PATIENT HEALTH MONITORING SYSTEM BASED ON E-HEALTH MONITORING ARCHITECTURE

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ABSTRACT *- Cloud computing is an emerging technology that can be used with health monitoring system to provide better health management services. Internet of things (IoT) is another trending technology to which has great impact on making our planet more interconnected. This paper is aimed at developing a smart phone (i.e. especially on Android Devices) and sensor based medical application. Patient Health Monitoring System leverages the idea of IoT for monitoring the patients on remote location in a pervasive environment. We have developed an application called health monitoring system which facilitates the prognosis and diagnosis through tele-monitoring over the remote location. It provides continuous investigation of patients taken care by caregivers and attendees.*

It uses medical sensors to monitor the patient's body parameter (i.e. Blood pressure, Temperature, Oxygen level and Heart rate) and relies it on smart phone. It uses the cloud database to store and manage the data of the patient. The data is then relayed on the cloud via smart phone and then it relayed from the cloud to Hospitality Services. The doctor monitors the patient remotely in real time using the data received from cloud store. It provides a real time health service and action based on the analysis done by doctors and caregivers. We have also implemented a novel set of value added services through this system which include Real Time Health Advice and Action (ReTiHA) and Parent monitoring for people with their family.

Keywords - Internet of Things, Cloud, Wireless Sensor Network. ReTiHA, Smart Device

I. INTRODUCTION

The Internet of Things (IoT) is the next paragraph moved towards, various section where sensors are interconnected to the Internet, which gathered data for survey to make our planet more instrumented, interconnected and intelligent [1]. IoT and Wireless Sensor Network (WSN) has made up the way for developments in various aspects of sensing. These advancements have been possible with advent of smart sensing techniques with small transceiver and sensing modules as well as strong processing units. An important feature of WSN has been the design of health onitoring systems centring on wearable sensor [2] modules for patients. With the increasing population in the world, research into remote health monitoring application has received salience over the recent years.AnAndroid device used to analyse ECG signals from a mobile monitoring terminal is mentioned in existing literature [3].

This paper is aimed at designing and developing an architecture based on android based smart devices and wireless sensor networks to monitor health of patients in various scenarios. The patients are observed using a portable and mobile device which holds up and processes data from a matrix of wearable sensors. This data is moreover correlated to data from sensors embedded in the surrounding environment. The accuracy of the data received and reactiveness to an imminent emergency increases with the use of higher quality of sensors or with sensors possessing strong sensing and processing capabilities. The total number of parameters to be observed has to be designed keeping mind the balance with complexity and the reliability of the system.

The proposed e-health monitoring is extremely suitable for the following four scenarios. First is with patients unstable

Physiologic regulatory systems for e.g. a patient suffering from respiratory congestion as a result of drug overdose or anaesthesia. The second situation for patients is those with a suspected life threatening condition, e.g. diagnosis predicting possibility of a heart attack. Thirdly are patients with a high risk of a life threatening condition (e.g. a baby born with an abnormal heart or lungs). The fourth one type of patients requiring monitoring is those with a critical physiological condition, for e.g. patients with Posttraumatic stress disorder (PTSD) or recovering post-accident. Our system is also designed for the old people who require regular monitoring [4] for multiple situations of the above mentioned cases. This system is focused at providing accelerated diagnosis of diseases and also increased efficiency and accuracy in the process. It is also designed to sense of insecurity in the patient at all times by providing on time attention for emergency. In our designed architecture for the system, the smart device

takes a major role in processing as well as relaying of data acting as a middleware hence reducing costs in the process.

We have developed this architecture based on the perception of the potency of this being used in rural parts of India, where health care centre and hospitals are not as well equipped as their urban regions. In these speculated areas, this system with mobile sensors and smart devices can be used for diagnosis of patients. The rest of the paper is organized as follows. The underlying system framework and architecture of the system for monitoring of patients is mentioned in Section II. Section III Details the design of this system. The privacy and security measures regarding this system are taken into advisement in Section IV along with countermeasures to these issues. Section V and VI illustrates a use case and scenario respectively. We have discussed the prospects of this system and its applications in the concluding section.

II. E-HEALTH MONITORING ARCHITECTURE

The architecture contains three major layers which play as the major part for our system. We have categorized the architecture of our system into three layers based on the functions of the components being used. Following figure depicts the overall architecture of the system.

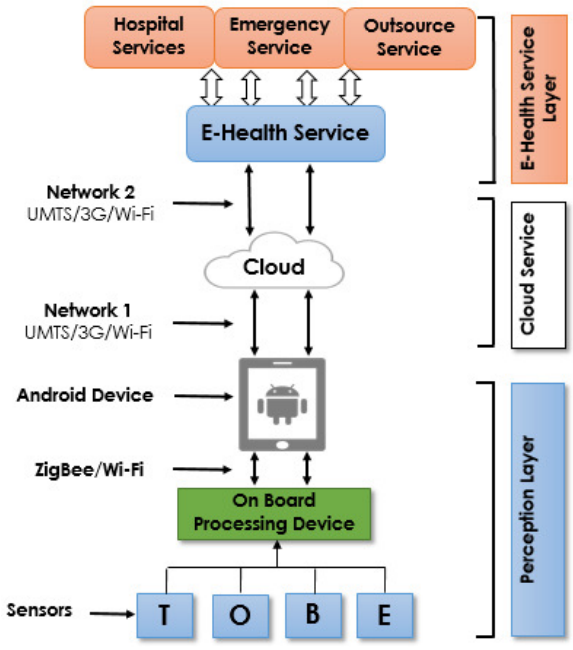

Fig.1. E-Health Monitoring Architecture

A. Perception Layer

The first layer at the bottom of the hierarchy contains various types of sensors which acquire real time data. These wearable sensors are embedded in and around the environment surrounding the patient and in his/her body as well. They can be classified into two types: medical sensors and environmental sensors. The medical sensors monitor body parameters of the patient. The data acquired by the sensors are sent to a processing unit which attaches several data like unit, timestamp etc. and thereby creating metadata. With that, one unique id is marked to each unit data in order to distinguish which report is for which patient. The data is fetched by the next layer in the hierarchy through Device.

1. The data is transmitted in the form of Sensor Mark-up Language (SenML)[5]. The communication between the sensors and the device are conducted through short range communication systems including Local Area Network (LAN), Bluetooth or Wi-Fi.

B. Cloud Service layer

This layer is the crucial layer of the system consisting of various APIs. The cloud storage stores the medical history data of the patient as well as present records of the monitored parameters. This storage plays a major role in the emergency response and hospital monitoring system to correspond the data acquired from the sensors to the stored offset for the parametric values. The cloud storage is instrumental in detecting an emergency and announcing the state of emergency for the patient. Whenever a patient is registered in the following system one API creates the new profile for that patient. Another API can also be constructed which would retrieve the patient history for a patient who has previously used the system and analyse the report. These APIs support the profile management, storage, queries regarding patient history and other reports are adjusted with the complete system. The data from the cloud is related to another Network 2 over UMTS or over Wi-Fi. The data is then put across to this layer for outsourcing applications and services from theNetwork 2 or E-Health Service Capability module.

C. E-Health Service Layer

The third one layer of the system is a terminal layer providing outsourcing services for the observed data. This layer offers

E-health Advice services to the patient. This process consists of prescribing medicines and providing suggestions to the patient related to the values of parameters that are being received from the sensors. Based on the design of data from the previous medical history of the patient, the e-health services gives advice comparing the previous trends with the current one of sensor data. The emergency response system act as the informing agents to the doctors and the nurses in according with the level of emergency. Depending on the level of emergencies the response team takes necessary action. The hospital module monitors the patient remotely from the location where the patient lives, if the monitored patient is at

home or a remote location. This module also allows to analyse all patients monitoring centrally in the hospital or health care centre. The mode of intercommunication in between layer 2 and layer 3 is duplex in nature, the data for this service is received from the cloud storage and the targeted response for the patient is related to the layer 2 for storage and circulation.

III. FUNCTIONAL COMPONENTS OF THE ARCHITECTURE

In this section we have discussed about the functionality of the system with focused on the operation of sensors, the types of parameters monitored, process of accretion and Circulation of data. We have also considered the various services that are provided within this monitoring system in this section.

A. Sensors and Processing Units

The monitoring architecture is based on primarily four type's sensors. These sensors are medical sensors which are attached with the patient to measure critical parameters. These values considered together present the real time situation of the patient at all times.

1) Medical Sensors:

These sensors are used to analyse the health of the patient by measuring various vital parameters. The sensors in the environment as on the patient should be small in size and as unnoticeable to the patient as possible for collecting natural values of the parameters. The sensors consists of heart rate monitor, oximeter, blood pressure sensor, ECG Sensor, and thermometer. These sensors produce raw data which are wirelessly relayed to a central transceiver unit attached to the patient. This transceiver unit processes the raw data and converts it into meaningful metadata [6]. Raw sensor data consists only of values of parameters measured hence has little value. Sensor Metadata when added to these values, which are type of parameter being supervised, feature of interest, timestamp and unit of measurement makes meaning to these values.

2) Central Transceiver Unit

The Central Transceiver Unit is a wearable unit/module and can be attached to the patient. This is designed to obtain the raw data from the wearable medical sensors by various channels fixed to multiple frequencies. Serialized transmission of data through one channel might cause collisions, thus loss in data. Hence multiple channels are used to make sure that different sensors send their values at different frequencies separated by a value to obstruct interference. This transceiver unit then transfers the processed metadata to a central base station using wireless communication like LAN, Bluetooth or Wired Medium. The central base station collects the values from the medical sensors as well and then relates the data to the layer 2 as mentioned in the architecture in Section II. Hence, the Central Base Station acts as a Network for the system between layer 1 and layer 2 of the architecture. The use of the central base station can be made cheaper and mobile by using a smart device as the Network as it is always carried by the patient. The metadata of sensors sent from the base station to the cloud storage is in form of XML (eXtensible Mark-up Language) [14] which provides sharing of SenML data. The android smart device can be also used for local processing of data to analyse the health condition of the patient.

B. Services for the monitoring system

The data received from the sensors are stored in a central database on the cloud. This data is processed in two ways, which are on-board processing and on device processing [7].

1. On-board processing can be done by the central base station preferably a smart device. This allows current detection anomalies and care should be taken before the patient reaches healthcare institutes.
2. On-server processing uses the real time metadata collected from the sensors to calculate them with respect to data stored in the cloud. This type of processing requires better resources in the form of memory and processor, output and processing time and hence is more suitable for on server processing than processing on smart phone. Based on the processing and storage of data our system offers a set of services as follows.

1) Hospital Services

The patient is monitored using the critical parameters from the sensors attached on the patient as well as in the surroundings. The values are further supervised by attendees present in the health care centre. For any anomalies in the values both visual and audible alarm are deployed. The caregivers monitor these alarms for each of the suffered patients and attend the patients with required medication to the present situation. These services are also available to patients which chooses for private monitoring at their residences. In this case, a nurses are present on the particular region however the monitoring is done remotely at a hospital. If an alarm is triggered it alerts the caregivers and the nurses on premises as well.

2) Cloud Storage Services

In this set of services we offer a particular set of services as cloud storage.A number of Cloud Computing platforms are already
available for distributed management of user data, either free

(e.g., iCloud [8] and DropBox [9]) or commercial (e.g.
GoGrid [10], Google Cloud [11], Microsoft Azure [12] and Amazon AWS [13]). The cloud storage is used to store medical data of the patients with a particular data relating to each patient. These records can be used to relate the present data received from the sensors for prognosis and diagnosis. This pattern recognition process plays an important role in the services mentioned in the paper.Cloud Storage can be used to store

i) Medical reports,
ii) Medical prescriptions along with specific medicines for which the patient has showed best recovery patterns and
iii) Medicines by which the patient is allergic.

The preferable method of storage for these prescriptions would be in the form of XML files. This would allow easier parsing of data and would hence facilitate the processing on the cloud.

3) Emergency Response Services

Different response from caregivers mentioned in the Hospitality Services, there are cases in which quick attention is required from the caregivers for situations which may prove to be life critical conditions. There may be cases in which the threat may be beyond the scope of the caregivers and require direct consultation from the doctor. Fig. 3 illustrates the block diagram of the emergency response module. The values collected in real time from the sensors are forwarded to the cloud for storage and for the processing. The database for each patient stores abnormal values for each parameter is considered. On-server processing is used to analyse all these values to the thresholds in real time. The breaches in threshold values collected from the initial stage of processing are then fetched to the Emergency Type Handler (ETH). The ETH then applies predefined logic to determine whether the intrusions are related to each other and pose a greater threat combined. Based on the type of threat the Emergency Type Handler assigns one of three levels to the threat. Emergency Response System is illustrated in fig 2.

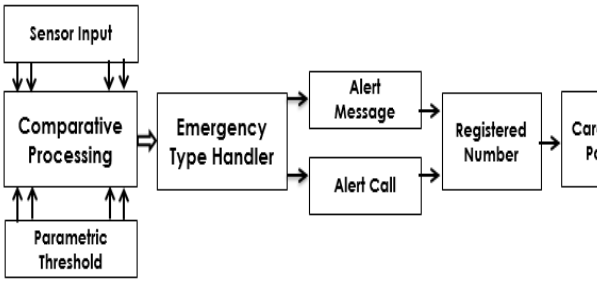

Fig. 2. Illustration of Emergency Response System.

1. For Level III emergency, a message/alarm is passed with critical parameters and threshold breaches only to the nurses.
2. For a Level II emergency, a message/alarm is alerted in a similar manner but to both the patient's doctors and nurses.
3. For a Level I Emergency or emergency associated with maximum threat, the system triggers a call with a installed message of the threat and breached parameters to both doctors and caregivers.

According to these alerts the patient can be urgently attended by the doctors or the caregivers in an attempt to bring the patient back to a normal state with needed treatment and medications.

4) Real Time Health Advice and Action (ReTiHA)

This service is engineered to handle when the Emergency Response System fails or the patient is not attended even though a level I emergency is triggered. If the monitoring system in the On-Server computing determines further diagnosis of the patient as a result of further breaches in thresholds frequency, this service is alerted.In this service the On-Server program executes a pattern recognition program to examine whether such an emergency has been triggered earlier in the records. If such a pattern is resulted in matching the current pattern of parameters, the on- Server program cross checks with the prescribed history as to which medicine was used to treat the patient in such a situation. If such a suitable medication is found, the On-server program provides a suggestion the medication to the patient through the central reporting system. The medication can then be given by a relative present in the bedside or by the nurses. This is particularly useful and applicable to patients with a severe disease requiring identical yet important medications on emergency and for patients on individual monitoring where emergency response might be delayed.

5) Parent Monitoring Services:

With the increasing in population worldwide and wide chances to work abroad, it is a common condition in which the parents stay away from their working children. In cases of sudden health challenges and medical emergencies the children are often lack the information regarding the emergency because of the delay in communication. To bridge this gap between working professionals/children and their parents we have designed this service. This is designed as a value-added service in which the offspring's receive continuous updates of the critical parameters of their parents and are updated on the emergencies with the help of alerts similar to that of a nurses. The application of this service we can send these updates through an android phone application.

This smart device application will be consisting of an API which can received updates from Layer 2 of the architecture.
For e.g. the date and time for the further appointment with the doctor or change in given medicines can be relayed by this application.

IV. SECURITY AND PRIVACY

In this section we have discussed about the different security threats and risks to this e-health monitoring system. As the system is related with the condition of our health and prescriptions are prescribed online by the doctor, we need to consider strong security measures. This is required in order to protect the patient's health and to make sure whether the patient is receiving proper medical treatment. If the patient's profile is mistreated or a prescription is uploaded by any un-authenticated person other than the doctor, this can have a major effect on the patient. Hence the following conditions of end-to-end security are to be taken into consideration to make sure that there are no defects in the security of the system.

A. Confidentiality

It is a basic requirement to keep the health records of the patient confidential such that the data of the patient is entrusted with the system. While the health record is transmitted between the doctor and the patient, no other person is allowed to hack on this exchange in an unauthorized way. In our architecture, we have kept a set of certain rules for some trusted people to access the patient profile. The timestamp ensure the correctness of the data. These data sets are fetched to the cloud from devices through HTTPS connection to exclude any kind of security obligations concerned to the confidentiality.

B. Integrity

Integrity ensures accuracy of data throughout the process. The data should not be strictly made available to an unauthorized person as he/she may corrupt the data, leaving the patient in helpless condition and leads to wrong diagnosis. Secure hash algorithms are used in this system to makes sure message integrity. The timestamp is also continuously checked to know the freshness of the data. If the data is not fresh it has to be removed as the condition of health of a patient may vary within a second.

C. Authenticity

The identity of both the doctor and patient retains validation in order to make sure true state of the system. In this case digital signatures are useful as a symbol of validation through which we can make it possible to test that the person is real and is truly who it is claiming to be. Digital Signature is one of the most approved process of making sure the authenticity in this case.

D. Non Repudiation

Frequently we come across some phenomenon of medical in which some treats are neglected in hospitals and Health care centres. Non Repudiation is one of those principles of the security system which makes sure integrity and authenticity of data. If a message is passed, the sender cannot negate that he/she has sent the data. Similarly the receiver cannot reject the fact that the data has been acquired. In our system non repudiation is necessary to ensure that the doctor itself is receiving the medical data and not getting it done by someone else. If non reputed action is assured the doctor should be responsible for each of his actions through the system. The digital signature will ensure the doctor acquire the data and takes action according to the condition as the permission of writing prescription will be strictly for the doctor only.

V. USE CASES

In this section, we have discussed some of the real life applications of our system. There are many real life incidents, where the system can prove to be useful. We have explained two of such cases and the system's function in the same.

A. Doctor Finder

This architecture supports the storage for regional databases from which the information about a patient can be retrieved based on his/her location. The details about the availability of doctors in this area will be stored in the database. It will consists all details like doctor’s specialization, address of the clinic, timing of appointment, fee of the doctor and availability of appointment. The database has to be updated periodically, so that, whenever the patient feels sick, he/she can have an appointment through the system, choosing a doctor from the suggested list of doctors by the system. This will help a patient to reach nearby doctors for emergency and minor check-up instead of going to the clinics. A patient can use an android smart phone application which establishes a connection to the database with location information and doctor preferred by a patient. The system can provide the patients the details about the available doctors in that particular locality.

B. Location information for Emergency Response Team

A smart phone can also send a report of the location of the patient to the Emergency Response Team (ERT). This is quite handy for people having trouble with their health while not being at home. Even when there is no one present to help the patient, the mobile application will send every necessary information with some suggestions as well as the current location of the patient to the ERT which is proximate to the

patient according to the information from the database. This will alert the ERT to come and take action as soon as possible.

VI. RELATED WORK

Pulse Point Respond.

Pulse Point empowers individuals, within communities, with the ability to provide life-saving assistance to victims of cardiac arrest. Application users who have indicated they are trained in CPR are notified if someone nearby is having a cardiac emergency and they require CPR. If the medical emergency is in a public place, the application uses sophisticated location-based services to notify trained citizens in the immediate backyard of the need for CPR. The application also directs these citizen rescuers to the precise location of the closest public access Automated External Defibrillator (AED).

Pulse Point currently provides coverage for hundreds of cities with many more on the way. The Pulse Point app is a virtual window into these 911 communication centres and provides real-time access to emergency activity as it is occurring. Users can see incidents - including the current response status of dispatched units - and instantly pinpoint the location on a map. Curious as to where that fire engine or ambulance that just passed is going to? Is there an accident up ahead causing this traffic tie-up? Just tap the application to quickly search the incident location or plan an alternate route.

As well as users can choose to receive incident notifications when they are dispatched and listen in on live emergency radio traffic via this modern version of the traditional fire scanner. A photo gallery of significant events along with other company images and information can also be easily accessed [15].

VII. CONCLUSION

Even though a lot of research has been supervised on e-health monitoring systems, we have proposed a set of ideal services based on the monitoring system. ReTiHA will require lot of research and testing before its application, howeverit needs a new path for remote health monitoring systems. We have also extended other ideal services in the form of ParentMonitoring system as well as the Emergency Response Services. The use of SenML in our system makes sure that organized transmission of sensor metadata. The medical data and history acquired for the patients are personal in nature. Hence our system makes sure the security of the highest order for the medical data on cloud storage. With further research in this concept, our system can change the view towards the remote health monitoring services.

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