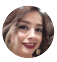
Diabetes Patients Monitoring by Cloud Computing

Chapter · January 2017

DOI: 10.4018/978-1-5225-1002-4.ch006

3 authors:



Sepideh Poorejbari
Pervasive and Cloud Computing Laboratory

Hamed Vahdat Nejad
University of Birjand

Wathiq Mansoor
University of Dubai

Chapter 6
Diabetes Patients Monitoring by Cloud Computing

Sepideh Poorejbari
Pervasive and Cloud Computing Laboratory, Iran

Hamed Vahdat-Nejad
University of Birjand, Iran

Wathiq Mansoor
University in Dubai, UAE

ABSTRACT

The healthcare system is important due to the focus on human care and the interference with human lives. In recent years, we have witnessed a rapid rise in e-healthcare technologies such as Electronic Health Records (EHR) and the importance of emergency detection and response. Cloud computing is one of the new approaches in distributed systems that can handle some of the challenges of smart healthcare in terms of security, sharing, integration and management. In this study, an architecture design of a cloud-based pervasive healthcare system for diabetes treatment has been proposed. For this, three different components are defined as follows: (1) The home context manager which gathers necessary information from patients while simultaneously providing feedback, (2) a patient health record manager that is accessible by nurses or physicians at the hospital, and (3) a diabetes management system which is located with the cloud infra-structure for managing and accessing patient's information. The performance of proposed architecture is demonstrated through a user scenario.

DOI: 10.4018/978-1-5225-1002-4.ch006

INTRODUCTION

Information technology can play a vital role in healthcare services in terms of electronic health. Recent advances in e-health can be broadly defined as the application of information and communication technologies in healthcare systems (Varshney, 2009). Making use of the internet for storing, accessing and modifying healthcare information and digitizing many processes and tasks is a necessary step for realizing e-health. In this case, we have the advantages of e-health such as a rise in the quality of services in aging societies, reduction in cost and in medical errors and the ease by which data can be moved to the right place. However, digitizing paper-based records, collecting and storing medical information as well as lack of suitable technology for preventive care can become rather challenging.

After the emergence of the pervasive computing paradigm, pervasive healthcare technology has been proposed to support a wide range of applications and services including patient monitoring and emergency response. However, they simultaneously introduce several challenges including data storage and management, interoperability, availability of resources and ubiquitous access issues (Ziefle & Rocker, 2010).

Diabetes is one of the major chronic diseases in the world. Diabetes, often referred to by doctors as diabetes mellitus, describes a group of metabolic diseases in which the person has high blood glucose (blood sugar), either because insulin production is inadequate, or because the body's cells do not respond properly to insulin, or both. Diabetes manifests itself in three types:

Type 1: This type of diabetes is usually diagnosed in children and young adults, and was previously known as juvenile diabetes. Only 5% of people with diabetes have this form of the disease. In this type of diabetes, the body does not produce insulin.

Type 2: Is a problem with your body that causes blood glucose (sugar) levels to rise higher than normal. This is also called hyperglycemia. Type 2 is the most common form of diabetes; About 90 percent of people with diabetes have type 2 diabetes.

Type 3: Gestational Diabetes is a temporary condition that occurs during pregnancy. It affects approximately 2 to 4 percent of all pregnancies and involves an increased risk of developing diabetes for both the mother and child.

All forms of diabetes increase a patient's risk of emerging different health complications. Short-term complications such as hypoglycemia and hyperglycemia (very low and high blood glucose), and long-term complications such as eyes, heart, kidneys, nerves and feet failure are serious and life-threatening. The proper management of blood glucose levels reduces the risk of developing these complications. Factors such as the illness that patient suffers, treatment, physical and psychological stress, physical activity, drugs and diet (meal plan) can cause unpredictable and dangerous consequences such as hypoglycemia, hyperglycemia, and falling into a coma.

The management of diabetes is becoming an increasingly important problem worldwide. In 2014, according to the International Diabetes Federation, at least 387 million people (or 8.3% world population) suffered from diabetes and it is expected that by 2035, the number of diabetes will increase to more than 590 million.

Case Study: *This scenario originates from the Imam Reza hospital, one of the leading and technical hospitals in Mashhad, Iran.*
Mr. Toosi, a 62 year old man has suffered from type 2 diabetes for more than 10 years. In this period of time, he has caught different health complications such as diabetes foot, eye problems, high blood pressure, and heart problems. His prescription includes 20 units of insulin per day, 12 units in the morning and 8 units at night. In addition he has to check his glucose level on a daily basis. On one early morning, Mr. Toosi woke up with shortness of breath and weakness in his body. Without special attention, he had his breakfast and injects his insulin. After two hours he feels more pain and weakness in his chest and body, but because he is alone at home he prefers to wait until one of the family members returns home, before heading out for a check-up. When Mr Toosi's son arrives home, he immediately drives his father to the nearest hospital. At the hospital, the physicians and nurses run some treatments, however due to the lack of medical information and patient health records they are unable to make precise decisions and prefer to send the patient to the hospital where Mr. Toosi's main physician is available. Unfortunately, after sending the patient to another hospital he falls into a diabetes coma and passes away after a second heart attack.

The above scenario leads to a few issues that need to be addressed in pervasive diabetes health system. Here we focus on the following two problems:

- Monitoring patient remotely at home and detecting and managing different situations.
- Accessing patient health records and medical history at anytime and anywhere by legal persons.

The concept of cloud-based pervasive healthcare system is a new paradigm for the healthcare sector that uses cloud computing to treat, manage and control patients pervasively. The systems are supported by different algorithms, cloud infrastructures, smart homes, devices, and sensors and create several service types according to their context and environment. This paper presents a Cloud-based pervasive healthcare system architecture for treating diabetes, in order to manage and control diabetic patients and reduce the hypoglycemia and hyperglycemia conditions and consequently their risks. The system, which we will refer to as DICPer-Health, is designed to control patients pervasively at their homes. Three environments including a home, hospital and cloud structure are considered as main parts of this system, by which each of these sections has its own components and acts separately.

We have selected diabetes type 2 as the chronic condition cannot be cured and is the condition of 9/10 diabetes patients. In type 2 diabetes, the body cannot use insulin properly. This is called insulin resistance. Type 2 is treated with lifestyle changes, oral medications, and insulin injections. This type of diabetes usually gets worse over time, and in order for individuals with type 2 diabetes to control their blood glucose levels, they need to eat healthy, stay active, and use prescribed drugs appropriately. In this case we have considered three important factors in our framework; diet, activity, and insulin. These three factors control and manage the lifestyle of type 2 diabetes patients.

The following sections of the paper are organized as follows; Section (2) presents the pervasive healthcare projects and related works. Section (3) presents architecture to support diabetes treatment. The architecture parts are described in subsections. Section (4) presents the evaluation of work according to real life patient scenario. Finally, section 5 will conclude the paper.

RELATED WORKS

Today, there is a great amount of research work in the field of pervasive healthcare to improve e-health services; however only a few number target the use of cloud infrastructure as a new IT paradigm and are surveyed as below.

“The Integrated Cloud-based Healthcare Infrastructure” project, ICHI has been developed in Edinburgh Napier University of United Kingdom. ICHI presents a system that integrates a formal care system (DACAR) with an informal care system (Microsoft Health Vault) that enables not only sharing and access of health records right along the patient pathway, but also provides a high level of security and privacy within a cloud environment (Ekonomou, Fan, Buchanan, & Thuemmler, 2011). Another project in the University of Central Greece, “Bringing IoT and Cloud Computing towards Pervasive Healthcare”, IoTC, proposes a platform based on cloud computing for management of mobile and wearable healthcare sensors (Mu-Hsing Kuo, 2011). In another research project concluded at the University of Greece, namely “Managing Wearable Sensor Data through Cloud Computing” (MWSC), a wearable textile platform that collects motion and heartbeat data and stores them wirelessly on an open cloud infrastructure for monitoring and further processing was studied (Wan, Zou, Ullah, Lai, Zhou & Wang, 2013). "Cloud-Enabled Wireless Body Area Networks for Pervasive Healthcare (CWBAN)" is another article in the same context that focuses on a cloud-enabled WBAN architecture and its applications are within pervasive healthcare systems. CWBAN develops WBANs with MCC (Mobile Cloud Computing) capability, a Cloud-Enabled WBAN (Woon Ahn, Cheng, Baek, Jo & Chen, 2013). This project has also been developed in different universities including South China University of Technology, King Saud University, and the University of British Columbia. Another article namely "An Auto-Scaling Mechanism for Virtual Resources to Support Mobile, Pervasive, and Real-Time Healthcare Applications in Cloud Computing" (RTHA) proposes a novel server-side auto-scaling mechanism. The model is based on cloud computing with virtualization technologies in collaboration with the University of Houston and Korea University (Corredor, Tarrio, Bernardos, & Casar, 2013).

As mentioned above, the number of pervasive healthcare projects related to cloud computing for diabetes are few. Moving forward, we have scrutinized just two articles that introduce a personal health system (PHS) to manage diabetic patients. One of these projects at the University of London, is "COMMODITY_{12}: A Smart e-Health Environment for Diabetes Management" that emphasizes on designing the PHS to address major problems of both diabetic patients and doctors who treat diabetes (Kafah et al., 2013). COMMODITY_{12} consists of ambient, wearable and portable devices, which acquire, monitor and communicate physiological parameters and other health factors and vital body signals of a patient. In this system, there are intelligent agents that use expert biomedical knowledge to interpret data and then present a feedback from a patient's health status directly to the patient from the device (Kafah et al., 2013).

University of Murcia, Spain, has developed another healthcare project for diabetes, "An Internet of Things-based Personal device for Diabetes Therapy Management in Ambient Assisted Living (AAL)", that presents a personal diabetes management device based on the Internet of Things. The target is to support a patient's insulin therapy to decrease hyperglycemia and hypoglycemia counts and the risks involved (Jara, Zamora, & Skarmeta, 2011). This project focuses more on insulin dosage based on mobile assistance services. The project considers different factors such as the illness that patients suffer, drugs, treatments, stress, physical activity and meal (diet) for insulin therapy.

One related survey is "An Introduction to Cloud-Based Pervasive Healthcare Systems", that reviews different projects in healthcare sector with the focus on cloud computing (Poorejbari & Vahdat-nejad, 2014).

THE PROPOSED FRAMEWORK

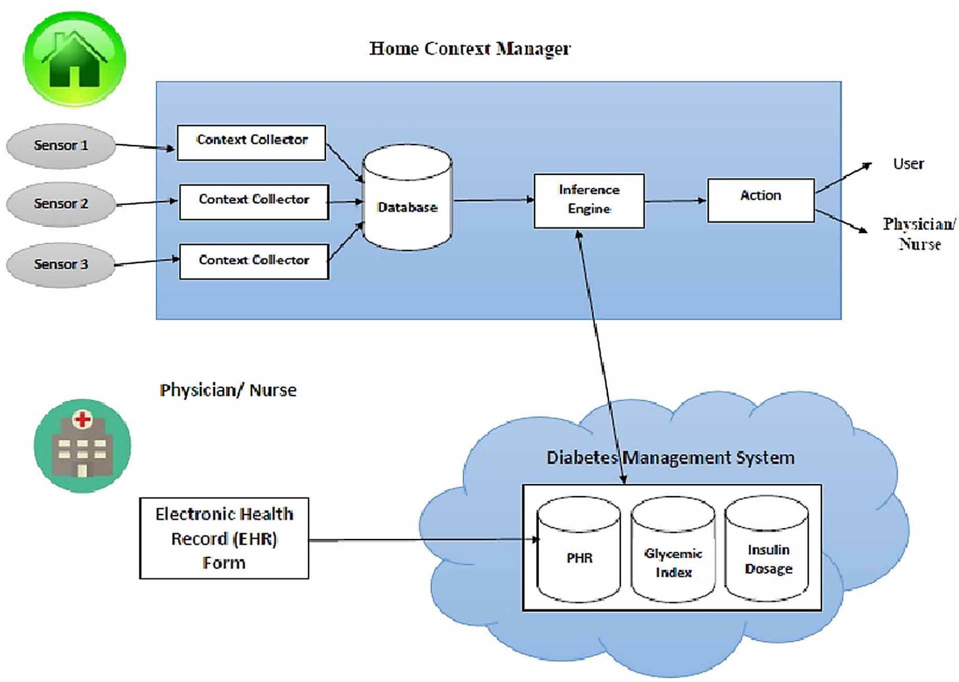
Overview

To introduce DICPer-Health, our first initiative is to present the general architecture of the system in order to briefly describe the main components. We will then concentrate on the description of three key components: Home Context Manager, Hospital Environment and Cloud Infrastructure.

Figure 1 depicts our proposed architecture for a smart healthcare environment. The figure consists of three main components which are connected via Internet: (i) The home context manager which gathers necessary information from patients while simultaneously providing feedback, (ii) a patient health record form that is accessible by nurses or physicians at the hospital, and (iii) a diabetes management system which is located with the cloud infrastructure for managing and accessing patient's information.

In our proposed architecture, the home context manager plays a major role in collecting, storing and processing data. Once the initial procedures are complete,

Figure 1. General Architecture of DICPer-Health



the system presents alerts, suitable treatments, and advices to the patient. The function of the home context manager and its components will be described in a later section.

Home Context Manager

The main role of the home context manager is collecting different information such as blood glucose level, blood pressure, and heart rates from patients through various sensors at specific times. After gathering patient health parameters, all the required information is stored in a context database. The inference engine then infers two different important conditions; High risk and emergency situations. According to the conditions and patient health history, suitable advices and alarms will be communicated to the patient's smart device or in an application connected to nurses or experts. The home context manager consists of the following components.

Wireless Sensors

Sensors are essential components in smart environments which sense and collect physical parameters. We utilize three types of wireless sensors in our framework, which gather fundamental physiological information from diabetes. The sensors are depicted in Table 1 and described below with the objective of sensing our requirements.

- Glucose monitoring by finger prick (GlucoTel Sensor).
- Blood pressure monitoring (PressureTel Sensor)
- Heart rate monitoring (Pulse Sensor)

None of the above sensors are expected to be considered obtrusive by the patients. Patients without any special knowledge can use them with ease.

Table 1. Schema of context table

Parameter	Date	Time			
		8 A.M.	10 A.M.	3 P.M.	10 P.M.
Blood Glucose					
Blood Pressure					
Heart Rate					

Context Collector

After sensing raw data by sensors, the context collector collects the data and delivers the information to the context database. 6LoWPAN is a technology for transferring sensed data to smart devices. This technology connects wireless clinical devices like glucometer to the smart environments or gateways. We proposed 6LoWPAN technology for sending data from the sensors to the context collectors and then by using SQL statements, context collector inserts data into the context database.

Context Database

This database consists of one table, namely the context table by which physiological parameters are the defined fields (Table 1).

The parameter field is designed to evaluate a patients important physiological factors such as blood glucose, blood pressure, and heart rate levels. The date and time fields reveal patient check-up timings. For diabetic patients monitoring and managing blood glucose is an essential task as blood glucose levels should remain within normal ranges. There are two types of blood glucose measures that are very important in a diabetic treatment; FBS[1] and the THG[2] level check-up. In this case we have proposed four specific times in order to measure these parameters. It begins early morning at 8 A.M. for an initial measuring FBS, 10 A.M. for measuring the 2 hours glucose level after breakfast meal, 3 P.M. for evaluating the 2 hours glucose level after lunch time, and 10 P.M. for evaluating the 2 hours glucose level after dinner. In addition the patient's blood pressure and heart rate levels will be checked simultaneously. After monitoring all the parameters via wireless sensors, the sensed data will be stored in a context table, by which the inference engine can use them for inferring suitable outcomes.

Inference Engine

The inference engine determines two principal situations; high risk and emergency based upon specified rules and algorithms. The inputs of the inference engine are the context table data and, the outputs of this function in high risk condition, is a patient form that shows alarms and useful advices such as practical diet, activity and correct insulin dosage, and in emergency situation, is a nurse or physician form that presents an alarm and dangerous factors to the nurse or experts.

In our proposed framework, the data interpretation is based on the specific rules and defaults. Moving forward, we will describe the basic definitions and default rules.

Table 2. Glucose different ranges

	Very Low	Low	Normal	High	Very High
Glucose Level	<70	70-90	90-126	120-200	200<

Table 2 presents the normal and abnormal range of blood glucose levels and the unit of blood glucose is measured as mg/dl (milligrams per deciliter). And all physicians and experts try to keep the patient blood glucose level at the normal range.

So, the rules of our proposed architecture are defined according to these ranges for distinguishing hypoglycemia and hyperglycemia conditions.

The other important parameter is the blood pressure levels that should be considered. Most diabetic patients have a high blood pressure problem that requires monitoring. The normal range of blood pressure is between 80-120 mmHg (millimeter of mercury), ranges are considered abnormal when reaching the upper range at approximately 135 mmHg. If the blood pressure of a patient becomes more than 135 mmHg, then the system recommends some treatments for this condition.

Heart rate is another essential factor in diabetes treatment. The normal range of a heart pulse is 60-100 beats per minute (bpm). In our system, we have labeled it as “Low”, if the number of the heart rate becomes less than 50 bpm, and “High” if the number of the heart pulse reaches more than 100 bpm.

Diet and meals play an essential role in diabetes treatment and control of blood glucose level. According to nutritional views, diabetes patients are required to have a specific amount of nutrients such as carbohydrate, fiber, sodium and protein in their daily meals. The proposed amounts of nutrients are classified in Table 3.

For daily activities, the body needs energy and this energy comes from foods. Each food has a specific amount of calories. The number of calories the body consumes in a day is different for every individual.

In our proposed framework, according to the calculated energy for each patient, the amount of carbohydrate that should be used by patients is at least 55 percent and at most 70 percent of a patient total energy. The amount of fiber is 20-30 grams,

Table 3. Range of nutrients in daily meals

Carbohydrate	Fiber	Sodium	Protein
55%- 70%	20-35 gr	2000-3000 mg	15%-20%

the amount of sodium is 2000-3000 milligrams and the range of protein is 15 to 20 percent of total daily calories.

The inference engine interprets acquired data according to various rules that we have described, and grouped into five rules in the following sections.

First, 2 different emergency situations are described in Case 1 and Case 2. And to continue 3 high-risk conditions are shown.

Case 1:

```
If (FBS is very high and PR is low and BP is high) or
    (THG is very high and PR is low and BP is high)
           Then
                 Emergency Situation;
```

Case 1 shows a condition where FBS or THG is very high and simultaneously the pulse rate is low and blood pressure is high. In this case we have labeled this condition as 'Emergency Situation', meaning fast and critical treatments are required.

Case 2:

```
If (FBS is very low and PR is high) or
    (THG is very low and PR is high) then
             Emergency Situation;
```

In Case 2, when the fasting blood sugar level is very low and the pulse rate is high, or when the two hours glucose level is very low and the pulse rate is high, then it is immediately labeled as an emergency situation. In this case the inference engine sends an alert to the nurses or physicians. As a result medical professionals become aware of the critical situation, allowing the experts to act immediately.

Case 3:

```
If (FBS is low and PR is high) or
    (THG is low and PR is high) then
             Diet:
                 (Use 15gr carb)
                 (Carbohydrate is high)
                 (Protein is high)
                 If (BP is high) then (Sodium is low)
                      Else (Sodium is medium)
            Activity:
                     Stop for at least 15 min.
```

```
            Insulin:
                  Increase 2-unit insulin dosage
```

Case 3 presents a condition where the FBS of a patient is low and the pulse rate is high, or the THG is low and PR is high. In this case suitable treatments related to the diet appear in the patient smart device. As a result the patient is notified that he/she should eat 15 grams of carbohydrates immediately in order to prevent hypoglycemia. The amount of carbohydrate and protein can be maximum for the other meals. There is a rule here, if the patient blood pressure is high then the amount of sodium must be at a minimum level, otherwise it is average. In this scenario, the patient must stop activity for at least 15 minutes. Insulin dosage can increase 2 units.

Case 4:

```
If (FBS is very high and PR is low) or
    (THG is very high and PR is low) then
           Diet:
                      (Carbohydrate is low)
                      (Protein is low)
                      (Fiber is high)
                      (Sodium is low)
           Activity:
                 Stop for at least 15 min.
```

Another high-risk condition is presented in case 4. In this case the FBS or THG is very high and PR is low, so for diet the amount of carbohydrate, protein, and sodium is low and the amount of fiber is high. With regards to patient activity, it is suggested that the patient does not perform any kind of sport or other related activities for the next 15 minutes. The patient may decrease 2 unit of insulin dosage for better control and treatment.

When the FBS and THG levels are high then a diet is proposed where by the amount of carbohydrate and sodium are maintained at a minimum level, and the fiber levels remain high. In this condition, if there is a kidney problem the amount of protein should be low.

Case 5:

```
If (FBS is high) or (THG is high) then
           Diet:
                      (Carbohydrate is low)
                      If there is a kidney problem then
                                  (Protein is low)
```

```
                    (Fiber is high)
                    (Sodium is low)
        Activity:
                Walking for 15 min.
```

Case 5 shows another high-risk condition where FBS or THG is high. In this condition carbohydrates should be kept at a low level and again the kidney problem should be considered. For fiber, it's high in daily meals and sodium is low. It is suggested that walking for 15 minutes can help to control the glucose level.

Hospital Environment

Before a patient can be monitored and treated in a smart home environment, medical experts are required to collect important and useful clinical information prior to initiation. All the health information related to diabetes will be gathered in a hospital environment. In our proposed work, we have designed a patient health record form that should be completed by a nurse or physician. A complete compilation of data including diabetes tests, health history, and insulin dosage information will be stored in a table, called the patient health record (PHR) The PHR is centralized within the cloud infrastructure in order to provide the health information necessary for detection alerts and treatments according to the medical professional analysis. In the next section we will look at the cloud structure.

Cloud Structure

The use of the cloud has provided many benefits to the proposed structure such accessibility, flexibility, globalizing, reducing costs and so on. The main goal of using cloud computing in our framework is, designing a diabetes management system in cloud structure that can be accessible at anytime, anywhere. We have proposed a public cloud like the GoogleAppEngine as a cloud infrastructure. In this case the diabetes management system consists of three databases that are described in following subsections.

PHR Table

This table consists of patient health information that are gathered by nurses or physicians. The PHR table includes three types of information; Personal information (Table 4), Tests information (Table 5) and the history of different diseases and problems (Table 6).

Table 4. Patient personal information

P-ID	Name/ Family	Birth Date	Height	Weight	Address

Table 5. Patient medical tests

HbA1C	FBS	GTT	UG	Keton	Chol

Table 6. Patient problems

Heart	Kidney	Blood pressure	Surgery

GI Table

Glycemic Index is a number associated with a particular type of food that indicates the food's effect on a person's blood glucose. Foods with low glycemic index and glycemic load are suitable for diabetes. The inference engine with use of the information retrieved from the GI table, advice may be provided regarding appropriate foods in diabetes meals.

ID3 Table

The insulin dosage table consists of all insulin information related to a patient. Information such as insulin dosage, insulin types, and insulin units can be provided for every meal as shown in Table 8. All required data are gathered by professionals for better cure and treat.

Table 7. Glycemic index for different food

Food	GI	Serve (gr)	Carbohydrate	GL

Table 8. Patient insulin information

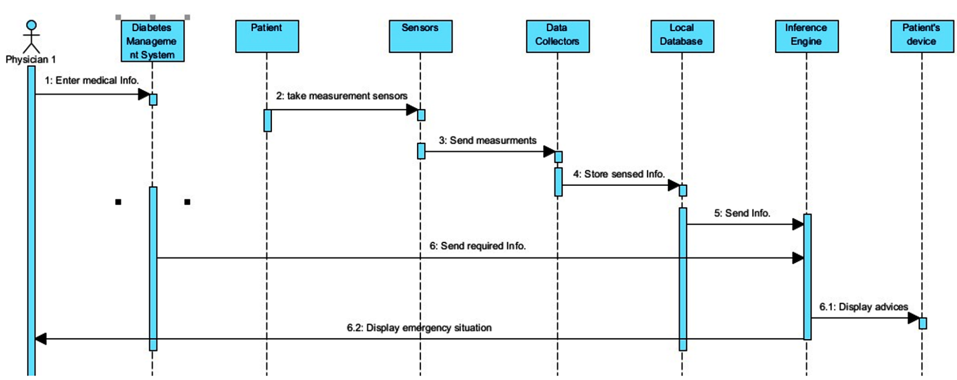
P-ID	Total Insulin	Insulin Units			Insulin Type	FBS	THG
		Morning	Noon	Night			

SCENARIO ANALYSIS

Based on the cloud-based pervasive healthcare framework we present, in this section, we analyze how it support the scenario described in the introduction. The whole operation process is illustrated by a UML sequence diagram shown in Figure 2.

When Mr. Toosi feels weakness and shortness of breath in the morning, according to our proposed framework he can measure his blood glucose, blood pressure and heart rate levels. According to the measured data, the proposed framework (home context manager) reveals the high risk factors, appropriate solutions and treatments in the patient's smart device. Under this scenario, Mr. Toosi is able to retrieve important information about his current condition, discover a treatment plan, and he may also ask for additional advice from his doctor about decreasing the high risk factors. In another condition where the family members decided to transfer their father to a hospital, the issue on arrival to the nearest hospital was the lack of information on Mr Toosi's condition. In this scenario all of Mr. Toosi's medical information will have already been stored in a diabetes management system. As a result, the information on the cloud will be accessible for physicians in emergency situations in order to support medical decisions.

Figure 2. Sequence diagram of framework



CONCLUSION

We have presented a structure supported by a cloud-based pervasive healthcare system that assists in controlling and managing diabetic patients. The aim is to empower their lifestyle and quality of life. The framework consists of different sensors, home context manager, hospital environment and cloud structures which acquire, monitor and process parameters. The data is interpreted by an inference engine that uses expert knowledge to derive important insights about the individual's health status. The data is presented as a feedback to the patient's smart device or physician portal.

Our work has focused on two important conditions, high risk and emergency situations and with the aim of reducing hypoglycemia and hyperglycemia conditions.

REFERENCES

Abowd, G. D., Dey, A. K., Brown, P. J., Davies, N., Smith, M., & Steggles, P. (1999). Towards a better understanding of context and context-awareness. In *1st International Symposium on Handheld and Ubiquitous Computing*. doi:10.1007/3-540-48157-5_29

Alicja Muras, J., Cahill, V., & Katherine Stokes, E. (2006). A toxonomy of pervasive healthcare systems. In Pervasive Health Conference and Workshops.

Bali, R., Troshani, I., & Wickramasinghe, N. (2013). *Pervasive Health Knowledge Management*. Springer. doi:10.1007/978-1-4614-4514-2

Bamiah, M., Brohi, S., & Chuprat, S. (2012). A study on significance of adopting cloud computing paradigm in healthcare sector. In *International Conference on Cloud Computing, Technologies, Applications & Management*. doi:10.1109/ICCCTAM.2012.6488073

Coronato, A., De Pietro, G., & Sannino, G. (2010). Middleware services for pervasive monitoring elderly and ill people in smart environments. In *Seventh International Conference on Information Technology*. doi:10.1109/ITNG.2010.139

Corredor, I., Tarrio, P., Bernardos, A. M., & Casar, J. R. (2013). An open architecture to enhance pervasiveness and mobility of health care services. *Communications in Computer and Information Science*, *413*, 296–307. doi:10.1007/978-3-319-04406-4_30

Dooley, J. (2012). *Intelligent Environments Group*. University of Essex. Retrieved 6 18, 2014, from http://iieg.essex.ac.uk/idorm.htm/

Doukas, C., & Maglogiannis, I. (2011). Managing wearable sensor data through cloud computing. In *International Conference on Cloud Computing Technology and Science*. doi:10.1109/CloudCom.2011.65

Doukas, C., & Maglogiannis, I. (2012). Bringing IoT and cloud computing towards pervasive healthcare. In Innovative Mobile and Internet Services in Ubiquitous Computing. doi:10.1109/IMIS.2012.26

Ekonomou, M., Fan, L., Buchanan, W., & Thuemmler, C. (2011). An Integerated Cloud-based Healthcare Infrastructure. In *Third IEEE International Conference on Cloud Computing Technology and Science*. doi:10.1109/CloudCom.2011.80

Guo, B., Sun, L., & Zhang, D. (2010). The Architecture Design of a Cross-Domain Context Management System. In *8th IEEE international conference on pervasive computing and communications workshops*. doi:10.1109/PERCOMW.2010.5470618

Imam Reza Specialized & Sub-Specialized Hospital. (n.d.). Retrieved 3 05, 2014, from http://www.imamreza.ajaums.ac.ir

Jara, A. J., Zamora, M. A., & Skarmeta, A. F. G. (2011). An Internet of things-based personal device for diabetes therapy management in ambient assisted living (AAL). *Personal and Ubiquitous Computing*, *15*(4), 431–440. doi:10.1007/s00779-010-0353-1

Kafah, O., Bromuri, S., Sindlar, M., Weide, T., Aguilar Pelaez, E., Schaetchle, U., … Stathis, K. (2013). COMMODITY12: A smart e-health environment for diabetes management. *Journal of Ambient Intelligence and Smart Environments,* 479-502.

Le Bellego, G., Noury, N., Virone, G., Mousseau, M., & Demongeot, J. (2006). A model for the measurement of patient activity in a hospital suite. *Information Technology in Biomedicine,* 92-99.

Mell, P., & Grance, T. (2011). *NIST*. U.S Department of Commerce. Retrieved June 15, 2015 from http://www.nist.gov/itl/csd/cloud-102511.cfm

Mileo, A., Merico, D., & Bisiani, R. (2010). Support for context-aware monitoring in home healthcare. *Journal of Ambient Intelligence and Smart Environments,* 49-66.

Mu-Hsing Kuo, A. (2011). Opportunities and challenges of cloud computing to improve health care services. *Journal of Medical Internet Research*. PMID:21937354

Pardamean, B., & Rumanda, R. (2011). Integrated model of cloud-based e-medical record for health care organization. In *10th WSEAS International Conference on E-Activities*.

Poorejbari, S., & Vahdat-nejad, H. (2014). An Introduction to Cloud-Based Pervasive Healthcare Systems. In *4th international workshop on pervasive and context-aware middleware (PerCAM 14)*. doi:10.4108/icst.iccasa.2014.257442

Rantz, M., Skubic, M., Koopman, R., Phillips, L., Alexander, G., Miller, S., & Guevara, R. (2011). Using sensor networks to detect urinary tract infections in older adults. In *13th International Conference on e-Health Networking, Application and Services*. doi:10.1109/HEALTH.2011.6026731

Rashidi, P., & Cook, D. J. (2009). Keeping the Resident in the Loop: Adapting the Smart Home to the User. *IEEE Transactions on Systems, Man, and Cybernetics. Part A, Systems and Humans*, *39*(5), 949–959. doi:10.1109/TSMCA.2009.2025137

Rashidi, P., & Mihailidis, A. (2013). A survey on ambient-assisted living tools for older adults. *IEEE Journal of Biomedical and Health Informatics, 17*(3), 579-590.

Shadab Ansari, W., Alamri, A. M., Hassan, M., & Shoaib, M. (2013). A survey on sensor-cloud: Architecture, Applications and Approaches. *International Journal of Distributed Sensor Networks*.

Singh, S., Puradkar, S., & Lee, Y. (2006). Ubiquitous Computing: Connecting Pervasive Computing through Semantic web. *Information Systems and e-Business Management, 4*(4), 421-439.

Tamura, T., Kawarada, A., Nambu, M., Tsukada, A., Sasaki, K., & Yamakoshi, K. I. (2007). E-healthcare at an experimental welfare techno house in Japan. *Open Medical Informatics,* 1-7.

Vahdat-nejad, H., Zamanifar, K., & Nematbakhsh, N. (2013). Context-aware middleware architecture for smart home environment. *International Journal of Smart Home, 7*, 77-86.

Varshney, U. (2009). *Pervasive Healthcare Computing: EMR/EHR*. Wireless and Health Monitoring. doi:10.1007/978-1-4419-0215-3

Wan, J., Zou, C., Ullah, S., Lai, C., Zhou, M., & Wang, X. (2013). Cloud-Enabled wireless body area networks for pervasive healthcare. *IEEE Network*, *27*(5), 56–61. doi:10.1109/MNET.2013.6616116

Woon Ahn, Y., Cheng, A. M. K., Baek, J., Jo, M., & Chen, H. (2013). An auto-scaling mechanism for virtual resources to support mobile, pervasive, real-time healthcare applications in cloud computing. *IEEE Network*, *27*(5), 62–68. doi:10.1109/MNET.2013.6616117

Zhang, R., Lee, M., & Liu, L. (2010). Security models and requirements for healthcare application clouds. In *3rd International Conference on Cloud Computing*. doi:10.1109/CLOUD.2010.62

Zhang, Y., Lee, M., & Gatton, T. M. (2009). Agent-Based Healthcare Systems for Real-Time Chronic Diseases. In *2009 World Conference on Services-I*. doi:10.1109/SERVICES-I.2009.104

Ziefle, M., & Rocker, C. (2010). Acceptance of pervasive healthcare systems: A Comparison of Different Implementation Concepts. In *4th international conference on pervasive computing*. doi:10.4108/ICST.PERVASIVEHEALTH2010.8915

ENDNOTES

[1] Fasting Blood Sugar
[2] Two Hour Glucose
[3] Insulin Dosage