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IoT based Counteracting Services for CARDIAC Patients

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Abstract: Cardiovascular Disease (CVD) is the single foremost cause of mortality around the globe and is projected to stay so for a while. Cardiac Arrhythmia is a very common type of CVD and may contribute to an increased risk of stroke or sudden cardiac death. But, this can be averted now, due to the swift growth in technology. The proposed system utilizes a unique and efficient architecture for improving the existing healthcare systems by reducing the delay in medical attention with the help of Android-based mobile devices and a smart wearable with Bluetooth interface. This system focuses on building a real-time heart monitoring system considering the ease of application, cost, and accuracy. The system on the user (or patient) side mainly consists of various sensors for data acquisition, a microcontroller (e.g., Arduino), and software along with a smart device. The hospital side system will contain a Windows application which will be used to access the patient's data. The patient's temperature, heart rate, blood pressure, blood glucose level and ECG data are continuously monitored, displayed, and stored by the system.The records of the patient will be synchronized to the central server to reflect the current status of the patient. The wearable device on detecting any abnormal readings will immediately report it to the smart device (mobile phone or tablet) which can further contact the nearest hospital, the listed Emergency contact, and the family doctor. Communication from a smart device (via the application) to hospital or family doctor will be using GSM Network.

Keywords: Internet of Things (IoT), Cardiovascular disease (CVD).

1. INTRODUCTION

Health is one of the prime global challenges for humanity [9]. According to the constitutions of World Health Organization (WHO), the highest attainable standard of health is a fundamental right of every individual. The Internet and the overwhelming technology that surrounds it has changed the human life by providing the facility of connecting any number of people or devices, anywhere at any instance. Similarly, the advancements in the fields of hardware such as processors, sensors, transmitters, receivers have led to massive developments in the field of communication which in turn has changed the pace of our everyday life. So, to expand services of Internet, concept of Internet of Things can be utilized. Though a relatively new concept, it's gaining fame in the recent endeavors of technology.

1.1 *Internet of Thing:* It is a network of computer systems and the real-life objects that we interact with in our daily life. These real-life objects include mobile devices (e.g. Smartphones, smart-bands, and smart-watches), vehicles, home appliances such as lights, television, radio, refrigerator, etc. This network communicates via standard protocols.

1.2 Things: Things may be real or virtual, steady or mobile entities which continuously relay information to each other. This type of communication is called things-to-things communication. When these things communicate with humans, it is called as things-to-humans communications.

A modernized healthcare system should be able to provide better healthcare services individuals at any time and from anywhere in a patient friendly and economical manner. Currently, due to boom on the internet, the healthcare system is undergoing a cultural shift from a traditional approach to a modernized patient-centered approach. IoT currently is one of the emerging technologies and is believed to change human lifestyle tremendously in the upcoming years. This concept can be used in remote healthcare monitoring of people. This means that a particular person can monitor his health-related parameters like temperature, heart-rate, etc. with the help of some monitoring devices. The monitoring device can read these health parameters of the user so that user can be informed about his health condition. A healthcare monitoring band is used to track user health parameters which may change during minutes leading to the heart attack. The band will be connected to an Android device using Bluetooth. The connection between the band and the Android device will be mostly one directional which means that band can only send data but cannot receive any. The implementation of this methodology will lead to a drastic decrease in delay between the occurrence of heart attack symptoms and the arrival of the ambulance. In India, the average time for a patient to receive medical attention, after the first symptoms of a heart attack, is somewhat between two to five hours. But unfortunately, this delay covers the golden hours of recovery of the patient which are the first few hours of experiencing the problem. The proposed system will be capable of reducing this delay as it will handle all of the communications to the respective authorities.

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The aim is to provide the users with a system which not only monitors their health parameters(like temperature, heart rate the most common factors related to heart attacks) but also generates a message in case if there are any cardiac issues. This will help in providing the users with prompt medical services in the event of any emergency using smart sensor bands.

2. EXISTING SYSTEMS

Wireless Health Monitoring Systems (WHMS) have drawn significant attention of the research community as well as the software development industry during the last decade. Numerous yearly-increasing studies and development efforts have been posted in the literature. The focus is primarily limited to include only some of the very recent related works.

2.1 NFC-Based System

Presently, there are many existing systems which facilitate the monitoring of a patient's health-related data and various health parameters. One of the techniques that were used is a mobile healthcare management system implemented using NFC (Near Field Communication). This technology is used to access patient's health-related parameters once he is admitted to hospital thereby making all his medical data available in the form of NFC cards. NFC is a short range wireless RFID technology which requires the devices to maintain close physical proximity for efficient working and security. This issue is one of the major drawbacks of NFC-based healthcare systems as maintaining close physical proximity is not always possible.

2.2 ZigBee Based System

One of the techniques uses ZigBee and GSM for transmitting data from sensors to the smart device which further transmits it to the local monitoring unit as shown in Figure 1. The local monitoring unit is then contacted to display these readings. The displayed information can be saved and published too. This process will help physicians to study them and then use them as general guidelines.

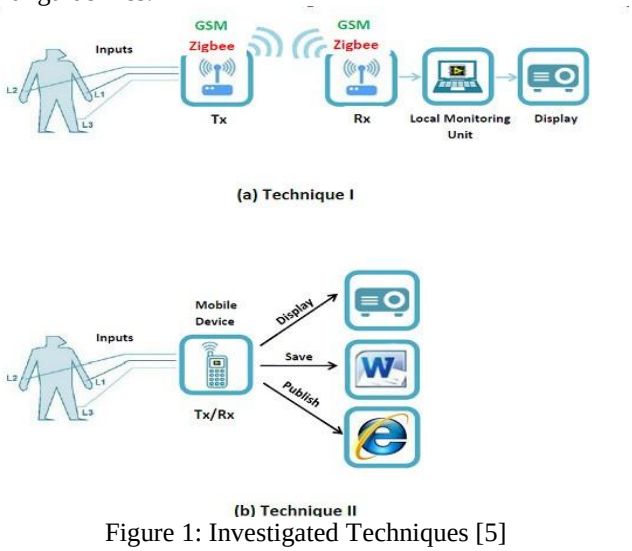

Figure 1: Investigated Techniques [5]

2.3 Bio-Sensor Based System

A real-time mobile healthcare system for monitoring the elderly patients for all possible locations indoor or outdoor areas is presented in [6]. The principal components being a smartphone and bio-sensor. The data collected by the bio-signal sensors are transmitted to a server via GPRS network. The system is can to monitor the mobility, location, and vitals of the elderly patient from a remote location.

In [7] a smart shirt's design has been proposed. The smart shirt can measure electrocardiogram (ECG) and acceleration signals for continuous and real-time health monitoring of a patient. This shirt mainly consists of sensors and conductive fabrics which assist in the monitoring of various body signals. The measured vital signals are transmitted to a base station and a server PC via IEEE 802.15.4 network. The wearable device will consume little power, and they are small enough to fit into a shirt. Reduction of noise associated with the ECG signal an adaptive filtering method has also been proposed in this work.

2.4 Windows Mobile Based System

A Windows Mobile-based system for monitoring body parameters has been presented in [8]. The system consists of a body sensor network that is used to measure and collect physiological data. Bluetooth is used to transmit data from the sensor network to a mobile device. The reliability and robustness of the system have been verified rigorously by the

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authors. The experimental results show that the proposed system can monitor the physiological data of patients while they are mobile. Another system was introduced in Saudi Arabia which uses internet facilities to monitor vitals status on mobile devices. In this system, the Android device and the band are connected to the web, the main drawback being that many people do not have access to internet facilities which caused problems in implementing such a health-monitoring system. Many systems today are using health care bands to follow the health of patients but none of the systems present today takes the necessary action of providing emergency services when in need. All the currently existing systems either use excessively short range technologies or lack the freedom due to their constant requirement of the internet for monitoring the patients. Moreover, once such systems read any abnormal signals through the input data, there are no necessary actions associated with any of them to provide help in emergency situations. The action of calling an ambulance to the rescue of the patients is not present in current service packages. Rectifying this will lead to a plummet in the deaths caused by the lack of emergency services.

3. PROPOSED SYSTEM

We have focused our attention on concepts which are more feasible and cost effective, combining them with a few of our own ideas. We have designed a system by adapting the components of existing systems in order to achieve a more reliable and economically sound system.

3.1 Architecture

Many health monitoring systems make use wearable bio-sensors that produce continuous data and generate many false alerts. Hence, these systems become unsuitable for clinical use. Machine learning approaches have been proposed to solve above mentioned the problem in [10]. In this method, data generated by the wearable bio-sensors in combination with clinical observations is used to provide early warning signals to severe physiological changes in the patients. The effectiveness of similar methods has been tested at Oxford University Hospital. Results of the analysis show that the proposed system can successfully combine data acquired from the wearable sensors. By combining this data with manual observations, the clinical staff can make important decisions about the patients.

Based on its working, proposed system has three sides, namely

1. User Side
2. Server Side
3. Hospital Side

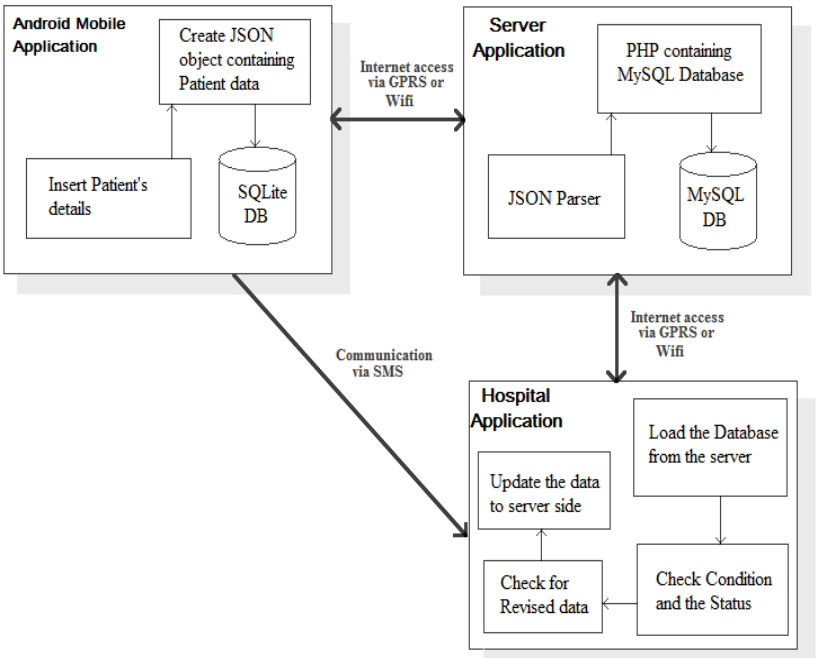

Figure 2: Architecture Diagram

The user side and server side communicate over the internet while the communication between the user side and hospital side takes place via SMS. The user and the server need to communicate only during the user registration process or when the user (or patient) wants to upload new reports in his existing logs. There is constant GSM based communication between the User-end and the Hospital end. The hospital side and the server side are both connected to the internet. Any Hospital employee can download the patient's medical history from the server database in case of emergencies.

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The data acquired from the user (or patient) side will be stored in a JSON object which will be parsed at the server side using a JSON parser. This data will be stored in a MySQL Database implemented with PHP. The status and condition of the patients will then be monitored using previous data as a baseline. If the situation and condition of a patient change then, the hospital staff will add these modifications to the patient's previous files.

3.2 Implementation

The system is aimed at automating the system of healthcare management. The user will be allocated a band which will monitor health parameters of the user continuously. The band will be connected to a user Android device using a Bluetooth connection. The user can view or check his health parameters on this device. The user can also stop the monitoring action of the band for as per his will by logging out of the app. Logging out of the app requires an internet connection. If there is any irregularity in user health parameters, then the system will generate a message which will consist of user location and health parameters along with the user id.

As soon as the message is generated, the Android device will sound a signal (beep) for a brief amount of time so that the user can manually interrupt the sending of a falsely-generated message. If the user does not manually interrupt the signal within a specified period, the generated message will be sent to the nearest registered hospital, the family doctor of the patient as well as to one of the designated emergency contact. This message will be received by the hospital system installed at the particular hospital. The hospital can then, deploy the ambulance service to the given location. The system will show the current and past data in pictorial and numerical format which will make an analysis of the person much easier.

The system consists of four modules, namely

1. Hardware module,
2. Bluetooth module
3. Software module, and
4. Display module.

The hardware module is used for data acquisition. It mainly comprises of the sensors that will be used to collect the subject's readings. The ECG sensor is used to detect suspected myocardial infarction, seizures, cardiac stress, etc. The temperature sensor is used to read the temperature of the patient's body. The sweat sensor will monitor the conductivity of a patient's body. The combined output of these sensors will help us predict if a patient is having the symptoms of a cardiac arrest. The Bluetooth module is used for transmitting data. The data will be sent from the smart band (sensor unit) to the mobile device continuously over Bluetooth. The software module will keep track of the readings that are being received from the smart band and cross reference it against patterns of cardiac arrest. The software module will mostly include Android programming. There will be a software system on both the patient's smart device as well as on the Hospital system.

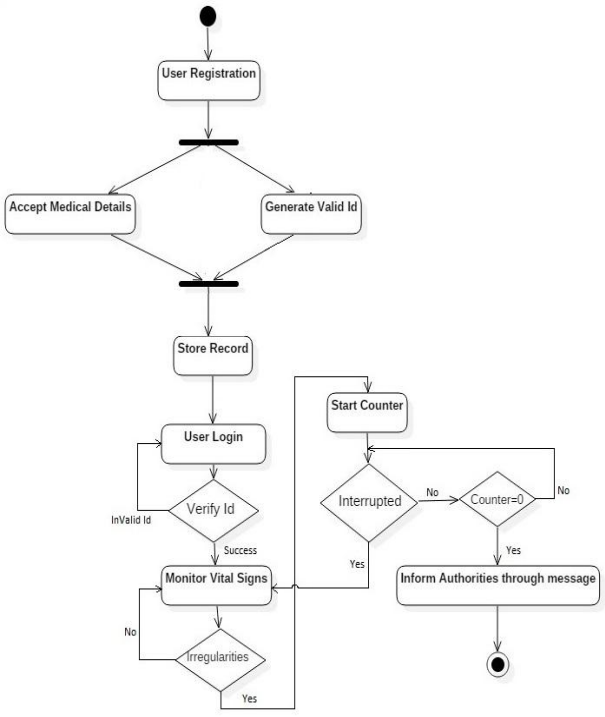

Figure 3: Activity Diagram

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Finally, the data can be displayed on the user device as well as on the hospital system by using the display module. The acquired clinical data, and the respectively generated pattern is sent to a database server over the internet (by using GPRS or Wi-Fi). The system performance has been tested on different patients, which led to findings that the proposed system will be very helpful for the cardiac patients.

The hospital web application will be connected to the database over the Internet. The hospital employees can gain access to all the medical details of the patient like previous surgeries, allergies and last uploaded statistics of all vitals of the patient by entering a unique id number, received via the alert text message (SMS), in Hospital-end web application. The signal will be generated once an irregular pattern is found in body temperature, heart rate, blood glucose levels or ECG data. The pattern should be able to handle erroneous values to a certain extent that may arise due to User error. Such a pattern detection should be applied which instead of a sudden rise or fall in readings focuses on a sequence of readings suggesting symptoms of cardiac arrests. This sudden rise or fall may be due to certain other physical factors such as an interruption in the connection between the band and mobile device.

Even when a person suddenly stands up, the heart rate goes slightly up for 15-20 seconds. The disruption in the signal may be due to simple reasons such as the mobile device is either lost or completely drained of battery, or the sensor has lost contact with the particular body part. A system which can handle these uncertainties will ensure that the alerts are legitimate and will avoid false alerts.

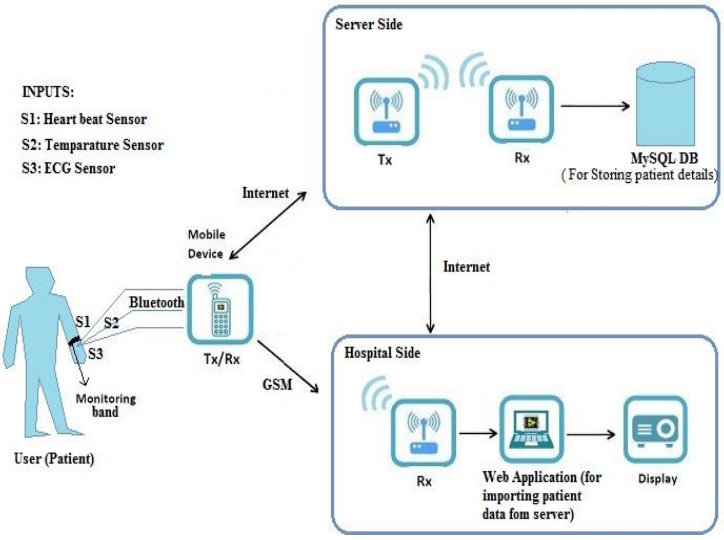

Figure 4: System Design

The alert generation mechanism should vary from person to person depending on their physical activities, lifestyle, age, etc. Take the example of a patient jogging in the park. While his heart beat will apparently be elevated, there is no need for an unnecessary alert generation due to this sudden increase in readings. Instead, the system should figure out the activity the user is performing and generate an alert only if those readings fall under the cardiac risk category while doing that particular activity. So taking all those factors into consideration, irregularities should be plotted for each one of them, independently. The system would need to classify the acquired data into different classes using various classifier which will help us predict if the readings are normal or not.

The sequence that the system follows is simple. But firstly, the user is required to register himself/herself with the system. The registration is done on an Android device where the user is required to fill in all medical history and upload any reports if he/she wants to. A unique id is associated with every registered user. This id is used by the Hospital employees to import medical history of patients in case of emergencies. This id is what is used to recognize a particular user. If the system detects any irregularities, then an alert sound (beep) is generated that lasts for a few seconds, suggesting an emergency message is about to be sent to the nearest hospital and the listed emergency contact. If the user manually cancels the message sending, then the message won't be sent. The user also has the facility to log out of the system. However, the user (or the patient) is advised to do so only when he/she wants to charge the smart band or do any other activity that involves interrupting the band-to-device connection. In case, it is a real medical emergency; the software algorithm will calculate the nearest hospital to the patient's location and generate a message containing the patient's readings, his unique id number, and the patient's GPS location. Once the hospital is notified, the Hospital Employees can use the Hospital side web app to import the patient's data from the central database. This database is where the data was initially stored by the user during registration.

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4. CONCLUSION

The proposed system is aimed at not only monitoring the heart related parameters but also for providing emergency services in case of medical emergencies. The main aim of the system is to make an efficient and more affordable monitoring system for any user (or patient). This system will help us to save a lot of valuable time by providing the hospital, the necessary time and information to make preparations for the patient.

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