An Approach to Integrate Wireless Sensor Networks with Cloud Computing Technology in Medical Context

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ABSTRACT:
Recently, with the advent of cloud computing technology and the growth of cell phone applications, the technology has been introduced as a solution for use in smart phones. Combining cloud computing and smart phones copes with such obstacles as performance including battery life time, storage capacity and bandwidth, environment as scalability and availability, and security like reliability and accessibility. Today, patient information collection processes require extensive analysis on the collected input data. In addition, this process has lots of errors, it is affordable and increases the time needed for access to the data. These conditions constrain effective monitoring and diagnostic capabilities by the hospitals. Unlike previous methods, data can be collected by devices such as Bluetooth and stored on a server in hospital. In this paper, a comprehensive research involves collecting data from patients and sending this data to a smart phone. Therefore, two algorithms were proposed for a list of physicians with the highest priority. Priority parameters are received by the hospitals server. These priorities include the initial weight, the weight indicating how busy the physician is, and the relationship between physician and patient's disease. Android application was simulated by Eclipse software. The application includes a diagnostic system that receives patient data and compared it with the reference table. If the patient's condition is not good, a short message is sent using two mentioned algorithms.

KEYWORDS: Cloud Computing, Wireless Sensor Networks, The Military Health Care System.

1. INTRODUCTION

Emergency and crisis management is the most important part in medical field. In emergency those who need help must be aided in a very short time. Therefore, a solution should be provided to immediately transfer them to hospital and medical centers. The greatest challenge in the emergency is time. If we delay delivering service to patients, irrecoverable losses such as death would be resulted. In fact, when emergencies occur, patients need special care and quick. In this case, the patient or their entourages try to quickly communicate with emergency. But sometimes the patient is in critical condition and is not able to contact hospitals and emergency medicine. This happens for the elderly and disabled individuals. Sometimes, patients have their medical information; however, the best situation is that the information be always available which Internet is an efficient idea for here.

Electronic Medical care has become an important part of health care centers. In this system, patient information, such as naming, medicine prescription, appointments, medical tests or surgery are stored in their personal record. Patients and physicians communicate with each other through web-based Technology and can view medical records. Physician can insert medicine prescription in the medical records. Patient also could insert their information such as temperature, blood pressure, etc. without going hospital.

1.1 Introduction to cloud computing

Traces of cloud computing and grid computations can be followed from 1960. When American scientists, John McCarthy stated that the calculations can be converted into a public service and people are provided with them. In the mid-1990s, grid was used to describe technologies that allowed customers to obtain the required computing power. Ian Foster et al [4]. have believed that the standardization of protocols used for computing power demand, can accelerate development of grid

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computing. Nowadays, grid calculations and cloud computing are discussed in scientific communities and many large companies are working on them. They have obtained good results and provided some products.

Buyya et al. have suggested that cloud is a kind of parallel, distributed system including a set of integrated virtual computers provided as one or more dynamic computational unit source [5]. This system is based on reasoning of service level and is built to negotiate among service providers and consumers. Cohen et al. however believe that cloud computing is one of the achievements that tries to progress in various aspects (load balancing, business model, architecture model, etc.). It is also a new step for providing software. The simplest definition of cloud computing is Internet intra-software [3].

1.2 Three models in cloud computing services:

• Software as a Service (SaaS): This provides the possibility for the consumer to use provider's applications that are running on cloud infrastructure. Applications are available through devices and a web browser. Consumer has no control or management on cloud infrastructure including network, servers, operating system, storage or even the original application settings, except for some limited users who have access to the application settings.

• Platform as a service (PaaS): consumer will have the ability to develop cloud infrastructure through programming languages, libraries and various tools. Again, in this layer consumer has no control or management on cloud infrastructure including network, servers, operating system, storage except for developing the application and its control settings.

• Infrastructure as a Service (IaaS): In this layer, the consumer can control on the network, servers, operating systems and storage.

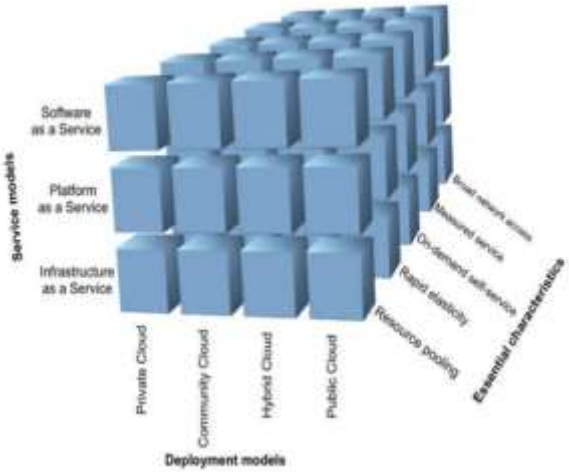

Fig. 1. Three services models in cloud computing.

1.3 The role of wireless sensor networks in medical care system

Existing processes for collecting patients' medical information need efforts to collect input data, processing and analyzing the collected data. These types of processes are often subject to errors while working and also spend considerable time for collecting data to be input. Today, in the body area networks (BAN) patient's medical information is simultaneously collected via medical sensors. Continuous patient's movements make wireless sensors necessary to the health care system. This demand causes new medical wireless networks implementations which have different architecture, capability f managing multi sensors, and monitoring various body signals with health care applications on smart phones.

In the last two decades, due to the direct impact of the health care system by phone, the number of patients who were hospitalized has been considerably reduced. Long-term monitoring on patients having physical, physiological and psychological problems is very important. Fig. 2 shows an overview on medical monitoring architecture using cell phone which [10], patient's medical information is collected by wireless sensors such as blood pressure monitor system, etc. The external devices have sensors and Bluetooth [11]. Smart phones that perform medical applications send received data to hospital server using internet. Medical personnel, who have access to data server via a secure online connection, monitor the patient's health status remotely.

Fig. 2. Patient monitoring system using smart phones.

2 OVERVIEW OF THE MEDICAL SYSTEM IN THE CLOUD COMPUTING

The cost of maintaining data centers at most hospitals are often divided in two parts, cost of infrastructure and ICT expert staff. Large storage capacity provided by a cloud service provider (CSP) for demanders makes an extraordinary opportunity to save the cost of maintenance in organizations.

Cloud services provider companies can offer better security, management, and maintenance services using powerful computational systems and vast capacities as well as expert and experienced personnel for maintaining and organizing information. Resource virtualization and processing systems makes the system cost become less than the cost of common infrastructure maintenance and staff salary [2]. At the same time the users may have the ability to control and maintain their own information, or when the database in data centers of hospitals is destroyed, they may lose their vital data and have no access to them.

Concepts of electronic health record (EHR), Electronic Medical Record (EMR), electronic personal record (PHR) are defined in HIPAA. EHR and EMR are commonly used in medicine both mean same thing, however they are completely different in their meanings in HIPAA. Fig 3 shows the relationship between the three records.

Electronic health record (EHR)

EHR as personal electronic health information is created, collected and managed by the personal health organization. This is a legal record that identifies what happened to the patient at the time they were in the medical organization.

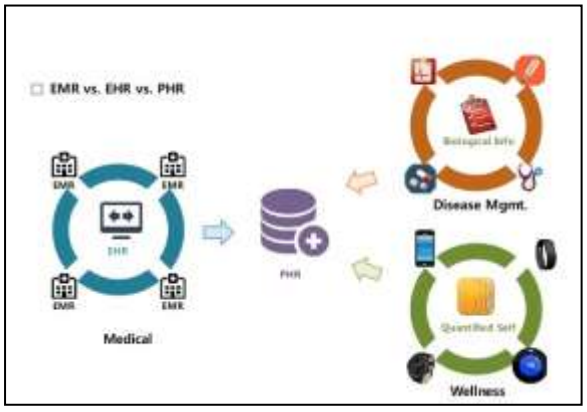

Fig. 3. Relations between EMR, HER, PHR.

Electronic Medical Record (EMR):

EMR is a series of individual electronic health information that is made, collected and managed by more than one health organization. EHR is a combination of several EMR built and maintained by the individual.

Electronic Personal Record (PHR):

PHR is personal electronic health information that is created and maintained by themselves. PHR contains all the medical history of the person obtained by EMR and EHR resources. The individual is responsible for the maintenance of electronic records. Microsoft Health Vault and Google Health are two examples for PHR.

3 THE PROPOSED APPROACH TO HEALTH CARE SYSTEMS

Information stored via applications on smart phones needs to be processed and some specific operations is performed based on whether abnormal information exist. A copy of the information received from the sensors is sent to the cloud to be accessible to the hospital. If an abnormal parameter data have received, smart phone send information via short message service (SMS) to medical organizations. HIPAA rules determine the amount of users' access to medical records. Therefore, some qualified individuals can access the data and receive the SMS sent by smart phone. Search Algorithm for physicians and auxiliary forces and proposed ranking algorithm could solve the problem by finding the highest priority. Short message is received by someone who has the highest priority among all of the parties.

3.1 The structure of health care systems based on smart phones and cloud computing

Any smart phone has a diagnostic application and several health care programs. All health care programs provide their information to diagnosis program. Then the diagnosis program processes the input data and according to defined input information and standards, it determines individual's conditions.

Generally, medical care system based on smart phones and cloud computing works as follows:

• smart phone using health care applications acquires heart rate or blood pressure. This layer is responsible for the communication of diagnosis layers using transformation of data obtained from the sensor leads.

• Diagnosis layer is designed to remove the demands of smart phone applications automatically.

• Diagnosis layers based on the current smart phone devices and data storage resources are limited.

• diagnosis application running on the smart phone reviews received data and determines its level by using reference table including some medical record. If there is abnormal data, medical records are sent to hospital. Smartphone transfers the information via SMS, including patient's medical parameters and the abnormal data. Diagnosis program sends a copy to EMR system that is running on a cloud in the hospital.

• Cloud layer can be provided as both PaaS and IaaS. This layer has such characteristics as large storage capacity, and large range for cloud computing. It is utilized to mass calculations without the limitations of synchronization [6].

• Data in cloud layer will be accessed by insurance companies and hospitals. HIPAA determines how the information to be accessed based on general regulations. Usually hospitals control patient's health status continuously [7].

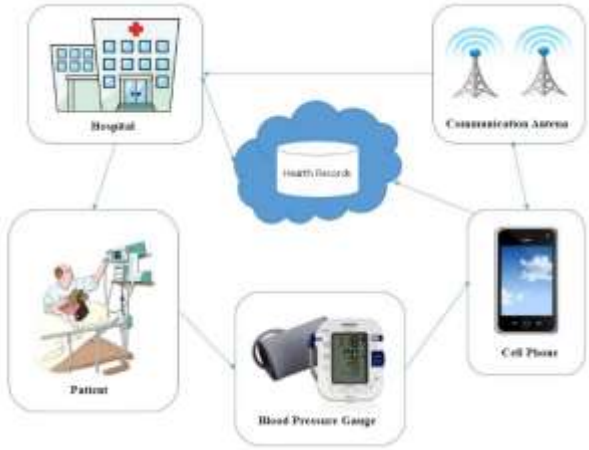

Fig. 4. Medical care system based on smart phones and cloud computing.

3.2 Reference table for diagnostic system

Reference table is a part of diagnosis that is running on a smartphone. The table contains some actual parameter for blood pressure, glucose and heart rate. The main task of the table is to determine whether the received data are normal or abnormal.

Table 1. Reference table for diagnosing blood pressure.

High	Low	The blood pressure
12≤	≤ 8	Normal
12,13.9	8,8.9	Typical
14,15.9	9,9.9	Relatively High blood pressure
16≥	10 ≥	High blood pressure
18>	11>	Very High blood pressure (emergency)

Table 2. Reference table for diagnosing blood sugar status.

Amount	Blood sugar
70 mg , 200 mg><	Normal
70 mg<	Low blood sugar
200 mg<	High blood sugar

Table 3. Reference table for diagnosing heart status.

Low	The heart rate
60 and 100><	Normal
100>	High heart rate
40 and 60><	Low heart rate
40<	Very Low heart rate

3.3 Search algorithm physicians and reinforcements

HIPAA specifies that only certain authorities, physicians and patients can have access to patient information. This capability ensures users and health organizations that only medical personnel can access to patient information. For example, if the sensors show that the patient's heart is stopping, the information must be sent to the cardiologist.

The proposed algorithm is the search key part of the system that determines whether abnormal data exist to provide information by SMS. Diagnostic system receives the data in .xml format. This information is received and data extracted from medical applications including blood pressure, blood sugar and heart rate. The medical parameters are called keywords. These keywords will be sent to the reference table. Reference table includes all parameters, actual medical and abnormalities. If the value of medicine parameter is natural, the data is ignored by the algorithm. If the medical parameter is abnormal, the parameter is taken into account for keyword in the search algorithm. By keyword the algorithm finds a list of physicians that abnormal data is sent to them. Search Algorithm for physicians and auxiliary forces follows the Google page ranking algorithm idea, which acts on the Internet as follows:

• find all pages that match the keyword
• rank based on factors pages
• Calculate the amount of anchor text
• Match the results using pages ranking

For each ranking Google page algorithm, the graph G = (n, e) for every user search is made on the Internet, where n includes a set of nodes that represent Web pages, and e is an edge between two nodes. Each node (web page) has a certain weight. Nodes weights will change based on relation 1:

$$PR(A) = (1-d) + d(PR(T_1)/C(T_1) + ... + PR(T_n)/C(T_n)) \quad (1)$$

Where:

• PR (A) is the Page Rank A
• PR (Ti) is Page Rank of pages (Ti) that are connected to A
• C (Ti) is the number of external links that are connected to Ti
• d is the equilibrium factor between zero and one (usually 85 percent)

In the proposed system, each diagnostic system receives medical information from hospital database. The graph G0 = (n0, e0) where n0 is the number of physicians and e0 is edge between two nodes that represent the relationship between the physicians. Each node has a certain weight W_{ni}

which has received from the hospital server database. Server database determines the availability of physicians or hospital medical personnel as well as all the nodes in the graph.

Inputs:
Am: abnormal keyword
Xm: amount of abnormal keyword
G0 = (n0, e0): with n nodes and Starter node, n_s, for n1 … nm and edges are shown as e1 …em.
A node containing various attributes:
o A unique identifier DocIDi
o keyword Ai and its value Xi
Outputs:
3 nodes are ranked based on the highest priority by establishing connected sub graph

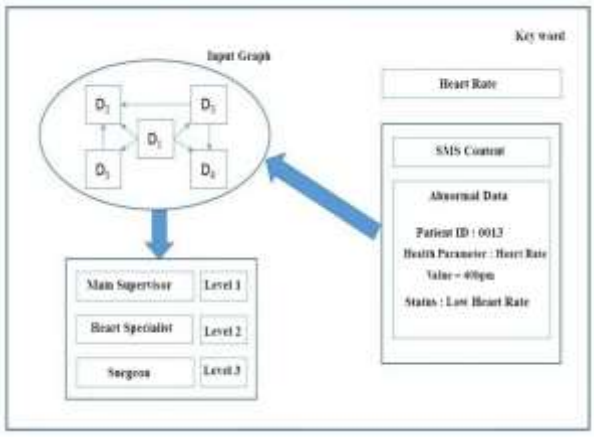

Fig. 5. Search system the doctor to diagnose the system status.

3.4 Physicians and auxiliary forces ranking algorithm based on priority

The patient may be in an emergency and he does not know who is in critical condition. Diagnosis using values sensed from the device determines whether patient is in critical condition. If the diagnostic system determines the status as critical, a general report with patient's address from GPS sensors on the smart phone will be sent to hospital. The main idea of this algorithm is that medical data must be reliable and only those have access to that information, who have permission.

Figure 6 shows how the physicians ranking algorithm works on a priority basis. Diagnosis stores medical information and its value during the last n hours (n is determined by the hospital operator) to form [x1, x2, ..., xn] that x_i is different medicine parameter values. This form is sent to the reference table. All natural data are removed and abnormal data is held in the form. GPS sensor is activated and the patient will be positioned. Then, the system provides the overall report containing the collected data, including sensed data in the last n hours and the address.

In the priority based ranking algorithm for physicians, a new graph is created using the input graph and the keywords with their values. New graph is established by merging all nodes with keyword and the weight of each node is calculated. This process is repeated for all keywords. If n is the number of keywords, n graph is made, and all these will be merged to make the final graph. The weight of each node in the merged graph is then calculated. Next, the nodes are calculated based on the weight of the highest ranked weight. Priority based ranking algorithm for physician's works as follows:
Inputs:
The graph G0 = (n0, e0): each node has the weight of W0i where i is a node with unique ID that is DocIDi. Each side has an initial weight W0k, m which connects the node k to node m.
A node contains different attributes:
o unique id as DocIDi
o Multiple keywords Ai ... Am and their values Ai [x1, x2, ... xn] ... Ap [y1, y2, ... yn]
Outputs:
3 nodes ranked based on the highest priority

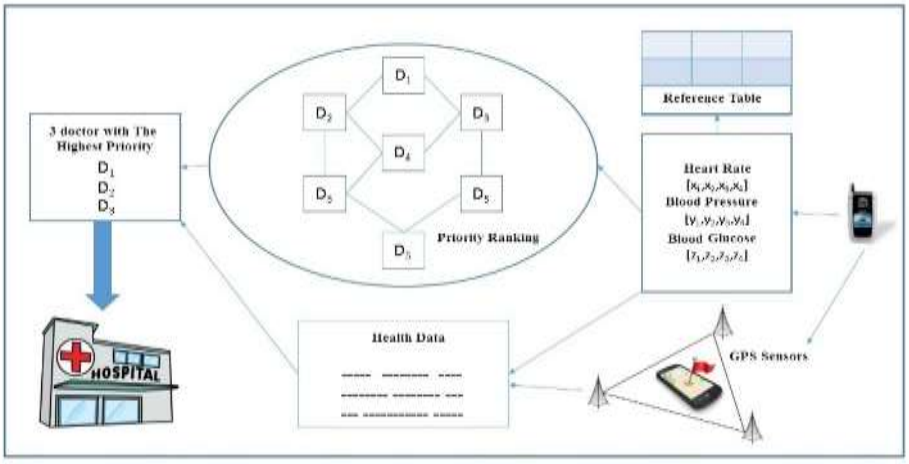

Fig. 6. Flowchart of priority based ranking algorithm for physicians

3.5 Simulation the service based on Pivotal open framework

Pivotal is a service based on open platform that has been proposed by Vmware [12]. It provides an environment where multiple languages and frameworks can be run inside or outside the firewall. Pivotal main features are as follows: Choose the development framework, selection infrastructure program services and selection clouds. Using Pivotal the constraints existing in PaaS disappears. The main feature in Pivotal is that it supports the spring and MySQL frameworks. This makes applications based on Java Spring framework can act in Pivotal. EMR systems have been implemented as a web application on Pivotal. EMR systems are intended to manage each patient's medical information. The data are stored by the smartphone and the cloud. Here, the cloud serves as a storage space and stores patient's vital information in disk space.

Fig. 7. Patient' general information on the PIVOTAL.

Fig. 8. Patient's medical information on PIVOTAL.

3.6 Diagnostic software on Android

Status recognition application has been simulated using Eclipse software. This program reads vital patient's information such as blood pressure, heart rate, blood sugar, etc. using sensors on the patient's body and sends them to the smart phone. The diagnostic program compares input data with the reference table, and if the abnormal data is observed, it sends an SMS to the corresponded physician.

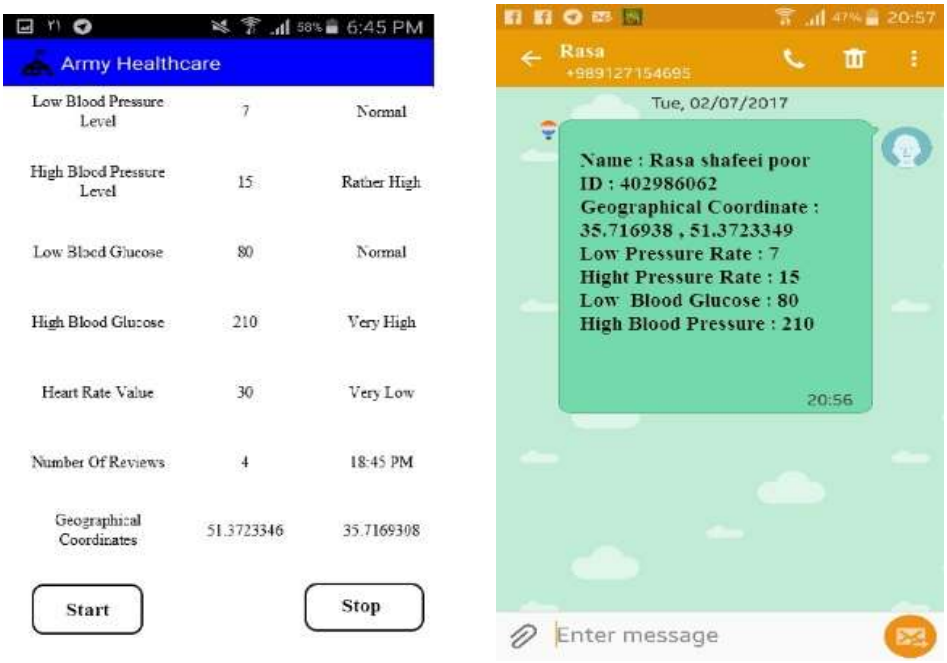

Fig. 9. The diagnostic program on Android.

4. CONCLUSION AND FUTURE WORKS

In this paper, a special approach for medical systems has been offered using cloud computing and smart phones. Smart phone was used as monitoring devices for patients [8]. The patient's medical information was stored and used in a hospital EMR system. If abnormal data was received, the smart phone using diagnostic system on it would send a SMS to the hospital and corresponded physician. HIPAA regulates the users' access to medical records sets. Therefore, only some qualified individuals can access to information. For this purpose, two physicians searching and physicians ranking algorithms were introduced on a priority basis. Using defined weights, the algorithms determine to which physician the short message should be sent. Simulation was performed on an Android phone using Java Eclipse. The input data supposed to receive from the hospital server, was manually entered the program to simulate physicians searching with the highest priority. After finding the corresponded physician, SMS is sent containing patient characteristics such as first name, last name, home address, disease type, etc. The proposed approach allows the patient to be monitored throughout day and night, recording the vital data regularly in medical record. By this way, the patient does not need to refer to physician and provide the medical information gathered manually. In such circumstances, the patient regularly interacts with their own physician, and the physician can be notified about the recovery. The proposed approach reduces the cost of lives, time and money for patients, hospitals and healthcare organizations.

For the rest of this article, the following suggestions are offered:

• It is expected that the data sent through the smart phones be secured [9]. Security protocols in this work are highly recommended. Because if the patient's vital information is stolen, it makes the system unreliable and the system performance is highly reduced.

• In addition to the EHR system, it is recommended that PHR system is also designed and used in the cloud.

• The algorithms can be greatly improved in terms of efficiency and temporal complexity.

• It is better to send a short message by the smart phone using encryption protocol which the information is coded before sending messages and data are secured. • The system must act in such a way that it can withstand the enormous workload and avoid mistakes in a mass scale and in real terms. Thus, it is better to use guidelines for balancing the load on the servers to maximize the efficiency of the system and to avoid the server disturbance by too much traffic.

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