HealthKiosk: A Family-Based Connected Healthcare System for Long-Term Monitoring

Chi Harold Liu, Jiajia Wen, Qi Yu, Bo Yang and Wenjie Wang
IBM Research - China
19A Diamond Building, Z-Park, Beijing, 100193, China
E-mail: {chiliu, wenjj, yuqi, boyang, wenjwang}@cn.ibm.com

***Abstract*—In this paper, we present "HealthKiosk", a family-based healthcare system, to provide rich contextual information and alerting mechanisms for continuous monitoring of health conditions. HealthKiosk significantly improves the reach and quality of regional and community healthcare services, and could potentially minimize the efforts of care professionals for the chronical illness, not only applicable for the elderly but also children and young fitness trainers. The proposed architecture leverages the RESTful design style, nevertheless introducing a novel development of the "sensor proxy", both in a stationary PC style and as a mobile widget. The sensor proxy behaves not only as a bridge between the raw sensor readings and the kiosk controller, but also as a data processing logic to integrate, correlate, and transform a variety of data from multiple data sources to an integrated XML format. We demonstrate the system performance by showing two complete case studies for both stationary and mobile sensor proxies used in the developed HealthKiosk system. Finally, 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.**

I. Introduction

One of the major challenges around the world recently has been the continuous increase of the elderly population, and thus the delivery of quality care while reducing the healthcare costs is highly needed [1]. Particularly with the continuing advances in sensors and sensor-supporting technologies including pervasive computing and communications capabilities, we are witnessing an emergence of a variety of promising applications from the integration of sensing and consumer electronics, allowing people to be constantly monitored [2].

Family-based healthcare services [3], [4] render the patient's full freedom at home, which dramatically reduces the need and waiting time for face-to-face contact with the care professionals, where the healthcare providers remotely monitor the patient's physical conditions 24/7, even when the patient is mobile. Furthermore, if the measurements show certain deterioration of the patient's well-beings, alerts are generated and sent to the patient's mobile phone. The care professional's help could also be invoked immediately as the part of the service requirement. Not only the elderly and chronically ill but also the working parents may derive benefits from these systems for delivering high-quality care services for their babies and little children. Also, the benefits can be extended to the young fitness trainers who are interested in continuous monitoring of their training outcomes. Hence, a family-based system should provide the *collaborative*, *interactive*, and *long-term* supports to all users, based on the powerful data processing and analysis units, but such kind of system sparsely exists within the research community.

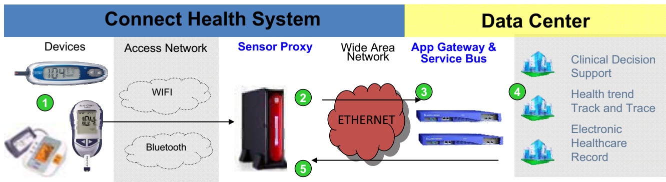


Fig. 1. A system diagram for the proposed HealthKiosk system, where (1) biomedical sensors send the sensor readings to the sensor proxy, (2) the sensor readings are processed and sent to the kiosk via Ethernet, (3) and (4) the data are further analyzed by the back end server, and (5) the treatment suggests are sent to the sensor proxy.

In this paper, we present "HealthKiosk", a family-based healthcare monitoring system that bridges the data centers and biomedical sensors. As shown in Fig. 1, biomedical sensors collect personal data of their health conditions and other vital signs, and report them to the sensor proxy, where the latter serves as a bridge between the sensor network (e.g. via WiFi, Bluetooth, RS232) and the kiosk controller. We note that the sensor proxy will also maintain some data processing logic, like correlating the blood pressure data with the patient's social security card meta data. Then, the developed kiosk system automatically connects to a variety of backend servers like clinical supporting system in major hospitals via wide area network (WAN, e.g., the Ethernet) for further treatments. For instance, after receiving the personal medical data, the application may decide to remeasure the blood pressure, and the sensor proxy will command the sensor accordingly.

We believe that the proposed solution provides a universal research asset to enhance the clinical process for streaming line interactions among care professionals and patients. It is also worth noting that the HealthKiosk system has been piloted and deployed at the Peking University People's Hospital (PKUPH[1]) since Feb. 2010, and has shown its success so far.

The rest of the paper is organized as follows. In Section II, we highlight related research activities. Section III establishes

[1]PKUPH, one of the biggest hospitals in China, founded in 1918, housing more than 2,400 staff and admitting more than 40,000 inpatients a year. It receives more than 1,560,000 outpatients, and more than 133,000 emergency cases annually.

a formal model of our system. Section IV describes the design of the sensor proxy and related technical challenges and solutions, and Section V presents the HTTP interface used between the kiosk controller and the sensor proxy. Two complete case studies are presented in Section VI, followed by the conclusions and future work in Section VII.

II. Related Work

Healthcare systems using either mobile or other equipments has been proposed and studied for over a decade to provide convenient and constant monitoring of patient's health conditions [5], [6], [7], [8]. It has been identified as an important branch of research of the machine-to-machine (M2M [9]) or, the Internet of Things (IoT [10], [11]) that aims to connect physical sensors to the Internet for better monitoring and analysis. Recently, low cost and effective sensors, such as blood pressure and heart rate sensor [12], make their availability to a large number of individual and families possible for healthcare solutions.

There are several case studies that take advantage of the above development to offer healthcare solutions to particular groups of patients in limited regions. For example, Columbia University monitors thousands of diabetes patients in great New York area [13]. There are also evaluation and actual field deployment to confirm that mobile Internet devices such as cell phone can be used as gateway to connect body area networks to the Internet [14], [15], [16]. Furthermore, efforts have been taken to define standard for mobile healthcare systems [17].

In this paper, we emphasize our architecture and framework that can accommodate various sensors, wide range of Internet connectivities, and comprehensive sharing and analysis of the data. We provide a middleware appliance, named "sensor proxy" that can speak the languages of both the physical world and the Internet, to bridge the gap and mediate the interactions between them. It can be deployed as a standalone box or part of broadband modem/routers and mobile handsets. More importantly, we design its interface to be RESTful [18], [19] such that its data can be obtained and shared to multiple parties easily. This reduces the efforts and power requirements on sensors since they do not have to provide such kind of interfaces [20], and consequently make them even more portable and energy efficient.

III. System Model

The overall architectural view of our proposed HealthKiosk system is shown in Fig. 1, where patients can use their installed biomedical sensors (e.g. glucose-meter, blood pressure etc.) to take measurements. Then, the data are sent to the sensor proxy via existing communication networks like 3G, WiFi and Bluetooth. The sensor proxy can be an small server or even an application in the mobile handset, and it holds certain data processing logic to integrate multiple pieces of the raw data from a variety of the physical sensors to a common format prepared for the uploading to the application gateway (or the "kiosk controller" in our design). Then, either the transformed and integrated data are relayed to the healthcare service supporting system in the backend (if needed), or they are locally consumed/shown on an easy-to-use touch-screen user interface (UI) at the kiosk. We also allow the interaction between the backend supporting system and the patients. If his/her medical data shows the deterioration of his/her health condition detected by the clinical decision supporting system, alerts are generated and sent to the sensor proxy, like the patient's mobile phone. If necessary, the care professional's intervention could also be invoked immediately as part of the service requirement. We next describe the functional designs and the challenges of the sensor proxy in Section IV.

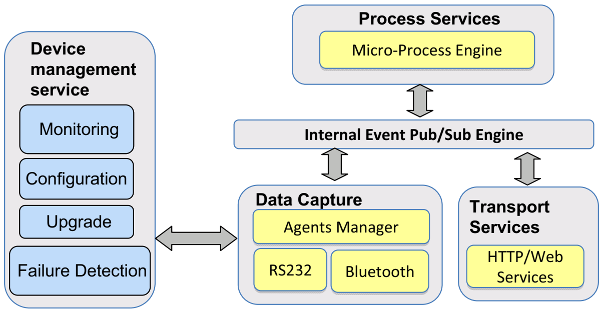


Fig. 2. A functional design architecture for the sensor proxy.

IV. Sensor Proxy Design

With the proposed HealthKiosk system, the sensor proxy serves as an important design element bridging different biomedical sensors with the kiosk controller, either wirelessly or wired connected. Furthermore, it also provides certain degree of sensing event processing and sensor management functionalities. A functional design architecture is shown in Fig. 2, and composed of five core elements:

1) Data Capture Module: It is a wrapper with which different agents connect to the biomedical sensors via underlying communication channels (e.g. RS232, Bluetooth). An "agent manager" is implemented to load these agents and transfer the data from medical sensors to a common business event of the sensor proxy.

2) Internal Event Pub/Sub Engine: Due to the instability of the wireless conditions between the sensor proxy and biomedical sensors, the data uploads might be blocked or delayed from the sensor agents. From the user experience perspective, they may feel uncomfortable keeping waiting for the response from the sensors. Therefore, we develop a lightweight "internal pub/sub engine" (see Fig. 2), to decouple the data from multiple physical sensors. In our design approach, the process service module subscribes the interested type of medical data, and the sensor agents publish the medical data whenever it arrives. Upon receiving an event from the data capture module, the internal event pub/sub engine will dispatch it into the process service module for further processing. After the processing is completed and the data is sent back to the internal pub/sub engine, the latter will choose a transport service (e.g. HTTP) to publish the event to the kiosk controller. Therefore, the user experience is significantly enhanced by our design.

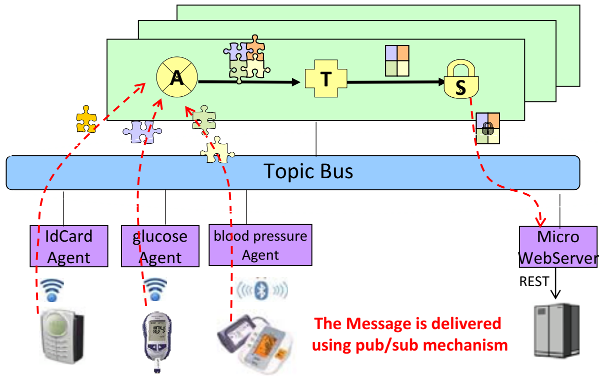


Fig. 3. The illustrative functional diagram for data aggregation, transformation, and encryption.

3) Process Service Module: It provides a micro engine to handle the event processing step by step, for example, a typical community healthcare service will require the sensor proxy to correlate the patient's meta data from his/her social security card with the patient's sensor data, and then send the combined data through an XML format to the remote repository (like the kiosk database). 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.

To achieve the design goal, we develop a lightweight process engine, called the "micro process engine" (see Fig. 2), which runs a simple data processing logic, and defines some reusable data operations. As shown in Fig. 3, 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. Fig. 4 shows a snapshot of the real XML code obtained after combining the social security card data and the blood pressure measurement.

4) Transportation Service Module: While the data capture module connects the sensor proxy to the sensor network, the transportation service module connects the sensor proxy to the Internet, and ultimately the kiosk controller. We leverage the RESTful design approach [18], [19], where the sensor proxy behaves as a HTTP server (while leaving other methods, e.g. MQTT [21], for future extensions), and receives the instructions from the kiosk server by HTTP request and methods (like `GET` and `POST`). In the mean time, the sensor proxy also acts also as a HTTP client and uploads the measured data and its associated patient's meta data to the kiosk controller database where the relational database is stored. The detailed HTTP interface from the kiosk server to the sensor proxy and backwards is described in Section V. Besides the fundamental capability of delivering the data back to the backend server, it is worth noting that the sensor proxy itself can also have certain exposure for the medical data in a web-friendly manner,


```
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSpy v2007 (http://www.altova.com)-->
<PHMReport xmlns="http://cda.ibm.com/accelerator/phmr" xmlns:xsi="http://
    <id>999021</id>
    <effectiveTime><value>20100507093047</value></effectiveTime>
    <confidentialityCode xsi:type="CEV">
        <code>N</code>
        <codeSystem>2.16.840.1.113883.5.25</codeSystem>
    </confidentialityCode>
    <actors>
        <author>
            <id>996-756-495</id>
        </author>
        <custodian>
            <id>996-756-495</id>
        </custodian>
        <subject>
            <identification>
                <id>996-756-495</id>
            </identification>
        </subject>
    </actors>
    <medicalEquipment>
        <title>Medical Equipment</title>
        <text></text>
        <device>
            <deviceId>1A-34-46-78-9A-BC-DE-F3</deviceId>
            <systemType xsi:type="CEV">
                <code>MDC_DEV_SPEC_PROFILE_BP</code>
                <codeSystem>2.16.840.1.113883.6.24</codeSystem>
                <codeSystemName>MDC</codeSystemName>
                <displayName>Blood Pressure Monitor</displayName>
```

Fig. 4. The combined data with social security card and blood pressure sensor information in one XML data format.

and thus the application developer can "mash-up" these data and show them in the mobile phone or desktop for patients.

5) Device Management Service Module: It provides a common infrastructure to configure, deploy, monitor, and update other modules. In different use cases, the sensor proxy might connect to different medical sensors, transform the sensor data into different formats and expose the data by different ways. Therefore, the device management service will configure and deploy different agents in data capture module, and different processes in the micro process engine for these use cases.

V. HTTP Interface

We next describe the a few important HTTP interfaces connecting the kiosk controller and the sensor proxy, including the naming and addressing, initialize and obtain sensor readings.

A. Get Naming and Addressing

We use the HTTP `GET` method by calling the URL http://hostname:port/healthcare/namingaddressing, to obtain the naming and addressing information of the sensory proxy and its connected biomedical sensors. Since multiple physical biomedical sensors connect to the sensor proxy simultaneously, we need an efficient naming and addressing mancinism so that the sensor readings are able to be identified, and the control commands are able to reach the physical world. We leverage the RESTful style [18], [19] as:

1) Sensor proxy naming: We name the sensor proxy 1 as:

```
<sensor_proxy name="proxy_1">
```

2) Biomedical sensors naming: For instance, the following pseudocode shows the naming mechanism of a social security card reader connected with the sensor proxy 1.

```
<sensor_proxy name="proxy_1">
<sensor type="social_security_card">
```

3) Biomedical sensors addressing: We use a URL-like address to hierarchically differentiate multiple sensors as:

```
<sensor type="bloodpressure">
<start_address>
  http://hostname:port/healthcare/
     bloodpressure/
     1A-34-46-78-9A-BC-DE-F3/start
</start_address>
```

B. Start Blood Pressure/Glucose Reader

We use the HTTP `POST` method by calling http://hostname: port/healthcare/glucose/deviceID/start, to start the sensor reader, e.g. deviceID=1A-34-46-78-9A-BC-DE-F3 uniquely denotes the blood pressure sensor. The request complies with the RESTful [18], [19] style, and the following returns may be generated:

(1) 200: OK, if the sensor is successfully started.
(2) 404: Not Found, if one cannot find the corresponding sensor.
(3) 400: Bad Request, if other errors in the request format exist.
(4) 500: Internal Server Error, identified in the sensor proxy.

C. Get Social Security Card ID

We use the HTTP `GET` method by calling http://hostname: port/healthcare/socialsecuritycard/1A-00-00-00-00-00-00-01/ data, to obtain the social security card ID from the kiosk controller, once the data is available. If not, the sensor proxy will return `200` but with an empty response body; nevertheless, for the successful data fetching, a `200` return will be generated with the body of <id hasCard="true">996-756-495</id>. The sensor proxy can also return <id hasCard="false"/>, which indicates that there is no card in the card reader. The following items summarizes the possible returns:

(1) 200: OK with body either <id hasCard="true">996-756-495</id>, or <id hasCard="false"/>, or empty.
(2) 404: Not Found, if one cannot find the corresponding device.
(3) 400: Bad Request, if there are other errors in the request format.
(4) 500: Internal Server Error, identified in the sensor proxy.

D. Get Blood Pressure/Glucose Data

We use the HTTP `GET` method by calling http://hostname: port/healthcare/bloodpressure/deviceID/data, to obtain the data from blood pressure and glucose sensors. Based on patient's current vital sign, the kiosk controller tries to get blood pressure data from the sensor proxy, where the message is flowing from the kiosk controller to the sensor proxy. The obtained measurements uses an XML format and embedded in the body of HTTP response. The following items summarizes the returns:

(1) 200: OK with empty body.
(2) 404: Not Found, if one cannot find the corresponding device.

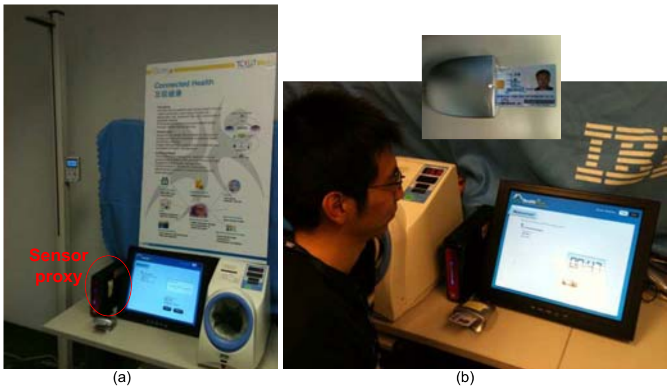


Fig. 5. An illustrative case study where (a) the overall system composed of a touch-screen kiosk, a sensor proxy, a social security card reader, a height and weight sensor, and a blood pressure sensor, and (b) a colleague of IBM Research - China is taking blood pressure measurement with his social security card.

(3) 400: Bad Request, if there are other errors in the request format.
(4) 500: Internal Server Error, identified in the sensor proxy.
(5) 200: OK with body of the combined XML data.

VI. CASE STUDIES

To better illustrate the rich set of functionalities our system is able to provide, we present two complete case studies in this section; one is the stationary HealthKiosk system where a PC-like sensory proxy is developed to connect the biomedical sensors (see Fig. 5 and Fig. 6), while the other one is to use the mobile handsets behaving as the sensor proxy, or the "mobile HealthKiosk", for the support of mobile healthcare solutions (see Fig. 7).

A. Stationary HealthKiosk

Fig. 5(a) demonstrates an implementation of the HealthKiosk system, composed of a kiosk touch-screen UI, a social security car reader to leverage the meta data of the patients, a height and weight scaler, and a blood pressure sensor. Fig. 5(b) shows that a colleague of IBM Research - China is taking blood pressure measurement with his social security card inserted into the card reader. The detailed touch-screen UI is demonstrated in Fig. 6, where Fig. 6(a) shows the welcome page, and by clicking the "next" button, the user will be directed to the choice of taking either height and weight measurements, or blood pressure measurements. The measurements of each sensor are shown in Fig. 6(b) and Fig. 6(c), respectively. It is also worth noting that our stationary HealthKiosk system has been piloted and deployed at the PKUPH for diabetes treatments by building an evidence-based clinical care solution focusing on chronic disease management. Extensive training has been offered by the IBM Research - China, and the current contract will be largely extended to the next year, where more systems and complicated offerings will be provided. Famous Chinese newspapers including China Daily, Reuters, and ZDNet have covered the news.

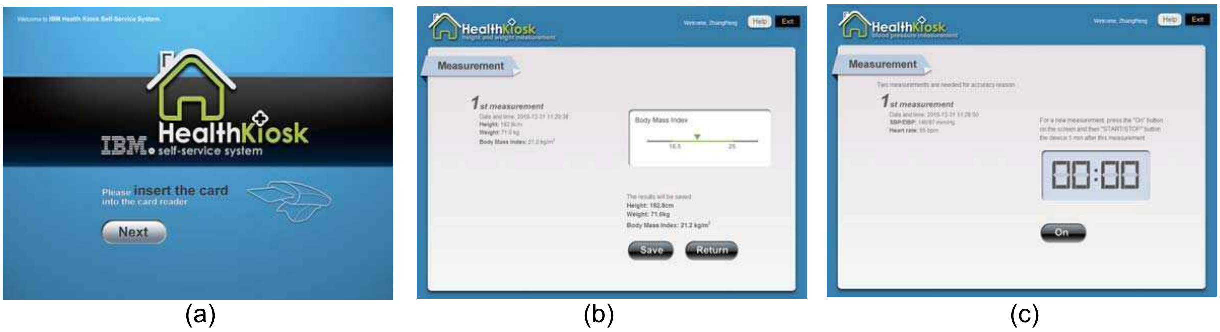
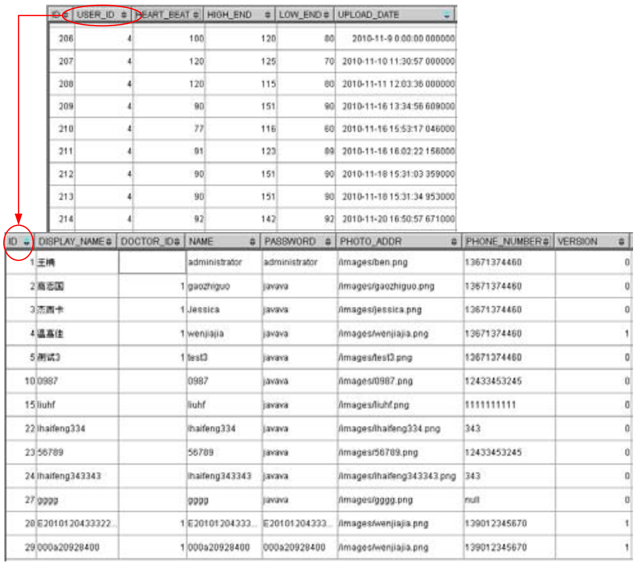


Fig. 6. The developed UI, where (a) the welcome page, (b) the height and weight measurement, and (c) the blood pressure measurement.

B. Mobile HealthKiosk

To take advantage of the mushroom popularity of the mobile devices, we also implement a *mobile* HealthKiosk system, complemented to the previous *stationary* sensor proxy, as shown in Fig. 7. Different from the stationary sensor proxy, we use the mobile handsets to behave as a sensor proxy; and the developed lightweight process service module periodically listens to the wireless connections of the biomedical sensors to obtain the newly arrived medical data. Then, the process engine helps with the data processing, e.g. to transform or enrich the data into a suitable format for upload. Apart from all these, further applications developed include the kiosk applications and a community widget. The kiosk applications provide an easy-to-use user interface for patients to interact with the biomedical sensors. The community widget renders the 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.

Fig. 7(a) shows the welcome page summarize the functionalities we provide in a user-centric and service-oriented manner, where patients are able to set their personal settings, take blood pressure and glucose and browse some healthy tips and community suggestions. A typical scenario using our deployed system is described as follows. James is a fifty-year-old man, who has suffered high blood pressure for two years. Provided by our mobile healthcare system, he owns a blood pressure sensor and glucose-meter. Furthermore, his personal mobile phone has installed our developed widgets and the mobile sensor proxy application. Every day, James is able to periodically take measurements by himself; then, his mobile phone obtains the medical data from the blood pressure sensor and glucose-meter. Fig. 7(g) shows a measurement result, i.e., 118/89mmHg for blood pressure and 76 times/min for pulse; and Fig. 7(h) shows the received tips from the community group members. Fig. 8 shows the relational database storing the patient's personal information and all historical measurements.



ID	USER_ID	HEART_BEAT	HIGH_END	LOW_END	UPLOAD_DATE
206	4	100	120	80	2010-11-9 0:00:00 000000
207	4	120	125	70	2010-11-10 11:30:57 000000
208	4	120	115	80	2010-11-11 12:03:36 000000
209	4	90	151	90	2010-11-16 13:34:56 609000
210	4	77	116	60	2010-11-16 15:53:17 046000
211	4	91	123	89	2010-11-16 16:02:22 156000
212	4	90	151	90	2010-11-18 15:31:03 359000
213	4	90	151	90	2010-11-18 15:31:34 953000
214	4	92	142	92	2010-11-20 16:50:57 671000

ID	DISPLAY_NAME	DOCTOR_ID	NAME	PASSWORD	PHOTO_ADDR	PHONE_NUMBER	VERSION
1	王楠		administrator	administrator	/images/ben.png	13671374460	0
2	高志国	1	gaozhiguo	javava	/images/gaozhiguo.png	13671374460	0
3	杰西卡	1	Jessica	javava	/images/jessica.png	13671374460	0
4	温嘉佳	1	wenjiajia	javava	/images/wenjiajia.png	13671374460	1
5	测试3	1	test3	javava	/images/test3.png	13671374460	0
10	0987		0987	javava	/images/0987.png	12433453245	0
15	liuhf		liuhf	javava	/images/liuhf.png	1111111111	0
22	lhaifeng334		lhaifeng334	javava	/images/lhaifeng334.png	343	0
23	56789		56789	javava	/images/56789.png	12433453245	0
24	lhaifeng343343		lhaifeng343343	javava	/images/lhaifeng343343.png	343	0
27	gggg		gggg	javava	/images/gggg.png	null	0
28	E2010120433322...	1	E20101204333...	E20101204333...	/images/wenjiajia.png	139012345670	1
29	000a20928400	1	000a20928400	000a20928400	/images/wenjiajia.png	139012345670	1

Fig. 8. Historical records of blood pressure measurements and the relational database containing the patient information.

VII. Concluding Remarks

In this paper, we presented a novel family-based healthcare monitoring system, called "HealthKiosk", with its detailed designs and case studies. The proposed solution is patient-driven and service-oriented, and provides a user-friendly interface for visible patient care. HealthKiosk could potentially minimize the efforts of care professionals, not only applicable for the elderly but also children and young fitness trainers. The proposed architecture leverages the RESTful design style, nevertheless introducing a novel development of the sensor proxy, both in the PC style and as a mobile widget. The sensor proxy behaves not only as a bridge between the raw sensor readings and the kiosk controller, but also as a data processing logic to integrate, correlate, and transform multiple pieces of data to an XML format. We demonstrated the system performance by showing two complete case studies for both stationary and mobile sensor proxies used in the proposed end-to-end HealthKiosk system. Finally, the proposed solution has been piloted and deployed at the PKUPH for diabetes patients, via building an evidence-based clinical care solution focusing on chronic disease management in China. In the future, we are planning to investigate an integrated mobile monitoring platform across multiple industry domains, like healthcare and logistics, and make it applicable in real scenario deployments.

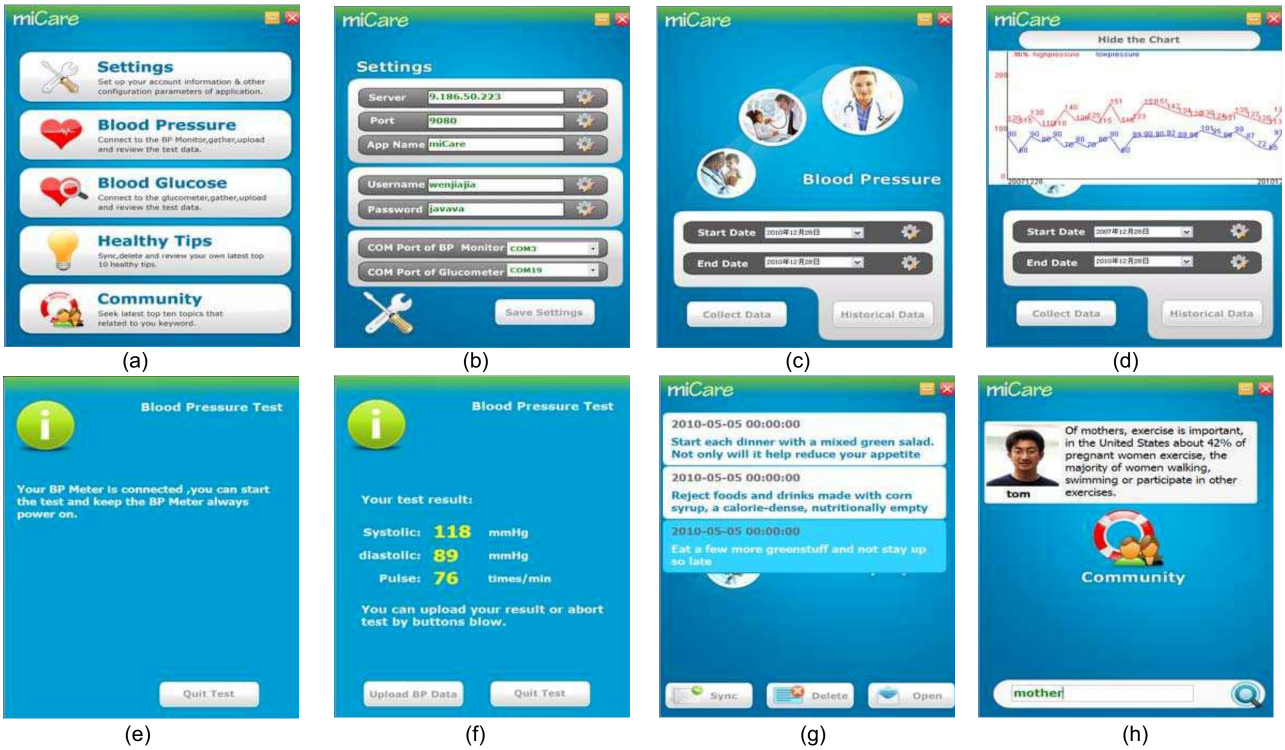


Fig. 7. The case study for the mobile HealthKiosk system, where (a) the welcome page, (b) the personal settings, (c) and (d) the blood pressure measurement entrance and the historical data trend, (e) and (f) new measurement, (g) and (h) healthy tips and community suggestions.

Acknowledgments

We would like to thank Dr. Wei Lu for her continuous supports and valuable discussions and inputs to our project. We would also like to thank Yuanbo Qin and Nan Jiang for their hard work on system implementations.

References

[1] H. Alemdar and C. Ersoy, "Wireless sensor networks for healthcare: A survey," *Computer Networks*, vol. 54, no. 15, pp. 2688 – 2710, 2010.

[2] V. Stanford, "Using pervasive computing to deliver elder care," *IEEE Pervasive Comp.*, vol. 1, no. 1, pp. 10 – 13, 2002.

[3] T. Mcfadden and J. Indulska, "Context-aware environments for independent living," in *IEEE 3rd National Conf. of Emerging Researchers in Ageing*, 2004.

[4] J. A. Stankovic, Q. Cao, T. Doan, L. Fang, Z. He, R. Kiran, S. Lin, S. Son, R. Stoleru, and A. Wood, "Wireless sensor networks for in-home healthcare: potential and challenges," in *IEEE High Confidence Medical Device Software and Systems (HCMDSS) Workshop'05*, 2005.

[5] V. Jones, R. Kleissen, V. V. Goldman, A. T. Halteren, I. A. Widya, and N. T. Dokovski, "Mobile applications in the health sector," in *Mobile Minded Symp.*, vol. 22, 1999.

[6] S. Sultan and P. Mohan, "How to interact: Evaluating the interface between mobile healthcare systems and the monitoring of blood sugar and blood pressure," in *ACM MobiQuitous'09*, July 2009, pp. 1 – 6.

[7] Y. Ren, R. W. N. Pazzi, and A. Boukerche, "Monitoring patients via a secure and mobile healthcare system," *IEEE Trans. on Wireless Comm.*, vol. 17, no. 1, pp. 59– 65, Feb. 2010.

[8] P. Mohan and S. Sultan, "Medinet: A mobile healthcare management system for the caribbean region," in *ACM MobiQuitous'09*, July 2009, pp. 1 – 2.

[9] G. Lawton, "Machine-to-machine technology gears up for growth," *Computer*, vol. 37, no. 9, pp. 12 – 15, Sept. 2004.

[10] M. Conner, "Sensors empower the internet of things," *EDN*, vol. 55, pp. 10–32, 2010.

[11] S. Haller, S. Karnouskos, and C. Schroth, "The internet of things in an enterprise context," *Future Internet–FIS 2008*, pp. 14–28, 2009.

[12] V. Jones, A. Halteren, I. Widya, N. Dokovsky, G. Koprinkov, R. Bults, D. Konstantas, and R. Herzog, "Mobihealth: Mobile health services based on body area networks," *Springer M-Health*, pp. 219–236, 2006.

[13] S. Shea, J. Starren, R. S. Weinstock, P. E. Knudson, J. Teresi, D. Holmes, W. Palmas, L. Field, R. Goland, and C. Tuck, "Columbia university: Informatics for diabetes education and telemedicine (ideatel) project," *J. of the American Medical Informatics Association*, vol. 9, no. 1, p. 49, 2002.

[14] T. Broens, A. Van-Halteren, M. Van-Sinderen, and K. Wac, "Towards an application framework for context-aware m-health applications," *Int'l J. of Internet Protocol Tech.*, vol. 2, no. 2, pp. 109–116, 2007.

[15] Y. Z. R. Istepanian and W. Huang, "Performance evaluation of a gprs/bluetooth diabetes management system," in *IET 3rd Int'l Conf. on Advances in Medical, Sig. and Inf. Processing'06*, 2007, pp. 1–4.

[16] S. Dagtas, Y. Natchetoi, and H. Wu, "An integrated wireless sensing and mobile processing architecture for assisted living and healthcare applications," in *ACM SIGMOBILE Int'l Workshop on Sys. and Netw. support for healthcare and assisted living environments*, 2007, pp. 70–72.

[17] R. Carroll, R. Cnossen, M. Schnell, and D. Simons, "Continua: An interoperable personal healthcare ecosystem," *IEEE Pervasive Comp.*, pp. 90–94, 2007.

[18] L. Richardson and S. Ruby, *Restful web services*. O'Reilly Media, May 2007.

[19] R. T. Fielding and R. N. Taylor, "Principled design of the modern web architecture," in *ACM ICSE'00*, 2000, pp. 407–416.

[20] D. Guinard and V. Trifa, "Towards the web of things: Web mashups for embedded devices," in *WWW Workshop on Mashups, Enterprise Mashups and Lightweight Composition on the Web (MEM'09)*, 2009.

[21] "MQTT," http://mqtt.org.