ICIC Express Letters
Part B: Applications
Volume **8**, Number **4**, April **2017**

ICIC International ©2017 ISSN 2185-2766
pp. 719–726

A UBIQUITOUS HEALTHCARE SYSTEM ENHANCED WITH INTERNET OF THINGS AND LOCATION BASED SERVICE

Shih-Jung Wu[1], Shih-Hao Chang[2], Rui-Dong Chiang[2], Han-Chi Chang[2] and Wei-Ting Chang[2,*]

[1]Department of Innovative Information and Technology
[2]Department of Computer Science and Information Engineering
Tamkang University
No. 151, Yingzhuan Rd., Tamsui Dist., New Taipei City 25137, Taiwan
[*]Corresponding author: tt90089@gmail.com

Received November 2016; accepted February 2017

Abstract. *Currently, communication between medical devices and healthcare systems is restricted to access of the server database: data can only be uploaded to the healthcare system, while requests sent from the system cannot be directly met, limiting the usefulness of healthcare system applications. We design and implement a prototype of a Ubiquitous Healthcare System (UHS) for chronic patients and their family caregivers to increase patients' self-care quality by the Internet of Things (IoT) technology. The UHS uses the IoT and Location Based Service (LBS) to provide functions including abnormality monitoring, healthcare services, and emergency medical contact. The prototype of the UHS was constructed by making use of existing mobile health devices, e.g., General Packet Radio Service blood glucose monitor (GPRS BGM), as well as integration with cloud platforms and mobile application. The UHS used in a GPRS environment enables communication between patients' mobile health devices (e.g., GPRS BGM) and family caregivers' mobile devices (e.g., smartphones application). The UHS can present patient's current information to their caregiver. This can avoid the caregivers regard outdated information as current information and enhance patients' self-care quality.*
Keywords: Ubiquitous computing, Ubiquitous Healthcare System, Internet of Things, Location Based Service

1. Introduction.

Aging societies and onset of chronic disease at younger ages are getting important social issues [1]. Chronic disease requires long-term healthcare, and demands that patients control their physiological parameters within a normal range through diet control, exercise, and medication. Loss of control not only results in chronic complications, but can also lead to immediate danger. Therefore, the world is facing a critical issue: to lower or defer incidence rates of chronic disease and to solve issues related to long-term care. Numerous studies have indicated that behavior change is the most effective precaution and self-care method for chronic patients [2,3]. Although patient behavior changes seem to be very personal, family caregivers' acknowledgement of patients' positive behavior changes could effectively enhance the quality of patient self-care.

In this paper, we take diabetes as an example to implement the UHS. Research has suggested that long-term blood glucose control is an effective method to reduce and defer chronic complications of diabetes [4,5]. Thus, most diabetic patients monitor their blood glucose concentrations by themselves using medical devices. With development of mobile applications being highly competitive, many researchers adopt existing Internet communication technologies, such as Bluetooth and wireless local area networks (WLAN), to propose healthcare systems [6,7]. These systems improve convenience and lower recording errors. However, since existing Internet communication technologies are still restricted by distance and location, most existing healthcare monitoring systems only provide one-way transmission of simple measurement data that is uploaded and recorded for follow-up visits and lab analysis [8].

For instance, Waluyo et al. proposed an mHealth system consisting of a PC and a PDA that could send messages [9]. As these applications are primarily used to transmit messages, it is not possible to track whether transmitted messages have been read by users, or other subsequent situations. Constantinescu et al. proposed a SparkMed framework using the wireless technologies and let user access multimedia data in a hospital's information system by his/her handheld devices [10]. However, those systems cannot receive real time information from the device, and direct communications between patients and family caregivers by mobile device are not yet possible [11,12].

In our last paper, we used the IoT technology to enhance the interactivity of healthcare system, and increase patients' self-care quality [13,14]. However, the acute complications of chronic disease maybe lead to immediate danger to chronic patients at any time. Therefore, in this paper, we combine with the IoT technology and LBS to design a UHS, to avoid the dangerous situations. Different from traditional healthcare system, when the patient is in an abnormal state, the UHS can show patient's current information to their caregiver, such as patient's current positioning information, and status. This avoids the caregivers regard outdated information as current information. In an emergency scenario, outdated information can sometimes be dangerous. For example, traditional healthcare systems with GPS regularly update a patient's position information to a database. In an emergency scenario, information on the server may be old and thus may delay rescue time.

Different from traditional healthcare system which can only perform message communication, this study proposes use of IoT technology to directly access and control a UHS mobile device and get real time information on patients' health conditions or location information. Moreover, the system combines with IoT technology and LBS to subsequent remote control operations. For example, we can use IoT technology to turn on GPS in order to update a patient's and/or their caregiver's current position. In an emergency, the communications medical devices can be turned on remotely to monitor a patient's position and subsequent status. The UHS consists of a GPRS BGM for patients, a cloud platform and a telecare Android/iOS app for caregivers. It uses these platforms to design and implement a ubiquitous healthcare system. Moreover, the UHS is an affordable healthcare system solution that makes usage of existing devices. With existing GPRS BGM and an Android/iOS smartphone, users simply have to pay a modest fee for 3G Internet to access this system.

2. Materials and Methods.

2.1. **UHS architecture.** As shown in Figure 1, the UHS consists of three platforms: GPRS BGM for patients, a cloud platform that integrates the main functions and a telecare Android/iOS app for caregivers. The UHS proposed by this study was designed and implemented using GPRS BGM equipment that complies with ISO 15197, the Health Insurance Portability and Accountability Act as well as 256-bit encryption. With a GPRS BGM for patients, the UHS collects patients' blood glucose data, and uploads it to a cloud platform via GPRS. Subsequently, the data is analyzed by the UHS and sent back to GPRS BGM for the patients and the telecare Android/iOS app for caregivers. When the caregivers receive the relevant care message, they can use the telecare app to send the care message to the patients. Moreover, in a scenario where a patient's health condition is critical, the UHS will automatically execute the LBS function to avoiding the risk of patients.

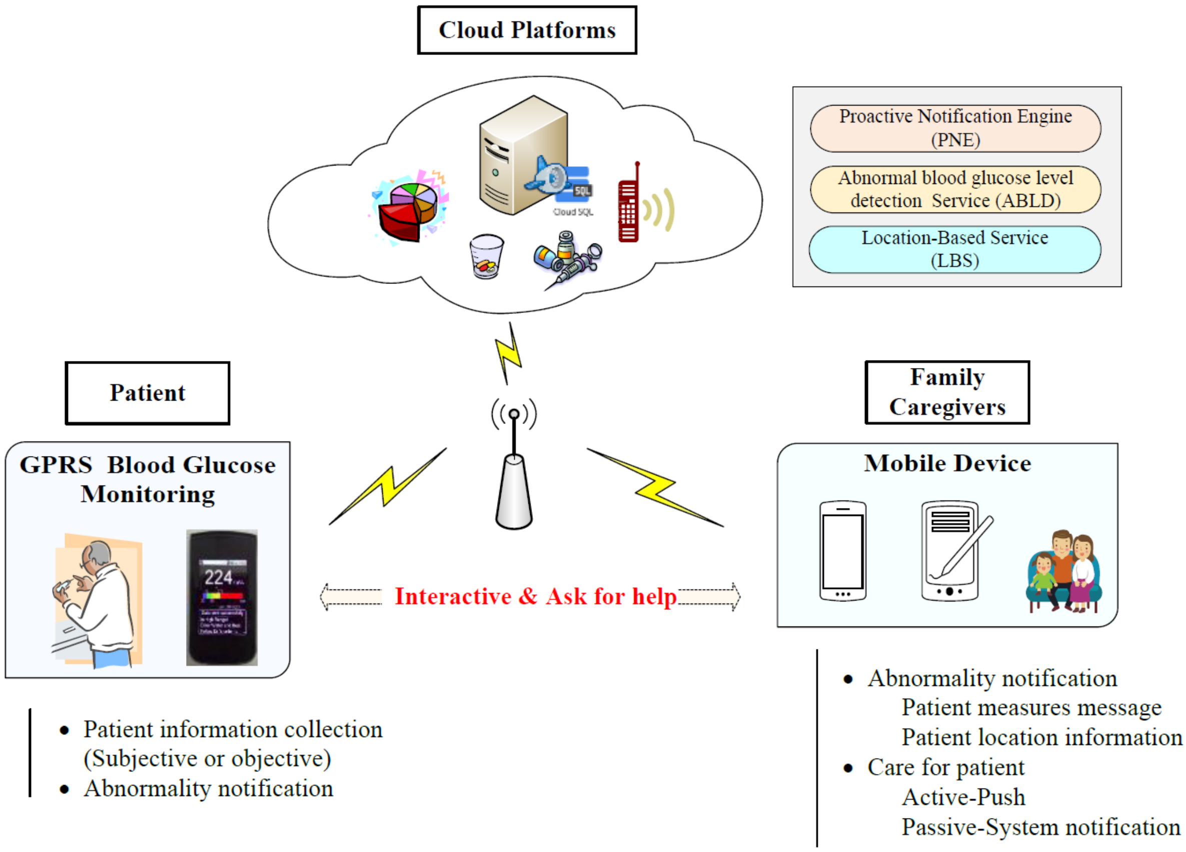


Figure 1. The UHS architecture

The cloud platform is the core of the UHS. It not only stores demographic data of patients, data and permissions of authorized family caregivers, but also includes three additional services: (i) Abnormal blood glucose level detection service (ABLD), (iii) Proactive Notification Engine (PNE), and (iii) Location based service (LBS).

2.2. **Abnormal blood glucose level detection service (ABLD).** The UHS uses a rule base system to provide ABLD service. Based on discussions with doctors and related references published by WHO [15,16], a number of rules and procedures for abnormal blood glucose detection as established. The ABLD divides the blood glucose abnormalities into four levels: Level 0 indicates a normal state; Level 1 indicates minor blood glucose abnormality that only needs observation; Level 2 indicates moderate abnormality that requires immediate hospitalization, but with no imminent danger present; Level 3 indicates imminent danger, such as severe abnormality with risk of coma, or unconsciousness. Depending on the different abnormal levels, the UHS will apply different follow-up action to avoiding the risk of patients.

2.3. **Proactive notification engine (PNE).** After an abnormality is detected, the UHS sends the analysis results to the patient and their caregiver by PNE. Moreover, in an emergency, the PNE will use the IoT technology to receive real time information fed back from mobile devices, and remotely turn on GPS components of a patient's mobile device, to monitor a patient's position and subsequent status.

2.4. **Location based service (LBS).** The UHS combines a Geographic Information System (GIS) with GPRS BGM and telecare Android app positioning. This gives the system the ability to look for the nearest medical organization, remotely switching on mobile devices to locate patients with PNE during emergencies, and transmitting emergency messages to the family caregiver nearest to the patient. The LBS has three positioning functions; GPS, AGPS and base station Cell ID. When the UHS cannot access a mobile device's GPS information, the UHS uses AGPS or neighboring base station Cell ID to get location information. If all three positioning functions are not available, the LBS will send this state to patient or caregiver, and wait until one of the positioning functions can get location information.

3. **The UHS Procedure.** Based on the abnormal level (Level 0 to Level 3) of ABLD, the UHS prioritizes the corresponding actions. As shown in Table 1, in Level 0 (Normal), the UHS will send the normal message to the GPRS BGM of patient. In Level 1 (Minor abnormality), the UHS will send telecare message to patient and caregiver and set the next measurement time automatically. In Level 2 (Moderate abnormality), the system will send telecare message to patient and caregiver and advise the patients to execute "Call Family Caregiver" to Call the Selected Family Caregiver, and enable the LBS function to Search for the Nearest Medical Organization. In Level 3 (Severe abnormality), in addition to Level 2 action, the system will execute "Call the Nearest Family Caregiver" automatically.

We use the Diabetic Ketoacidosis (DKA) as an example. KDA is one of the most common acute complications of diabetes. If not treated immediately, DKA is highly likely to result in death. This section presents a DKA case study. When the blood glucose value of a patient is equal to or greater than 300 mg/dl, the UHS determines that the patient is a Level 3 patient, who is undergoing a severe abnormality and is in immediate danger. Subsequently, PNE and LBS are activated to call for emergency treatment.

As shown in Figure 2, in the Unified Modeling Language (UML) sequence diagrams of Level 3, Step 1 involves the procedure of abnormality detection. A Level 3 patient may lose consciousness at any time, and therefore the UHS provides the "Call the Nearest Family Caregiver" function. Steps 2-5 involve the patient's use of the function to follow emergency treatment procedures. The UHS remotely turns on the patient's and the caregivers' AGPS or GPS service through PNE. Upon the authorization of the caregiver, the UHS then continues the required calculations regarding caregivers who are the nearest to the patient. The IDs of these family caregivers are transmitted to GPRS BGM equipment, which sends

Table 1. Patient conditions and critical levels in ABLD service

Level	Patient condition	Corresponding action
0	Normal	Send Normal Message to Patient
1	Minor abnormality	Send Telecare Message to patient and caregiver. To Be Observed (Reminder about Making Another Measurement after 2hrs).
2	Moderate abnormality (No immediate danger)	Send Telecare Message to patient and caregiver. Patients could execute "Call Family Caregiver" to Call the Selected Family Caregiver. Patients Could Enable LBS to Search for the Nearest Medical Organization.
3	Severe abnormality (Probably immediate danger)	Send Telecare Message to patient and caregiver. Patients Could Execute "Call Family Caregiver" to Call the Selected Family Caregiver. Patients Could Execute "Call the Nearest Family Caregiver". Executing "Call the Nearest Family Caregiver" automatically. Could Enable LBS to Search for the Nearest Medical Organization.

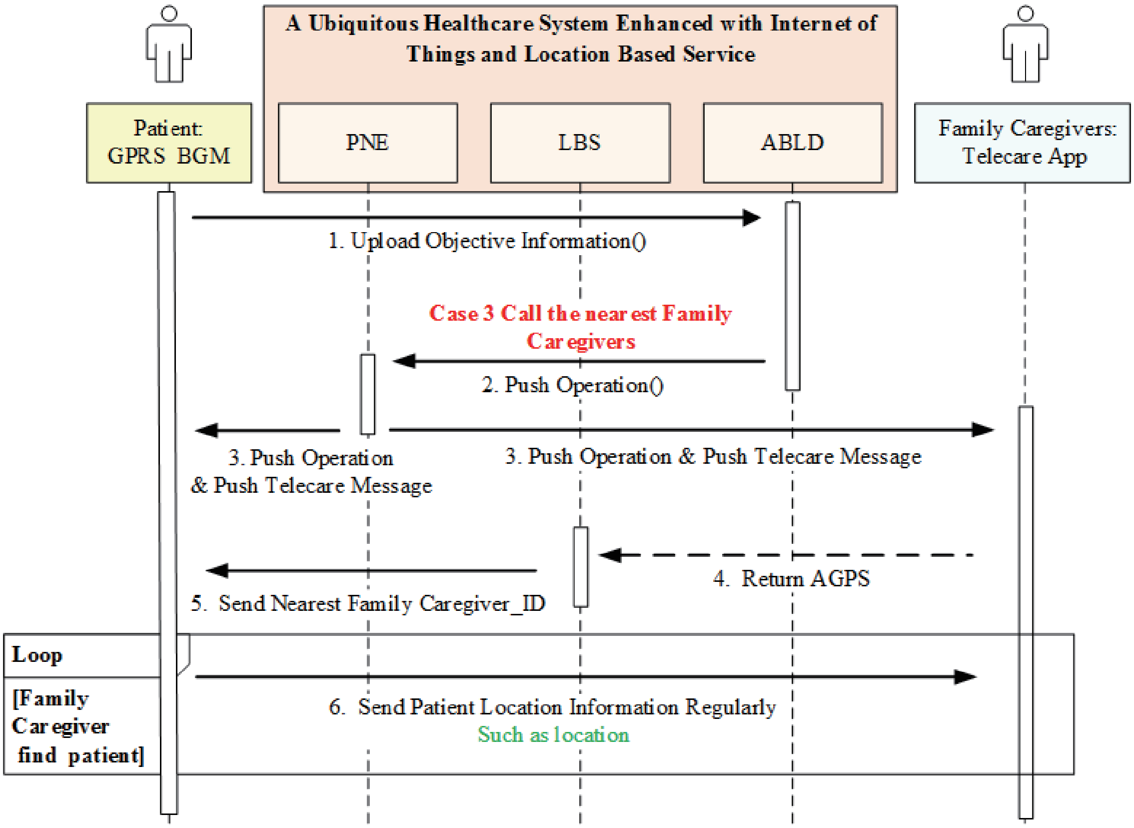


FIGURE 2. Level 3: Call the Nearest Family Caregiver UML sequence diagrams

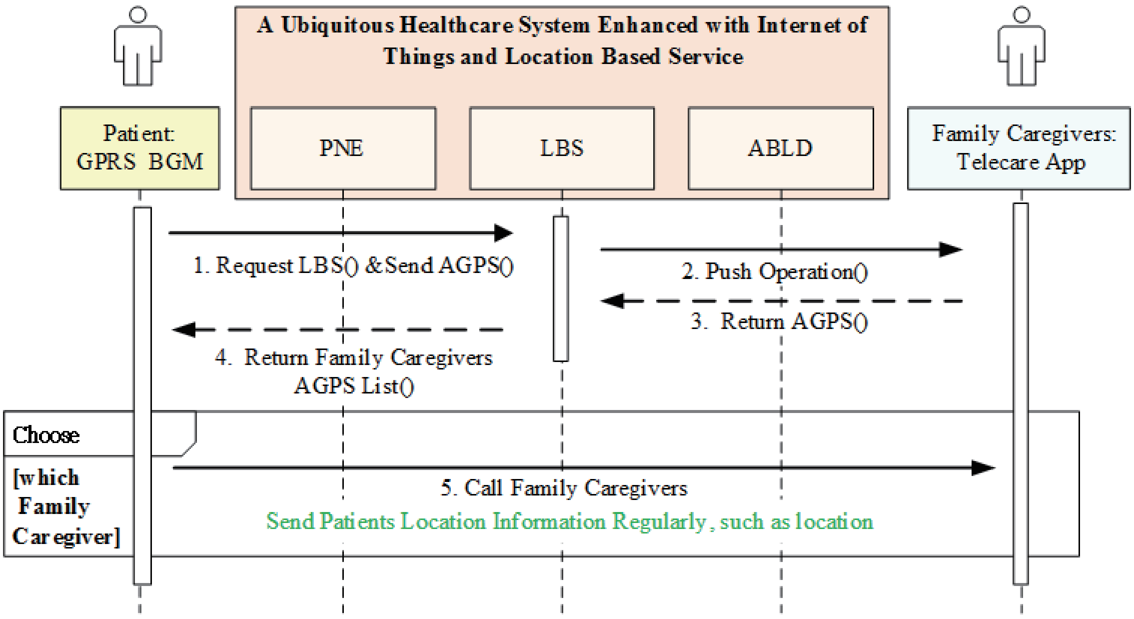


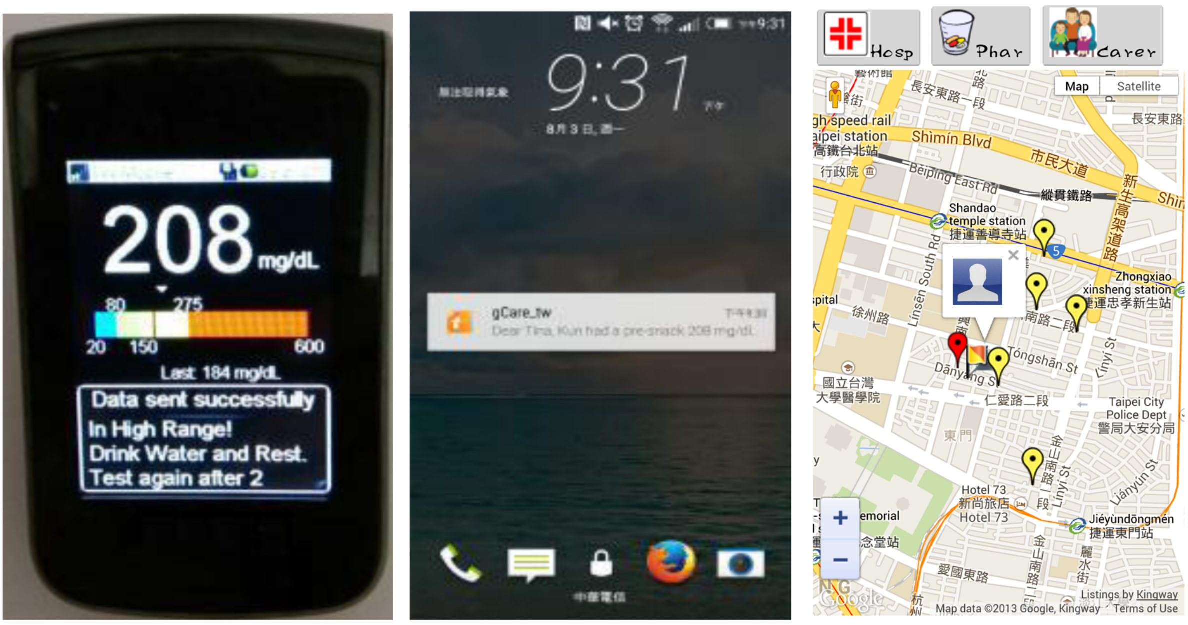
FIGURE 3. Patients' Call Family Caregiver UML sequence diagrams

the patient's location messages to the handheld devices of the nearest caregiver, until the caregiver arrives at the location of the patient or the patient is confirmed to be safe.

On the other hand, the patient also can select "Call Family Caregiver" function. As per Steps 1-5 shown in Figure 3, the UHS immediately sends this request and simultaneously sends the location of the patient to the LBS module of the cloud system. Then, the LBS module requests the telecare app to supply the locations of caregivers through PNE. Upon receiving the caregivers' authorization, the LBS module begins to calculate the required data regarding the caregiver groups that are the closest to the patient. The data is uploaded to the GPRS BGM equipment. With the data, the equipment marks the locations of responding caregivers on the map user interface. The UHS will call the caregiver that is chosen by the patient.

4. The UHS Implementation.

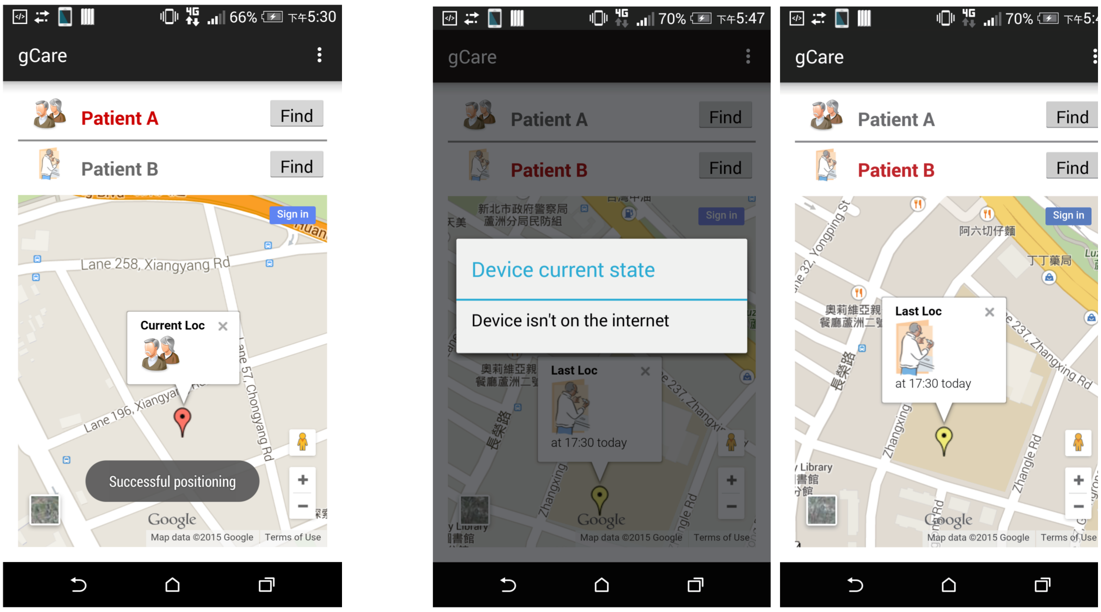
4.1. The abnormal notification function of PNE and LBS. As show in Figure 4(a), in this case, the patient had a blood glucose value of 208 mg/dl and was adjudged to Level 3. The patient will receive a reminder message from the GPRS BGM. Simultaneously, their family will also receive a message from smartphone (see Figure 4(b)). Moreover, as show in Figure 4(c), when a patient and accompanying family caregivers are located in an unfamiliar environment and emergency medical attention is required, they can turn on the LBS function to search for nearby medical organizations. The location of the patient is directed by UHS to find nearby medical organizations, and the sites that are found are marked in red. If the selected medical organizations are not familiar with the patient, the patient or accompanying caregivers can utilize the GPRS BGM equipment or the telecare app to download previous blood glucose records and medical history stored in the UHS from the cloud. The downloaded data serves as auxiliary data, and doctors can give a more precise diagnosis and ensure safety of the patient with this information.



(a) (b) (c)

FIGURE 4. The screen dump from the UHS platforms: (a) measurement reminder message on patient's GPRS BGM, (b) blood glucose abnormality message on family caregiver's smartphone, and (c) nearby medical organizations found by using LBS

4.2. The tracking function of LBS. As shown in Figure 5(a), when caregivers want to get the patient current information continually, they can use the LBS function form telecare app. The function will use PNE to real-time turn on the patient device GPS or AGPS and feed back the location information to caregiver, so that family caregiver can continue to track the movements of patients and their conditions. On the other hand, as shown in Figure 5(b), when patient' devices cannot locate or were not on the Internet,



(a) (b)

FIGURE 5. The screen dump from the UHS LBS functions: (a) caregiver can track the location of the patients continually, (b) when patient' medical devices cannot locate or were not on the Internet, UHS will show the message of this situation

UHS will show patient last positioning information and show the message of this situation. Avoid the family caregiver takes the old information as current information.

Different from any typical medical notification systems, UHS adopts IoT and LBS to let caregivers know the patient needs emergency treatment in the event of critical abnormalities. The use of this system can reduce diabetes-related risks.

5. Conclusions.

In this study, the UHS provides functions including abnormality monitoring, telecare services, and emergency medical contact through IoT and LBS function. Different from other healthcare systems, the proposed system adopts IoT and LBS to increase patients' self-care quality and avoid the risk of patients. The LBS positioning function of UHS can also be applied to children and elderly care.

As the UHS is still in an experimental prototype stage, we would consider improving the UHS to provide caregiver information after confirming the patient has received medical treatment. In this way, the UHS can inform other caregivers of the patient's current status, or allow family caregivers to accept or refuse to offer patient assistance, etc.; in addition, how to deal with the scenario where no GPRS signal can be found will also be considered in the near future. Moreover, after the UHS is formally launched, we will consider conducting a questionnaire to understand patient and caregiver opinions and improve the current system.

REFERENCES

[1] International Diabetes Federation, *IDF Diabetes Atlas*, 6th Edition, Brussels, Belgium, 2013.
[2] K. A. Sell, E. J. Amella, M. Mueller, J. Andrews and J. Wachs, Chronic disease self-management and behavior change attitudes in older adults, *SAGE Open*, vol.6, 2016.
[3] M. G. Ory, S. Ahn, L. Jiang, K. Lorig, P. Ritter, D. D. Laurent et al., National study of chronic disease self-management six-month outcome findings, *Journal of Aging and Health*, vol.25, pp.1258-1274, 2013.

[4] K. Kempf, T. Tankova and S. Martin, ROSSO-in-praxi-international: Long-term effects of self-monitoring of blood glucose on glucometabolic control in patients with type 2 diabetes mellitus not treated with insulin, *Diabetes Technology & Therapeutics*, vol.15, pp.89-96, 2013.

[5] E. Mattila, I. Korhonen, J. H. Salminen, A. Ahtinen, E. Koskinen, A. Sarela et al., Empowering citizens for well-being and chronic disease management with wellness diary, *IEEE Trans. Information Technology in Biomedicine*, vol.14, pp.456-463, 2010.

[6] D. Sethia, D. Gupta, T. Mittal, U. Arora and H. Saran, NFC based secure mobile healthcare system, *The 6th International Conference on Communication Systems and Networks*, pp.1-6, 2014.

[7] D. Kobylarz and J. Danda, A common interface for bluetooth-based health monitoring devices, *The 29th Southern Biomedical Engineering Conference*, pp.153-154, 2013.

[8] Y.-F. Lee, Personal medical monitoring system: Addressing interoperability, *IT Professional*, vol.15, pp.31-37, 2013.

[9] A. B. Waluyo, R. Hsieh, D. Taniar, W. Rahayu and S. Bala, Utilising push and pull mechanism in wireless e-health environment, *IEEE International Conference on e-Technology, e-Commerce and e-Service*, pp.271-274, 2004.

[10] L. Constantinescu, J. Kim and D. Feng, SparkMed: A framework for dynamic integration of multimedia medical data into distributed m-health systems, *IEEE Trans. Information Technology in Biomedicine*, vol.16, pp.40-52, 2012.

[11] A. Benharref and M. A. Serhani, Novel cloud and SOA-based framework for e-health monitoring using wireless biosensors, *IEEE Journal of Biomedical and Health Informatics*, vol.18, pp.46-55, 2014.

[12] N. Kamarudin and S. Salam, Enabling mobile location based services for emergency cases, *International Conference on Research and Innovation in Information Systems*, pp.1-6, 2011.

[13] S. H. Chang, R. D. Chiang, S. J. Wu and W. T. Chang, A context-aware, interactive m-health system for diabetics, *IT Professional*, vol.18, pp.14-22, 2016.

[14] B. Yip, H. W. Hirai, Y. H. Kuo, H. M. Meng, S. Wong and K. K. F. Tsoi, Blood pressure management with data capturing in the cloud among hypertensive patients: A monitoring platform for hypertensive patients, *IEEE International Congress on Big Data*, pp.305-308, 2015.

[15] American Diabetes Association, Diagnosis and classification of diabetes mellitus, *Diabetes Care*, vol.33, pp.S62-S69, 2010.

[16] American Diabetes Association, Standards of medical care in diabetes – 2016: Summary of revisions, *Diabetes Care*, vol.39, pp.S4-S5, 2016.