

# Smartphone Based Heart Disease Monitoring System

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**Abstract:** *There is a big demand for remote locations quality healthcare system and technological advancements in the field of medical electronics and mobile communication can help in providing quality monitoring as well as decreasing the cost of healthcare. This paper introduces a real time low cost Smartphone based heart disease monitoring system. The proposed monitoring system extracts the ECG signal from the patient, sends it through the Internet and stores it in the hospital server. The system implements an application based on Android platform to provide online information about the patient status such as the patient's heart beat rate, ECG, patient history and provides new reading every 30 minutes. The system also processes the ECG using MATLAB to detect any abnormality and alerts the doctor and hospital by sending email and SMS message if any abnormality is detected. The system enables doctors to remotely follow-up the status of their patients using their smart phones. The system was tested and checked by medical team for validation and proved to provide accurate ECG reading.*

**Keywords:** *Tele-health, ECG, Android*

## 1. Introduction

### 1.1. System Overview

In this paper a low cost remote monitoring of heart attacked patients is introduced. The remote monitoring enables the patient to live his normal life and help decreasing the cost of healthcare. With the recent advance in IC design, the computing power and the memory number of smart mobile devices have increased considerably. This development makes many mobile devices, capable of carrying out complex computing tasks and thus can be used in monitoring heart disease patient remotely. The system has two parts one carried by users, e.g. Chronic patient, which is ECG detection and sending device and the second is the smart phone of the service providers e.g., the medical doctors. The Chronic patient system has electronic circuit that acquires the ECG signal from the patient and sends it to a PC or laptop that serve as a home gateway. The home gateway sends the patient ECG through the internet to a hospital server. The hospital server publishes the ECG and makes it available to the hospital staff that monitors the patient status. The monitoring can be done by the authorized person through the hospital web using PC or smart phone. The monitoring provides online information about the patient status such as the patient's heart beat rate, patient's ECG, and patient history. This information can be updated every 30 minutes. The update time can be adjusted according to doctor requirement. Further the proposed system processes the ECG signal using MATLAB to detect any abnormality. The system can automatically alert medical service providers through Short Message Service (SMS). The system has been fully implemented where the ECG signals are streamed to the service provider web page as well as the medical team smart phone in real time. The results generated by the system were tested and checked by medical teams for validation.

### 1.2. Related Works

The use of telecommunications for remote diagnosis is growing rapidly, and there are several products and projects within mobile ECG recording using Internet solutions [1], Bluetooth technology [2], cellular phones [3],

[4], WAP-based implementations [5] and wireless local area networks, WLAN and Wireless Sensor Networks [6,7,8].

A remote diagnosis system integrating digital telemetry has been developed, using a wireless patient module, a homecare station and a remote clinical station [9]. Traditionally 24/72 h

Some ECG-recording systems, like “Holter-monitoring”, are using built-in mobile telephones to send information to the hospital [10], but are mostly used with a recording unit that physically has to be carried to the hospital for analysis. In [11, 12] a wireless and wearable electrocardiogram (ECG) sensor transmitting signals to a diagnostic station at the hospital is introduced. An ECG system has been proposed based on mobile platform which transmits abnormal heartbeats identified in a patient-worn unit (Holter) [13].

Another ECG analyzer system has been developed to capture, record, and analyze ECG signals on a PDA device carried by the patient [14].

In [15], a Decision Support System (DSS) prototype has been provided to deliver an ECG signal to a hand-held device which will be capable of providing remote mobile communication to speed up diagnosis.

In the electrical and computer engineering department of Cornell University, an ECG hardware design has been implemented to measure the electrical activity of the heart [16].

Another paper presented the design, implementation, and results related to the storage system of medical information associated to the ECG signal [17].

### **1.3.Objectives of the Research**

The objective of this research is:

- a. Design an affordable ECG system.
- b. Design a fully online system that monitors the patient status in real time and sends the results to health care server.
- c. Add features to the current available system such as:
  - i. Detecting abnormalities and send alert message immediately to doctors via e-mail and SMS
  - ii. Develop Android based application that helps doctors to follow up their patients remotely via smart phone.

### **1.4.Paper organization**

The rest of the paper is organized as follows. In section two the system architecture is given. Section 3 presents patient subsystem. In Section 4, Web Server and Database Subsystem are described. Section 5 discusses the Android unit subsystem. Section 6 shows the results and discussion. The last section is a discussion on future work and conclusion.

## **2. System Architecture**

The ECG system is shown in figure (1). As shown in figure (1) the system consists from the following subsystems:

3. Patient unit subsystem: This consists from electrodes that measure the electrical activity going through the heart, signal amplification circuit, conditioning circuit, data acquisition circuit and home gateway. The circuit takes a reading every 30 minutes and sends it to home gateway PC.
4. Web Server and Database subsystem: To store the patient ECG signal, detect any abnormality in the ECG signal and publish the results that can be accessed only by authorized people.
5. Android unit subsystem: Android based application that enables doctors to access the patient details using smart phone

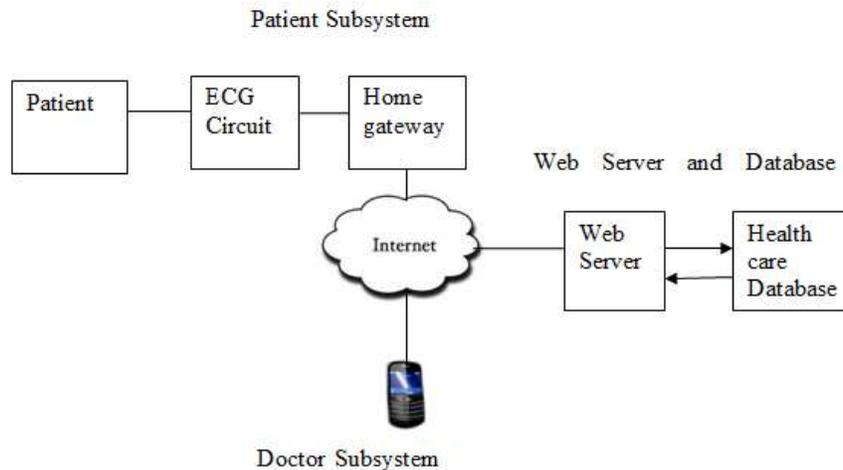


Fig. 1:Remote ECG System Architecture

### 3. Patient unit subsystem

The patientsubsystem contains the following components:

- Electrodes and cables (for the right arm, right leg, and left leg).
- The right leg drive for the ground reference.
- The Instrumentation Amplifier (IA).
- Signal conditioning (low pass filter, band pass filter, and notch filter).
- Data logger and Acquisition System (DAQ).
- Home gateway

The home gateway could be any PC, laptop, iPad, PDA or any other device that can be connected to the Internet. The Home gateway will receive the ECG signal from the data logger and send it to the healthcare server.

### 4. Web Server and Database Subsystem

#### 4.1.Database implementation

This unit provides detailed information to doctors in charge and restricted information to other authorized medical personnel or even relatives in case of elderly monitoring. It contains the patient information, ECG reading and heart beat rate.

SQL Server 2008 was chosen to implement the relational database, because of its support of data mining techniques (like, Clustering, Decision tree etc.) with Online Analytical Processing (OLAP) module. Intelligent agent Query systemthat receives the abnormality analysis from MATLAB has been implemented. This agent is responsible for providing requested information to the doctor's mobile.

#### 4.2.Abnormalities Detections

The proposed system detects the following abnormalities:

- 1- Sinus Bradycardia in which the Heart Rate is less than 60 bpm.
- 2- Sinus TachycardiainwhichtheHeart Rate is between (100 - 150) bpm.
- 3- Sinus Arrhythmia has Irregular Rhythm, R-R intervals must be (almost) the same. If the variation between the longest and the shortest intervals exceeds 120 ms, then an Arrhythmia is indicated.
- 4- Atrial Tachycardiain which the Heart Rate is between (150 - 250) bpm.

All the diseased ECG data have been taken from PhysioNet [18].

An effective algorithm has to be chosen to get indicative information from the real time monitored ECG. In such algorithms, QRS peaks should be detected accurately. There are many approaches for QRS detection including [19] non linear filtering with thresholding, artificial intelligence based method using hidden Markov models, time-recursive prediction techniques, and wavelet transforms [20]. The presence of noise in this signal is inevitable. Cubic Spline technique and digital filters have been used for base line drift removal [21]. One way of removing various noises is to use the established Pan Tompkins' algorithm for QRS detection [22], [23]. In Pan Tompkins' algorithm, frequency or spectrum analysis of the signal can be done using FFT algorithm. Power spectrum estimate represents the distribution of the signal power over different frequencies. From the spectrum, the frequency content of the signal can be estimated directly from the frequency sample values that correspond to the peak value. It is calculated based on the frequency representation of the discrete-time waveform [23].

In this paper Pan Tompkins algorithm has been applied on an ECG from a normal person and on three sets of arrhythmia data. Then the QRS detected signals are taken and power spectrum density (PSD) from each of the signals is obtained for analysis.

The system performs a feature matching operation for any incoming ECG recording and makes classification. If it discovers some pattern demanding urgent diagnosis, it will immediately alert the health care provider and the doctor via SMS

### **4.3. Web Server implementation**

The designed ASP.NET website gives the doctors the ability to monitor their patients' condition remotely. The website has three types of users:

- Web Admin: responsible for creating new accounts for both patients and doctors, manage their profiles, and the process of assigning doctors to patients.
- Doctor: Can access his/her assigned patients' ECG readings, add and view comments on his patients, add and view medical reports of his patient written by him/her or another doctor in charge of this patient.
- Patient: Can access his/her medical reports and view the doctor / doctors assigned to him/her. The doctor can "Filter" or search the patients either by name, File number, ID, or ID type. In order to get the full list he / she just can click the "Clear" button. The "select" column is used to access the information of a specific patient.

## **5. Android unit subsystem**

Two android applications were developed, one for the patient and another for the doctor, each having different functionality to suit the user.

### **5.1. Doctor Application (ECG Note):**

Doctor home page contains a list of the patient's names. The status of each patient can be seen within each patient name, to indicate whether he / she are online or not. The Green light or the Red will be shown to indicate whether the patients are in danger or not. This is useful for the emergency cases, so that the doctor can communicate directly with the patient. The doctor can access any patient info by pressing on his/her image to see his/her details, condition and other important info such his hear beat rate.

### **5.2. Patient Application (My Note):**

The patient home page contains a list of icons. These icons are "Your condition", "schedule", "share", and "options". The status of the patient can be seen at the top of the page, which is displayed in a Green or Red square.

## **6. Results and Discussions**

The system have been implemented, tested and achieved the design objectives mentioned in section 1.3 which are the design of affordable and cheap ECG system as compared with the available ECG systems as well as the streaming of the patient ECG to the health care provider web site so that doctors can monitors their patient

status in real time. Added features like detecting the abnormalities in patient ECG and send alert message immediately to doctors via e-mail and SMS is also implemented and tested. Finally Android based application that helps doctors to follow up their patients remotely via smart phone is implemented and tested. Figure (2) shows patient web pages as seen by doctors. The page shows the patient profile on the left and 4 icons that enables doctors to see the patient latest ECG, patient report. He can also add comments and contact patient. Android based smart phone doctor main page is shown in figure (3) where the lists of patients are shown. When a patient is selected from this page the patient page shown in figure (4) will be displayed which has four icons that display patient details, relevant details, patient condition and his visit schedule.



Fig. 2:Patient Page as shown from the Web Page



Fig. 3:Doctor Main page



Fig. 4:shows the patient information

When patient condition icon is selected the screen in Figure (5) will be displayed which shows the condition of the patient. When the doctor click the ECG, the corresponding zoomed ECG of the patient is shown in figure (6).

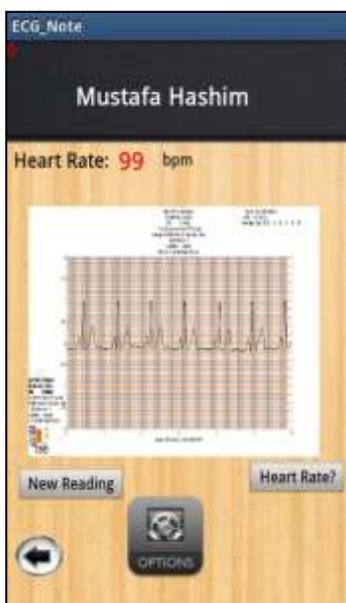


Fig. 5: Patient's ECG in Smart phone

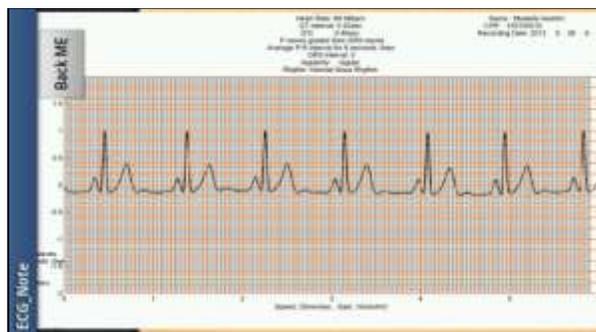


Fig. 6: Maximized ECG screen

## 6. Conclusion

In this paper a real-time low cost heart disease monitoring System is introduced. The developed system produce a live ECG that shows the real-time electrical activity of the heart, its rate, and analyze the readings for five of the most common and vital abnormalities, Sinus Bradycardia, Sinus Tachycardia, Sinus Arrhythmia and Atrial Tachycardia. The system processes the ECG using MATLAB to detect these abnormalities. When the system detects any of these abnormalities it will alert the doctor and hospital by sending email and SMS message. The system enables doctors to remotely follow-up the status of their patient using their smart phones. The system was tested and checked by medical teams for validation and the system ECG generation and abnormality detection were certified. This system provides some sort of freedom to both doctor and patient since the results are shown in real-time and the doctor will be alerted on his/her Android device in case of abnormality detection. The proposed system can be deployed as part of a Decision Support System (DSS) in hospitals. The cost of the hardware components from which the system was assembled is around USD120. As a future work, the system can be enhanced using Programmable system on chip integrated with biomedical ECG sensor to decrease the system size and get better response time.

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