m-Cardiac System for Real-time ECG Monitoring Using an RN-XV WiFly Module

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Abstract—Cardiovascular diseases are the leading cause of mortality worldwide. Research has shown that close monitoring can help improve the health of cardiovascular patients. Real-time monitoring of electrocardiograph (ECG) data can be performed with the advancement of wireless technology. This paper discusses the development and testing of a low-cost ECG monitoring system that uses a smartphone application. This system utilizes an ECG sensor connected to an Arduino Uno microcontroller and an ultra-low power RN-XV WiFly module for data communication. Real-time ECG signals are displayed on a smartphone and can also be stored in cloud storage to provide references for doctors. The system has a simple architecture and is easy to set up for ECG monitoring.

Keywords—cardiovascular; wireless technology; ECG monitoring system; RN-XV WiFly; Arduino microcontroller

I. INTRODUCTION

The prevalence of cardiovascular diseases has recently increased to the point where they have become the leading cause of death worldwide. According to the 2012 World Health Organization statistics report [1], cardiovascular diseases account for the largest proportion of deaths from non-communicable diseases (48%). The most common reason for critical delays in medical treatment is the lack of early warning and patient unawareness. The electrocardiograph (ECG) sensor has become one of the most commonly used diagnostic tests for monitoring heart activities. The accuracy of ECG depends on the condition being tested. In normal practice, ECG leads are attached to the body while the patient lies flat on a bed. For high-risk cardiac patients, ECG signals are the obvious data that should be collected continuously and given priority over other sensor data. Storing ECG signals for further analysis by cardiologists is also important [2]. What doctors actually prefer is to constantly monitor these parameters such that data regarding patient history and daily changes in condition are always available. When such findings and data points are accessible, early intervention can be made available to patients [3].

Smartphones can be used to find information, purchase items, or make video calls through wireless networks. Many applications can now be run in smartphones. Reference [4] concluded that long-term Evolution (LTE) and LTE-A are good candidates for delivering biomedical data from the smartphones down to the recipients.

This study presents a low-cost ECG monitoring system that uses a smartphone application. The system is intended for patients with a known cardiovascular disease who require round-the-clock monitoring. The proposed system is a portable device that is easy to use on patients. In addition, patients can upload ECG data to a cloud database, which can be used by doctors for future references. Such data can help improve diagnoses, save time for doctors, and save the lives of patients.

II. PREVIOUS DEVELOPMENT ON WIRELESS ECG MONITORING

Observational studies conducted in [5] suggest that telemonitoring (either used alone or as part of a multidisciplinary approach) may decrease hospitalizations and readmission rates among patients with heart failure. Reference [6] conducted a randomized controlled trial to test the effect of 3 months of patient care via home monitoring. This trial collected 12-lead ECG data during video consultations with clinic staff. The authors reported improved patient outcomes. The ECG signal can be transmitted to smartphones through Bluetooth IEEE 802.15.1 [7]. The system can efficiently detect and transmit high-quality ECG waves. This application can run on smartphones wherein ECG signals are plotted with body temperature and blood pressure. This system can also track patient location. The functions of the software can be improved by adding some algorithms to propagate diagnostic ECG waves. The disadvantage of this system is its high power consumption, which is mainly attributed to the type of microcontroller used and to Bluetooth.

A Wearable Mobile Electrocardiogram Monitoring System (WMES) mainly consists of a wearable ECG acquisition device, a mobile phone with global positioning system, and healthcare server [8]. With the wireless communication technique, WMEMS can monitor patient’s heart rate continuously anywhere in the globe if they are under GSM’s coverage cellular network. Therefore, the WMEMS provides a good system prototype for ECG telemedicine applications.

Reference [9] stated that the iPhone, iPod Touch, and iPad have been accepted as target media for mobile health (m-health). Many developers of m-health applications have chosen iOS devices to provide convenient tools to consumers. This situation has been proven by the increasing number of m-health applications. Such applications exhibit great potential in
public health care and health education. Advancements in mobile and wireless health care solutions contribute to different aspects of our lives ranging from diagnosis to treatment of various health problems such as cardiovascular diseases in [9]. If any abnormalities are found, the patient will be notified through an audible alarm and first aid techniques will be shown to the patient in the phone’s display [10]. Android applications are also part of the diverse groups of products that can provide health care solutions. These applications have also been adapted as references for developing Bluetooth applications in the Android platform. Reference [11] proposed that telemedicine can be applied to a greater extent in cardiology wherein ECG serves as a primary tool. Patient vital signs, such as ECG, heart rate, respiratory rate, temperature, and peripheral capillary oxygen saturation values, are captured and entered into the database. Then, the data are uploaded to a web-based server, which sends them to doctor phones with Android technology. Clifton et al. explained that several technologies that promise to significantly improve patient care are currently available or are being developed [12]. Vital sign recordings can be enhanced by automated transmission of the measured parameters to an electronic patient record. Therefore, these technologies should be carefully executed because poor-quality deployment can lead to bad patient care.

III. METHODOLOGY

The proposed m-cardiac system architecture is shown in Fig. 1. The system consists of ECG electrodes with an embedded Arduino microcontroller placed in a belt under the chest and belly of a patient. The RN-XV WiFly module is used as the communication medium to transmit ECG data to mobile phones. Real-time ECG data are displayed by using a mobile application. The application then sends the data via WLAN or GPRS to a patient medical profile (PMP), i.e., a personalized cloud-based health data center. The huge amount of health data is processed by using a specific algorithm tool. This tool performs real-time classification of vital signs based on data mining techniques.

We work with a three-lead ECG sensor in our prototype. Noise, interference, and non-rest conditions of the patient can contaminate signals. This condition implies that focus should be placed on extreme ECG signals. We used Lead II (Fig. 2) in the proposed ECG monitoring system because the voltage from the right arm to the left leg provides the strongest signal as it moves across the heart. Electrode placement on the human body is shown in Fig. 3.

The block diagram of the proposed wireless ECG monitoring system is shown in Fig. 4. The system consists of the following: i) ECG electrodes, ii) microcontroller Arduino, iii) e-health kit, iv) the RN-XV WiFly module, v) smartphone, and vi) database.

![Fig. 1. Complete m-Cardiac system architecture](image)

![Fig. 2. ECG leads as explained in McGill Physiology Virtual Laboratory](image)

![Fig. 3. Electrode placement as suggested in Libelium Comunicaciones Distribuidas](image)

A. Hardware System

The hardware system has a significant role in the operation of the proposed ECG monitoring system. We will provide a brief introduction to the sensor and the microcontroller in this section.
Arduino UNO is the main component used in the proposed system. It processes signals sent by the biosensors. This microcontroller board is based on ATMega328 and consists of 14 digital pin entries (input) and 6 analog productions (output), a 16 MHz ceramic resonator, a USB connection, a power jack, an In-Circuit Serial Programming header, and a reset button. Arduino UNO possesses the necessary features required to support the microcontroller by connecting it to a computer through a USB cable. The RN-XV WiFly is used to establish communication between the microcontroller and the smartphone. This module functions as a Wi-Fi antenna for transmitting data from the Arduino to the smartphone, as shown in Fig. 8.

B. Software System

For the software system, we use Arduino for programming and Tera Term to configure the RN-XV WiFly module. The connection properties of Tera Term are shown in Fig. 7. Before connecting the smartphone to the RN-XV WiFly module (Fig. 8), the module should be configured first. Tera Term is used to set up the IP address of the module to perform this process.

An Xbee USB adapter is connected to the RN-XV WiFly module to produce a serial connection during configuration. Configurations for Android (Fig. 4) and iOS (Fig. 5) are performed independently.

IV. RESULTS AND DISCUSSION

This chapter, which presents the results, is divided into two parts: (1) the serial monitor for the desktop and (2) data transmitted to smartphones. The output is initially tested on the serial monitor (Fig. 9) to ensure that the sensor is fully operational before being displayed on a smartphone. The smartphone processes sensor data. Raw data are then converted into ECG signals via Gaussian process regression to
eliminate noise. This algorithm will be further improved to generate ECG signal more accurately. The final ECG signal is shown on the smartphone based on Fig. 10 and Fig. 11. In Fig. 10, due to low sampling rate, the ECG signal appears inaccurately.

Users also have the option to store data in text form in PMP, as shown Fig. 12. Doctors can replot ECG data for a particular period that requires attention.

An m-cardiac wireless ECG monitoring system that uses smartphones has been developed. We have constructed a working prototype that focuses on ECG sensors. In addition, the features of the ultra-low RN-XV WiFly module as a communication medium between microcontrollers and smartphones have been described. This system helps reduce the number of times that lithium batteries should be recharged. ECG data that have been saved in the database can be retrieved by doctors for future reference. The target users for our application are patients who have suffered from a heart attack or at high risk of suffering from a heart attack. We have learned from discussions with cardiologists that these patients are worried that a heart attack may occur/reoccur, and thus, are willing to wear a monitoring device that can help reassure them of their safety. Intrusiveness is not an issue for these highly motivated patients.

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REFERENCES


