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A Novel Mobile Healthcare System in China

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ABSTRACT

With the increasing use of mobile phones and the worldwide deployment of mobile and wireless networks, the integrated solution with the above elements can potentially support many emerging healthcare applications. These advances make the healthcare assessable to anyone, at anytime and anywhere. In this paper, we present one such kind of family-based mobile healthcare monitoring system, which significantly improves the reach and quality of regional and community healthcare services. It utilizes the mobile technology and biomedical sensors, processes the complex raw data and eases its integration with existing electronic medical records/electronic health records (EHR/EMR), and clinical decision supporting system. The proposed solution has been piloted and deployed at the Peking University People's Hospital (PKUPH) for diabetes patients, via building an evidence-based clinical care solution focusing on chronic disease management in China. We envision that our approach has wide applicability and potential market not only in China, but also in other parts of the developing world, to ultimately provide pervasive and continuous care for community patients.

1. INTRODUCTION

Continuing advances in sensors and sensor-supporting technologies including pervasive computing and communications capabilities reduce the cost of introducing and using mobile phones to assist the healthcare applications. We therefore are witnessing an era that healthcare solutions can be assessable to almost anyone, at anytime and anywhere [1-3]. Furthermore, the system would better provide the *collaborative*, *interactive*, and *long-term* supports to the patients, based on the powerful data processing and analysis units; but such kind of system sparsely exists within the research community.

In this paper, we present a mobile healthcare system for family-based monitoring and a detailed case study is given. This solution has been deployed at the Peking University People's Hospital (PKUPH) in China for diabetes monitoring and clinical care deliveries. Patients are able to use the mobile phones or handheld devices to command the biomedical sensors to obtain the medical data and transfer them to the backend EHR/EMR server and

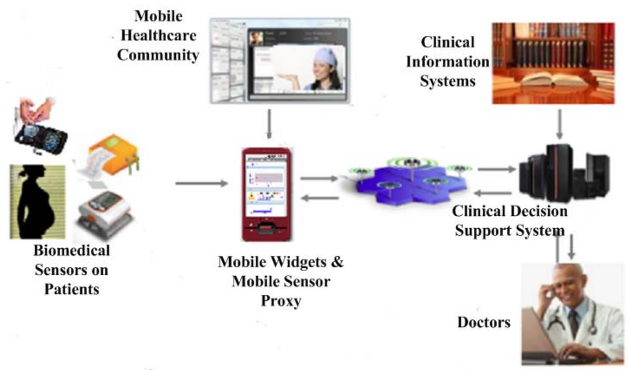

Figure 1. Overall architecture of the mobile healthcare system

clinical decision support system. This dramatically reduces the need and waiting time for face-to-face contact with the care professionals, while in the proposed solution the healthcare providers remotely monitor the patient's physical conditions 24/7, even when the patient is mobile. Furthermore, if the monitoring data shows certain deterioration of the patient's well-beings, alerts are generated and sent to patient's mobile phone. The care professional's help could also be invoked immediately as the part of the service requirement. We believe that our real deployment at PKUPH has demonstrated its huge potential for use not only in China, but other parts of the developing world in the near future.

We also present two technical challenges and their solutions to facilitate the design of the system. First is to provide uniform data processing and storage among multiple parties since healthcare itself is not a single entity but organized as a value-chain that integrates multiple domains like hospital, care center, and general practitioner etc. Therefore, a reusable data processing and transformation capability must be provided to convert potentially a variety of data formats to a common interface so that effective integrations among domains can be performed. Second is to decouple the sensor reading collections among multiple physical devices and their report to the user interface (UI). The difficulties could be further compounded by the wireless connections between the mobile device and biomedical sensors, so that a mediator is needed to collect the sensor readings and isolates their tight connections with the user. We use an internal pub/sub data bus to realize this functionality. We next present our system solution in detail, followed by the biographies of each author.

2. SYSTEM SOLUTION

2.1 System Overview

The overall architecture of our proposed mobile healthcare system is shown in Figure 1. Patients can use their mobile phones to command the biomedical sensors (e.g. glucose-meter, blood pressure etc.) to obtain the medical data. Then, the process engine embedded in the mobile phone can process the raw data to prepare for the uploading to the UI. The transformed and integrated data can be relayed to the healthcare service supporting system in the backend. If patient's medical data shows the deterioration of his/her health condition detected by the clinical decision supporting system, alerts are generated and sent to the patient's mobile phone. If necessary, the care professional's intervention could also be invoked immediately as part of the service requirement.

The applications developed in the mobile device are two parts: mobile widgets and mobile sensor proxy. The mobile widgets provide an easy-to-use user interface for patients to interact with the biomedical sensors. We also developed a widget for patient to leverage the resources from the mobile healthcare community, e.g. the care professionals and hospital equipments, where patients are able to receive good tips from other patients or doctors. The developed mobile sensor proxy is a lightweight process engine embedded in the mobile device. It periodically listens to the wireless connections of the biomedical sensors to obtain the newly arrived medical data, and then use the data processing logic to process the data, e.g. to transform or enrich the data into a suitable format for upload. Finally, the processed data can be relayed to the backend supporting system. The data flow in the mobile sensor proxy is described in detail in Section 2.2.

2.2 Data Flow in Mobile Sensor Proxy

We have identified two important design elements for data processing in the mobile sensor proxy: the "internal pub/sub data bus" and the "micro process engine", as shown in Figure 2. We also implemented a few sensor agents to receive and adapt/transform the sensor readings from multiple biomedical sensors of different data formats. The data process logic instance trigged by user operations on the UI in the micro process engine can get the medical data and process them in sequence.

To effectively integrate the mobile sensor proxy with the backend supporting system, we develop a lightweight process engine in the mobile device to run a simple data processing logic, which defines some reusable data operations. As shown in Figure 2, the processing logic is composed of an aggregation operation ("A"), a transform operation ("T"), and a security operation ("S"). When the logic receives any data, it first aggregates them together (by using the "A" operation) and then calls for a "T" operation to transform the combined data in certain format and use the security operation ("S") for encryptions.

Furthermore, due to the instability of the wireless conditions between the mobile device and biomedical sensors, e.g., via WiFi or Bluetooth, the data processing logic might be blocked or delayed on fetching the data from sensor agents. From the user experience perspective, they may feel uncomfortable keeping waiting for the response from the sensors. Therefore, we develop a lightweight pub/sub data bus to decouple the data from multiple physical sensors. In our design approach, sensor agents publish

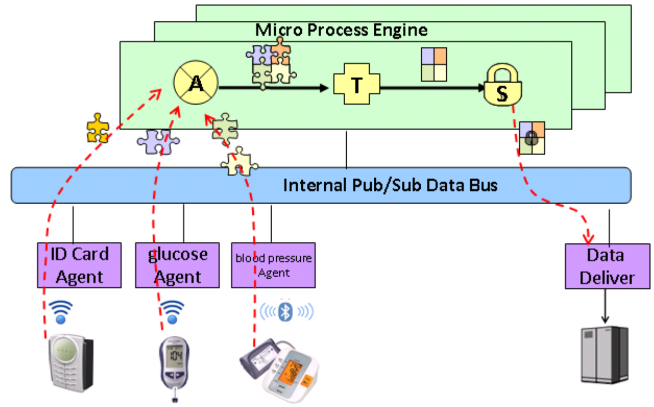

Figure 2. Data aggregation, transformation and encryption

the medical data whenever it arrives via the wireless connections and then the data processing logic subscribes the interested type of medical data. Once these data are published on the internal pub/sub data bus, the data processing logic can resume the processing work. Therefore, the user experience is significantly enhanced by our design.

3. A CASE STUDY

In China, mobile healthcare has been gaining much attention from both the public and the government perspectives. Our system has been piloted and deployed at the Peking University People's Hospital (PKUPH, one of the biggest hospitals in China, admitting more than 40,000 inpatients annually) for diabetes treatments by building an evidence-based clinical care solution focusing on chronic disease management. A typical scenario

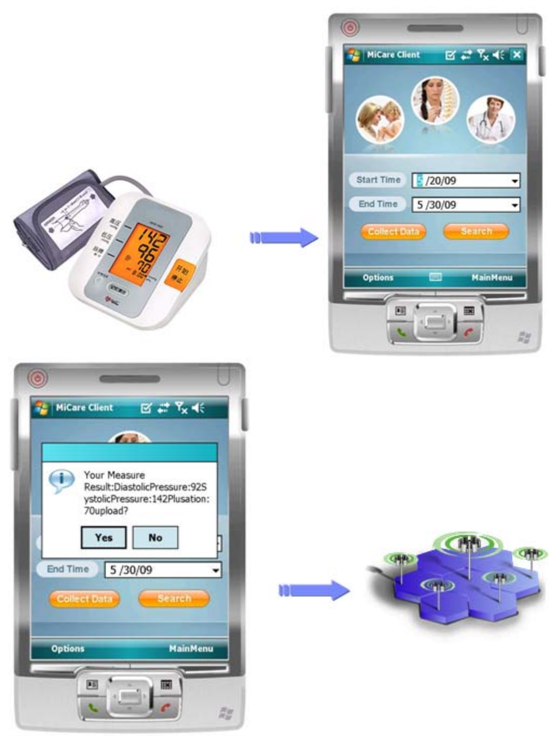

Figure 3 Obtain the blood pressure data for delivery

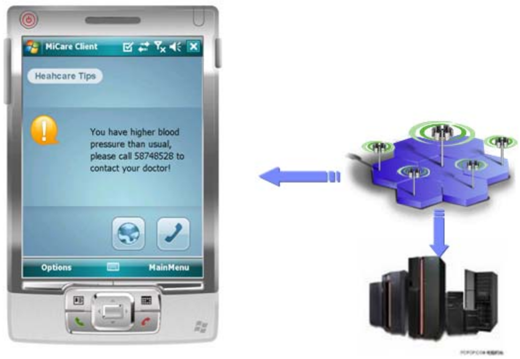

Figure 4 Received notifications from clinical decision system

using our deployed system is described as follows.

Jessica is a fifty-year-old woman, who has suffered diabetes for two years. Provided by our mobile healthcare system, she owns a blood pressure sensor and glucose-meter. Furthermore, her personal mobile phone has installed our developed widgets and the mobile sensor proxy application. Every day, Jessica is able to periodically take measurements by herself; then, her mobile phone can obtain the medical data from the blood pressure sensor and glucose-meter. If the mobile device detects that her current blood pressure level (e.g.142/96mmHg) higher than the normal level (see Figure 3), then the data is processed and sent to the backend supporting system.

Once the clinical decision system detects the abnormal condition of Jessica, her mobile phone immediately receives a message from the mobile healthcare service and notifies her about this abnormal situation. If necessary, Jessica's doctor can have a immediate conversation with her to discuss further about detailed conditions and/or suggests Jessica go to the hospital for further measurements (see Figure 4).

4. AUTHOR BIOGRAPHY

4.1 Qi Yu

Qi Yu is a research staff with the Department of Networked Computing at IBM Research – China. Qi received a M.S. degree in Computer Science from Beijing University of Post and Telecom. His interests include telecom service delivery platform, mobile computing and network computing technologies. Qi has worked on a series of projects focusing on telecom service delivery platform, mobile interaction and mobile computing. He has filed over five patents in above areas. He has designed and developed a subsystem named "Service Control Layer" as the first IBM Service Broker solution for the IMS telecom network, which was demoed on Mobile World Congress at Barcelona in 2008. Now he is working on the design of the common infrastructure for Internet of Thing in IBM Research-China Lab.

4.2 Dr. Chi Harold Liu

Dr. Chi Harold Liu is a staff researcher with the Department of Networked Computing at IBM Research - China. He holds a PhD degree from Imperial College, U.K., and a BEng degree from Tsinghua University, China. Before joining IBM Research - China, he worked as a PostDoc researcher at Deustsche Telekom AG in Berlin, Germany, where he was involved in the GlobalSense and ThinSense projects on social networks and collaborative sensing. He also has been involved in EU-FP6 MEMBERANE Project, and the US Army-UK MoD co-funded ITA Project on sensor and mesh networks. In 2009, he was a research intern at IBM T.J. Watson Research Center in Hawthorne, USA. His current research interests include the Internet of Things (IoT), context-aware computing, and protocol designs for ad-hoc, sensor and mesh networks. He has published more than 30 prestigious conference and journal papers, technical reports, and project deliverables. He also has served as the TPC and the Industry Chair of PESARO 2011, and peer reviewer of major conferences and journals. He is a member of IEEE.

4.3 Dr. Jia Jia Wen

Jia Jia Wen is a researcher from IBM China Research Lab, He participate in IBM's worldwide research efforts in Internet of thing and industry solutions, especially in telecom and healthcare areas. The application of connected healthcare technology is one of his current research focus areas. Before joining IBM, he got his Ph.D degree in Beijing University of Posts and Telecommunication. He has 6 years of research and development experience in the Information technology industry, with particular emphasis on telecom network.

5. CONCLUSION AND FUTURE WORK

In this position paper, we have presented a novel mobile healthcare system with its design and deployment in China. The proposed solution is patient-driven and service-oriented, and provide a user-friendly interface for visible patient care. The key design elements of the data transformation and combination technology can support interoperability between mobile devices and clinical supporting system, completely decoupled with the physical worlds. We have identified that such a mobile healthcare solution has wide applicability in the developing world, due to the mushroom popularity of the mobile phones, and continuing advances of the sensor-related technologies. We believe that our deployment has shown its feasibility in real deployment and usage in the hospital environment and could be an good example for further extensions in other developing countries. Finally, we notice that healthcare is only one of the many application scenarios for the integration of sensors and mobile devices, however the solution is potentially applicable in other domains like traffic and air quality monitoring as well. In the future, we are planning to investigate an *integrated* mobile monitoring platform across multiple industry domains and make it applicable in the developing world.

6. REFERENCES

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