A Secure Health Care Application Architecture for Integrating WSN's with Cloud Computing

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Abstract - In recent years, many healthcare organizations have started using wireless senor networks to remotely monitor patient health and also started using cloud as centralized database for storing the electronic medical record (EMR). The general scope of our work is to propose an architecture to integrate the healthcare cloud with wireless sensor network (WSN) technology through smart phones. The healthcare apps on smart phones monitor patients' health wirelessly providing real-time updates of the patients' health condition to the doctors and other medical professionals via the cloud. The proposed architecture contains a filter system running on the smart phones, which takes the patient's health records from the smart phone apps and compares with a lookup table, which contains the normal readings of the different health parameters. If the incoming health readings to the filter are found to be abnormal, then an alert SMS is sent to the doctors with whom the patient is associated and a copy of the record is also sent to the cloud running an EMR system maintained by the hospital. If the filter determines the situation to be critical, a consolidated report is sent to the doctor through SMS, along with the location (address) of the patient, sensed through the GPS(Global Positioning System) sensor running on the smart phone.

Keywords: Wireless sensor network (WSN), Electronic Medical Record (EMR)

1. INTRODUCTION

Existing processes for gathering patients' health data require a great deal of work that includes collecting the health data inputs, processing and analysis of the information collected [1]. These kinds of processes are usually error prone and considered to be slow. However, today's biomedical sensor solutions are effective for only an individual measurement (for example EEG, ECG, PCG and the like) but are not integrated into a complete body area network, where many sensors work simultaneously collecting information about an individual patient. Patient mobility also brings in the need for sensors in biomedical monitoring to become wireless. This creates the need for the implementation of new biomedical personal wireless networks with a common architecture and the capacity to handle multiple sensors, monitoring different body signals, with different healthcare apps running on smart phones [2]. To overcome this, this work proposes an architecture that integrates wireless sensors that communicate with the patient's smart phone and integrates them with the cloud computing paradigm and the hospital information system. The information is therefore made available in the cloud where it is processed and accessible to doctors and other medical professionals.

2. RELATED WORKS

The existing system in healthcare involves manual note taking, updating the notes to the computer and maintaining the records under a unique id assigned to every patient. Figure 1, shows the process of data collection in healthcare institutions that use manual note taking [7].

Usually this process is very slow and error prone and there is latency between data gathering and information accessibility.

Figure 1: Current Scenario for Patient's Data Collection in Hospitals [7].

Implantable and wear-able monitoring devices such as UbiMon [5] are used to generate vital patients' data required for clinical decision making. With the UbiMon architecture [5], the sensors are placed on the subject and it delivers real-time data to the local processing unit (LPU) via a wireless radio frequency (RF) link. The LPU then processes the incoming data streams and sends it over the wireless networks. The central server (smart phone) receives the real-time sensor data and stores it to the database, with which long-term trend analysis on historical data can be conducted. This allows the prediction and identification of potential life-threatening conditions.

In the last two decades, there has been a steady decline in the number of patients getting admitted and treated in hospitals due to the influence of mobile healthcare. Long-term monitoring of patients' physical,

physiological, psychological, cognitive, behavioral process is crucially important for those with chronic diseases [8, 9]. Figure 1, shows the process of data collection in healthcare institutions that use manual note taking [7].

Figure 2: WSN in Smart Phones Monitoring Patient's Health [9].

Figure 2, shows an overview of health monitoring architecture with a smart phone [9] which has links to external wireless sensor devices, such as a blood pressure monitor, weight scale, etc. to collect periodically health data. These external devices have sensors, which are Bluetooth enabled. The smart phones running healthcare apps monitor the wellbeing of the patient and transmit the data to the healthcare Data Server maintained by the hospital via the internet. The medical personnel access the Data server via a secure internet connection to monitor the patient's health remotely.

AMON [4] is a wrist-worn WSN medical monitoring system specially designed for patients with cardiac disease and respiratory problems. This system includes continuous collection and evaluation of several vital signs and it is connected to the medical center.

BeTelGeuse ([10], [11]) is a platform for gathering and processing situational data. BeTelGeuse runs on smart phones and gathers health data from a body area network over Bluetooth. It transmits the gathered health data to a server for further processing. The main advantage of BeTelGeuse system is that it can be extended to use new sensors and it runs on several platforms. BeTelGeuse's major disadvantage is that the server does not offer a general architecture for data processing and analysis and also the approach doesn`t consider major aspects like scalability and data security.

3. PROPOSED ARCHITECTURE

We have proposed an architecture which integrates wireless sensor networks running on smart phones, with cloud computing. The health data obtained from the healthcare apps running on the smart phones needs to processed and based on abnormality of the data, necessary actions needs to be taken. A copy of the sensor data is sent to the cloud from where the hospital accesses it. The proposed architecture integrating the smart phones and cloud solves the problem using the proposed filter system. If there is any abnormality in the health parameter, the smart phone sends an alert SMS to the healthcare organization. Medical Council defines a set of rules on who has access to the patient's health records. Therefore, only authorized medical personnel should receive the alert SMS sent by the smart phones. The proposed key search and priority ranking algorithm solves this problem by finding the highest weighted list of medical personnel to whom the alert SMS needs to be send.

For the integration of wireless sensor network with the healthcare cloud, we have proposed a three-tiered cloud based system. Each smart phone has a filter app and one or more healthcare apps running on them. All the healthcare apps are tied with the proposed innovative filter app which receives the healthcare data from different healthcare apps running on the smart phone. The filter provides patients and healthcare provider's insight into physiological and physical health states that are critical to the detection, diagnosis, treatment and management of ailments.

In particular the proposed architecture has the following:

- A smartphone layer senses the user's heart rate, blood pressure rate, glucose monitor, body temperature etc. using the healthcare apps. This layer establishes communication with the filter layer by sending the sensor data to the filter.

- The filer layer is designed to meet real-time requirements of the applications running on the smartphones.

o The filter layer is based on existing smart phone equipment and provides resources for limited data storage, caching, and processing power.

o The filter running on the smartphone checks the received data from healthcare apps with the thresholds of the respective health record using a lookup table containing different health record and their levels. If there is any abnormality in the health condition, the smart phone sends the health record to hospital. It sends the health record through an emergency alert message (SMS) containing the health parameter and its abnormal value to the hospital.

o The filter uses elliptical curve, an asymmetric cryptography technique and sends a copy to the EMR System running on the cloud for the hospitals reference. Hence the data is encrypted before sending it to the cloud for security reasons. We used an asymmetric algorithm as they are ideally suited for real-world use, as the secret key does not have to be shared. Every user only needs to keep one secret key in secrecy and a collection of public keys that only need to be protected against being changed. We used Elliptical Curve

because it is light-weight and compatible with lower power systems such as smart phones and PDA's.

- The cloud layer can be either a Platform as a Service (PaaS) or an Infrastructure as a Service (IaaS), where the Electronic Medical Record (EMR) System has been deployed. This layer has the feature of large storage, extensive computation, and is used for large-scale computations without real-time constraints.

- The data from the cloud layer is accessed by the insurance companies and hospitals to whom the rights to access the data is granted. Also the hospital keeps monitoring the health condition of the patients.

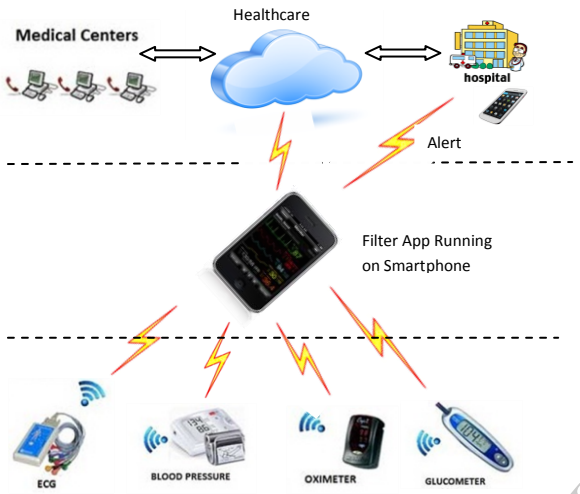

Figure 3: Proposed System Model

Security & Privacy Issues

In the proposed architecture, we use Elliptical Curve cryptography (ECC), a public key encryption technique based on elliptic curve theory. This is very fast and more efficient [12]. ECC generates the keys by the properties of Elliptical Curve (EC) rather than traditional method of generation as the product of very large prime numbers. Since, ECC establishes more security with less processing power and battery resource usage; it is widely used in smart phones for security.

SMS transmission in plain text through GSM is not considered to be secure. In order to maintain confidentiality and data security, we use TESLA (Timed Efficient Stream Loss-tolerant Authentication) broadcast authentication protocol for the proposed filter architecture to send secure SMS.

Our proposed approach maintains privacy and security, in that only the appropriate medical professionals who can help the patient are identified to receive the data. The proposed key search algorithm is implemented as a part of the filter system which on receiving the patient's abnormal data decides to whom to send the data through an alert SMS. When there are multiple health parameters with multiple input values, the proposed priority ranking algorithm serves as a solution.

4. IMPLEMENTATION AND RESULTS

The objective of the simulation is to implement parts of the proposed EMR (Electronic Medical Record) system on the cloud, implement part of the proposed filter system on android and perform a simple case study on the proposed priority ranking algorithm. For building the EMR system on the cloud, we used cloud foundry [16], an open source PaaS (Platform as a Service) which gives an environment to deploy java-spring based web-applications. We built this EMR system for the hospital to manage their patients' health information.

Simulation for the filter system was performed on the android emulator on Eclipse IDE, by developing an android filter app which sends an alert SMS on seeing abnormal health data. We tested the app by running two instances (one serves as a patient and the other serves as the hospital) of the emulator and sending alert SMS from one instance to another [18]. We also simulated the proposed priority ranking algorithm using Java 1.6 on Eclipse IDE, using some simulated abnormal health data.

EMR Healthcare System Running on Cloud Foundry

The developed EMR Healthcare system for the proposed architecture is a spring based java web application running on cloud foundry. This EMR system was developed for the hospital to manage each patient's profile and electronic medical records (EMR). This receives the encrypted health data from the patient's smart phone and the data gets stored in the cloud. Here, cloud foundry acts as a centralized database to store and manage a patient's personal and health information. The following two screenshots shows the EMR running on cloud foundry.

Figure 4: EMR Healthcare Cloud

Filter Application on Android

The developed filter application running on the android emulator is for the proposed filter system. It takes

the data from the healthcare app running on the emulator instance and sends it to the lookup table to find the severity level. If the data is abnormal, an alert SMS is sent to the hospital. Figure 37 shows the developed filter running on android.

Figure 5: Android App Simulating Filter App

Priority Ranking Algorithm Simulation

The priority ranking algorithm was implemented and a simple case study is presented below. The simulation was performed with Java 1.6 on Eclipse IDE. First, the input vector is given to the lookup table running on filter java class, which eliminates the normal data and takes only the abnormal value and sends it to graph. The graph G_f is the final graph which is constructed as a result of super-imposing the sub-graphs to find out the weights of each node after combining the graphs. Based on the resultant graph's weights, the nodes are ranked for the filter to find whom to send the alert SMS.

5. CONCLUSION AND FUTURE WORKS

Our work has left several directions for future work. The smart phone integration with healthcare cloud for monitoring patient's vital health information is expected to have significant impact in the healthcare field. Future work may include real-time implementation of the proposed approach, and integrating Electronic Health Record (EHR) and Patient Health Record (PHR) running on healthcare cloud, with the patient's smart phone. Extensive research needs to be carried out on integrating healthcare monitoring sensors within the smart phones itself. Future research needs to be done on improving and optimizing the proposed ranking algorithms for the filter system. Security model for the Electronic Medical Record (EMR) for the healthcare organizations and insurance companies needs to be developed.

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