the similarity with enterprise applications, while it has its own characteristics. Therefore, HSOA is the derivation of SOA, which means it solved the problems of sharing service among different sources and adapted the specialties of healthcare service. The architecture of HSOA is showed in Fig. 2, and the section in gray color is the specialties of HSOA.
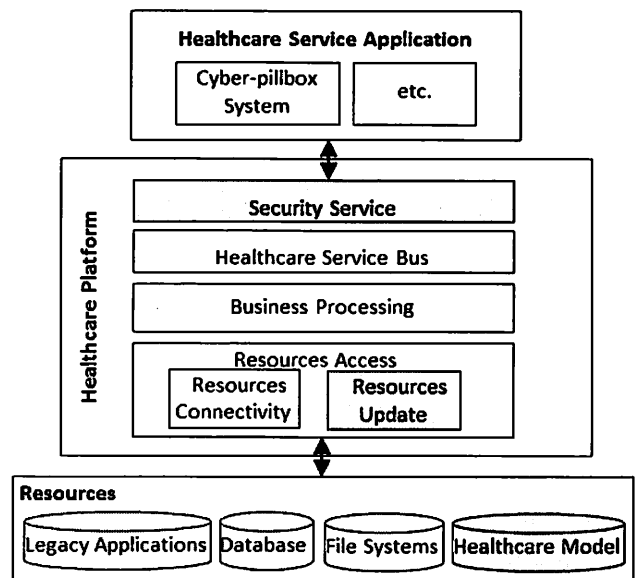

Fig. 2. Architecture of HSOA

The principles of SOA are standardized packaging, reuse and loosely coupled [12]. As the derivation of SOA, HSOA also needs to keep these principles in the design and implementation to realize healthcare service provision.

- Standardized packaging

Traditional software architecture has not completely solved the problem of interoperation of different applications due to the encapsulation technology and the dependent of platform. Traditional middleware technology can realize the interoperation of different software by realizing the access operation. It uses the standard Application Program Interface (API) to complete the interoperation between different systems. However it depends on the specific access protocols such like Java Remote Method Invocation (Java RMI). While SOA uses Simple Object Access Protocol (SOAP), which is a standard protocol, support Internet and is independent of operating system, to implement the connecting and interoperation. Moreover, the service package uses XML protocol, which means that it has the ability of self-analysis and self-defining and is easy to control and reuse.

- Reuse

Reuse means that the same thing can be repeated used without amend or change little. Subroutine, component such as DLL component in Microsoft operating system, and enterprise object component, or called distributed component such as .NET and EJB are the exist technology of reuse. But all of them are highly dependent on their computing environment and can't be assemble to reuse directly. Service as the core such like Web Service is the important feature of modern SOA. It implements high level of reuse, decoupling and interoperation through service, because service implements reuse through standard packaging, and assembling, arranging and reorganizing between service components. Moreover, this kind of reuse can be used in different enterprises, in global, and in dynamically configuration. That is the goal of healthcare service provision, reuse globally in a dynamic way.

- Loosely coupled

Decoupling process in SOA is also developed to a final state. Traditional software coupled the three core parts, network connection, data conversion and business logic, to a whole system, forming "monolithic software". That means affect one part will affect the whole, software would be difficult to adapt to change. Distributed object technology separates the connection and logic, and messaging middleware process connection logic in an asynchronous way, so that to increase flexibility. Message broker and some distributed object middleware also separate the process of data conversion from the whole system. While the SOA implements the decoupling of business logic, network connection and data conversion through packaging service.

Standardized packaging, reuse and loosely coupled, these three principles are the basis that HSOA must be kept. Moreover, as architecture of providing healthcare service, it has its own specialties, so that there are some principles that HSOA must be kept to implement healthcare service provision on the basis of SOA technology. These special principles are

dynamic service, high security and cumulative experience resource.

- Dynamic service

Traditional software architecture builds a system to provide service in a static way, which means that each users or users in the same group have the same process. They are designed by the providers and don't be changed after implementation. If one process wants to change, it is need to re-implement. Healthcare service is an active service that based on the situation of patients. The service providers need to change it based on the patients' body and context situation. Moreover, the reaction of patients is the resource for service providers to accumulate experience. Therefore, healthcare service is a both sides service for the service receivers and service providers.

- High security

Healthcare service provision includes lots of patients' private information. Keep the users' personal information out of snooping is crucial. SOA can provide the service to anyone who wants it and the authentication relies on the application that uses the service. It is not enough for the healthcare service provision systems. Each service provides in HSOA needs to check the users' authentication when they wants to access the personal information.

- Cumulative experience resource

Service provide in healthcare system are highly relied on the providers, which means service in high quality needs a provider in rich related experience. The resource stored in healthcare service provision system are not limited to database. Files or even videos will be used to provide a "Q&A" service as a resource. These resources are not built and filled at the beginning of deploy the whole system. They are the cumulative resources that accumulate in the process of providing service.
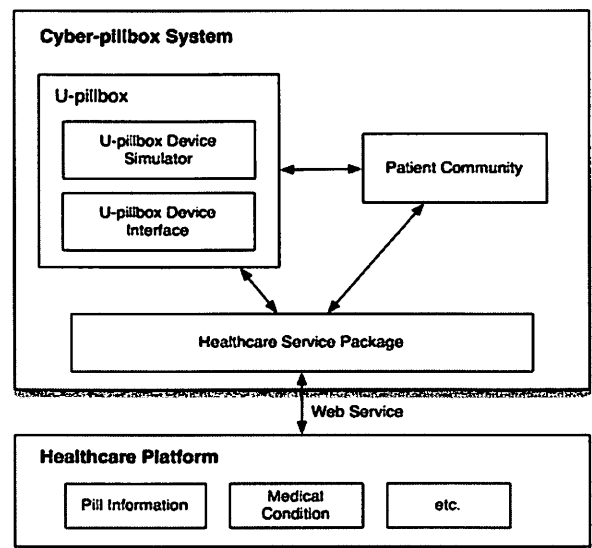
3) Healthcare service application

Fig. 3. Cyber-pillbox system architecture

Healthcare service applications are the real entity to provide service to the users. In the u-pillbox system, Cyber-pillbox system is the main platform to provide healthcare service to the patients and their relatives. Analogous to entities in the real world, the cyber-pillbox is the virtual mirror of the u-pillbox device with an ancillary information network in the computing virtual world. It is a reflection of the physical world and facilitates empathetic services after computer processing. It is used to manage the data that are collected by u-pillbox device, provide those data to a parallel mining process with the contributed network data.

As Fig. 3 shows, Cyber-pillbox system has three main sections: u-pillbox, patient community and healthcare service package.

a) U-pillbox
- U-pillbox device simulator

The function in this subsection are: (1) store the pills information and taking guidance, (2) record the user's medicine taking diary, (3) record the user's body signs and environment information, and (4) show u-pillbox filling content in each pill cabin in real-time.

- U-pillbox device interface

The function in this subsection are: (1) show the information including medicine taking diary, body signs and environment information to the users, and (2) medicine taking agenda changes and update this information to the u-pillbox device.

b) Patient community:
form a social groups that let patients, doctors, caregivers, recovered patients and so on share state-of-affaris information, testinmonials, advice and encouragement to speedy recovery.

c) Healthcare service package:
Cyber-pillbox can access to the healthcare platform and includes the service which provided by the paticipents in the healthcare platform to extend its capability, such as pill information which are provided by pharmacy, medical condition which are provided by healthcare professionals and so on.

III. IMPLEMENTATION OF THE PROTOTYPE

The implementation of the prototype that proposed in this paper contains two parts: Cyber-pillbox system and u-pillbox system simulator.

A. Cyber-pillbox System

Cyber-pillbox simulates the physical u-pillbox device in the cyber world in the healthcare service application layer, running on top of the healthcare platform, which further runs on top of the open healthcare infrastructure. The cyber-pillbox runs in the healthcare server and has a browser interface to users, which can be accessed from a terminal like computer, PDA, or even smart phone, from which the elderly or a patient can interact with the system.

Its basic functions included are as described in the section of healthcare service application above. Moreover, it has the

functions that doctor and pharmacist-shared interface with which they can edit a patient's medicine taking agenda under authentication and send the change notification to the users; and medicine taking agenda updating to the u-pillbox device when having changes or after the u-pillbox device refilling.

The system is implemented in Java, and implemented in three layers. Where, in the persistence layer, is completed the transactions with the database, which uses a Hibernate persistence framework to access and maintain a MySQL database. The Business layer, which uses a Spring framework as the inversion of the control container, is the core function congregator that completes all the logical and computing processes. It uses Data Access Objects (DAO) classes, which are the objects of each table from the database, to obtain and transmit data with the persistence layer. Users interact with the system through an interface, which is implemented in the UI layer. This system uses an Apache Struts web application framework to manage and interact through a service locator with the business layer. Spring + Struts + Hibernate (SSH) is a typical combined framework to develop a Java EE web application because of its strong stability, fast development and easy maintenance.

B. U-pillbox System Simulator

A u-pillbox system simulator is used to verify the idea of empathetic u-pillbox system before concrete detailed design and future manufacture.
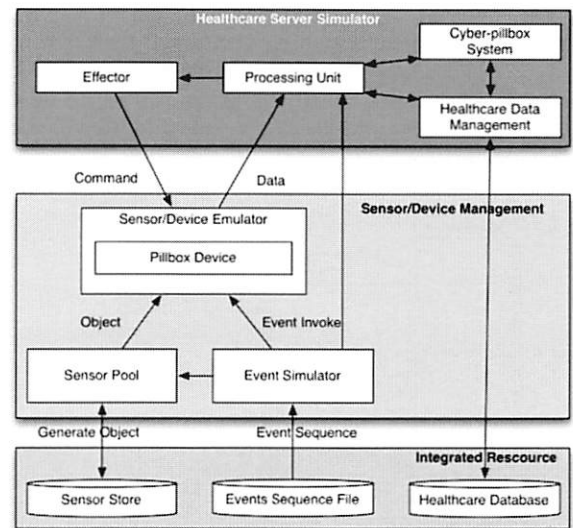

Fig. 4. U-pillbox system simulator

As Fig. 4 shows, the simulator system mainly includes three layers of the home server simulator, the sensor/device management, and the integrated database. The sensor objects specified in the event sequence from the events sequence file can be generated from the sensor store and are collected in the sensor pool. When any event is invoked, its associated sensors are triggered to start their emulators and generate simulation data. The processing unit in the healthcare server simulator takes three categories of inputs from the sensor/device emulator (namely dynamic stream data from the physical

world), the event simulator (namely a scenario setting), and the healthcare database (namely empathetic healthcare associated data from the context awareness analysis, from the healthcare service platform, etc.) The output of the processing unit is the effector on the sensors, devices, and environment for providing services to the users.

This system is hard to verify its feasibility due to the uncertainty of physical devices and lack of real healthcare data. Designing scenarios to go through is a good idea. An example scenario is as follows.

Alice is a 70 years old lady, often forgets what needs to do after been interrupted, has a chronic disease and need to take several kinds of medicine. One afternoon, u-pillbox system recognizes that she had lunch at 12 o'clock on that day. U-pillbox reminds her to take medicine 30 minutes after lunch according to doctor's advice. She hears the reminding voice from u-pillbox, takes the pills out of the box, leaves them on the table (all the pills store in u-pillbox used a small special plastic zip bag) in the zip bag and goes to kitchen to get water. After getting the water bottle, she finds that the smoke exhaust fan is on. She turns it off, finds a class of water in hand, thinks a while, drinks the water and goes back to bedroom sitting on a sling chair. The system finds a zip bag with pills on the table and recognizes Alice is in the bedroom through tracking system [13]. She hasn't taken her pills. U-pillbox sends a second reminder, makes sure that she takes pills and leaves the zip bag in the recover box; then records the medicine taking diary. Fig. 5 shows how the simulation system works under this scenario. When an activity happened in the scenario, event simulator will generate the event. Sensor/device simulator will generate data based on the event and sends them to healthcare server. After process and check the rule file, it will response and provide the healthcare services to the users.
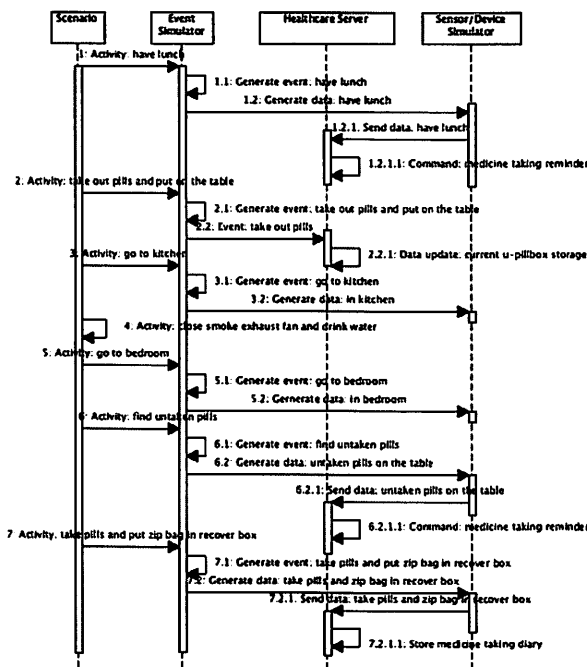

Fig. 5. U-pillbox system simulator running sequence chart in scenario case

IV. CONCLUSIONS

Provision of empathetic healthcare services to the elderly is the key of the u-pillbox system. In this paper, a prototype of the u-pillbox system is proposed to implement the idea of empathetic u-pillbox system. 3-layer architecture of the prototype was described, they are: data acquisition, context awareness and service provision. In the service provision layer, healthcare service-oriented architecture is proposed to organize the resource and service in high quality and efficiency. Finally, the implementation of this prototype was showed and an example scenario concerning the problem of forgetfulness in the elderly was demonstrated to verify the system.

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