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An ECG Monitoring and Alarming System Based On Android Smart Phone

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ABSTRACT

ECG monitoring in daily life is an important means of treating heart disease. To make it easier for the medical to monitor the ECG of their patients outside the hospital, we designed and developed an ECG monitoring and alarming system based on Android smart phone. In our system, an ECG device collects the ECG signal and transmits it to an Android phone. The Android phone detects alarms which come from the ECG devices. When alarms occur, Android phone will capture the ECG images and the details about the alarms, and sends them to the cloud Alarm Server (AS). Once received, AS push the messages to doctors' phone, so the doctors could see the ECG images and alarm details on their mobile phone. In our system, high resolution ECG pictures are transmitted to doctors' phone in a user-friendly way, which can help doctors keep track of their patient's condition easily.

Keywords: ECG Monitoring System; Android Smart Phone; Alarm

1. Introduction

Heart disease is the leading cause of death in the world over the past 10 years. According to European Public Health Alliance's report, heart attacks, strokes and other circulatory diseases account for 41% of all death [1]. Treatment and prevention of heart disease are important issues for modern medicine. ECG monitoring in daily life is a necessary way for curing heart disease, and it is also a hot issue in medical and engineering fields. With the widespread popularity of smart phones and its portability, smart phone plays a role in monitoring heart nowadays. Many researchers have done some studies on the application of smart phone in ECG monitoring, such as [2,3]. In [2], the author shows us an ECG monitor system based on android smart phone. ECG signal is transmitted to an android phone and then be forwarded to a remote server. Using a PC, doctors can view the ECG after logging in the server. In this system, Android phone is sending ECG signal all the time when the system is running, which could cause a lot of power and network consumption. Besides, the author does not offer an alarm program. There are some researchers proposed the way of alarming, most of them use the SMS or calls such as [3-6]. In [6], pulse alarms details are described in a SMS. But for an ECG image, it is hard to describe in a SMS. In [3], author use the MMS and email to send the abnormal ECG images. The disadvantage of this way is that MMS is not able to carry a picture in high resolution, and if using email as the transmitting way, doctors may not see the email timely, and it also causes inconvenience.

To solve the above problems, we designed and developed an Android based system which focuses on ECG monitoring and alarming. In our system, real-time ECG is collected and monitored by the ECG device (we have developed and tested it in [7]). By detecting alarms, an android phone sends the alarm messages and ECG pictures to the Alarm Server. Once received a message, alarm server would push it to the doctors' phone by the Android Notification way. So doctors could see the alarm details and a high resolution ECG picture through this Notification. By this way, doctors could access the ECG alarm information almost everywhere in time only by a phone.

The paper is organized as follows. In Section 2, we briefly describe the system architecture and its working mode. In Section 3, we present the implementation of the system, including ECG data processing on Android phone, Alarm Server, and Alarming process. In Section4, We show the operating results in real environment. Besides, we test its reliability and time delay. In Section 5, a conclusion is made to summarize the advantages and disadvantages.

2. System Model

Our system is composed of four parts: a portable device with an ECG senor for collecting and analyzing ECG signal, an android phone to be a processing center for detecting and sending alarms, an alarm server for handling the alarm messages and report to doctors, and android phones which are held by doctors and family to receive alarm message. The system architecture is shown in **Figure 1**.

Between the ECG device and the Android phone, a wireless transmission channel is maintained to transport real-time ECG signal. Here we chose Bluetooth because of its good performance on Android phone. When an alarm occurs, a TCP connection is established between the Android phone and Alarm Server, which is used to transmit alarm messages and ECG pictures. As for the connection between Alarm Server and client phones, a long IP connection is maintained all the time, which could ensure the timely arrival of the alarm messages. When an alarm Notification is read on a client phone, the ECG alarm image could be browsed via a HTTP connection to Alarm Server. In this way, high-quality ECG image is transmitted to doctors' mobile phone.

3. System Design and Implementation

3.1. ECG Data Processing On Android Phone

The ECG data frame format is defined in [7]. 7-lead ECG with three kinds of alarms is carried by the ECG data frame. The Android phone reads and extracts the ECG data and alarms data the ECG data from the Bluetooth input stream. We build two to buffer on Android phone to buffer these data. ECG data is read from the Bluetooth channel and is put in BUFFER1. An alarm detecting thread performs a detecting operation on the data in BUFFER1. If an alarm is detected, the Android phone starts the alarming program. Its process is described in the next section. By detecting alarms, the alarm detecting thread transfers the ECG data from BUFFER1 to BUFFER2. The UI thread gets ECG data from BUFFER2 to draw dynamic ECG on screen. **Figure 2** shows the process.

3.2. Alarm Server Design and Implement

Alarm Server provides reliable cloud services in the system. It handles the alarm messages which are come from Android phone and deliver them to doctors' phone. Our Alarm Server consists of four parts: Message Receive Server, Alarm Information Management, Message Push Server and Web Server, as is described in **Figure 3**. Message Receive Server is used to receive the alarm messages. If an alarm was received, a copy will be store in Alarm Information Management. The ECG image will be put under the Web Server, Push Server push this alarm message to doctors' phone. After getting this message, the doctor could browse the ECG image from Web Server by his/her phone.

Medical data are personal privacy data, so the system's security is very important. At the two sides of Alarm Server for user accessing, 1) and 2) in **Figure 3**, we set authentication keys. Only the authenticated phone could access the alarm server. For 3), Web Server maintains an IP list, which is authenticated by Key1 and Key2. Only those IP could browse the ECG image under the Web Server.

3.3. Alarm Processing

After the Android processing center detected an alarm, it extracted the relevant parameters, and read 5s' ECG data in both BUFFER1 and BUFFER2, so 10s' ECG data is obtained. And then draw the waveform on a bitmap which resolution is 1400 × 600. At the same time, Android called the Location API to get the geographic information. In our system, we use the BAIDU's free location API, because it integrated Android Location API well and it offers text location message service.

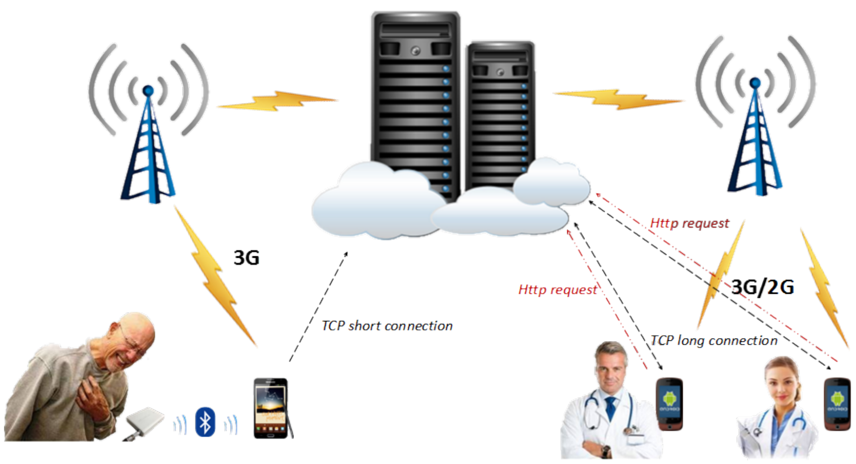

Figure 1. System Architecture.

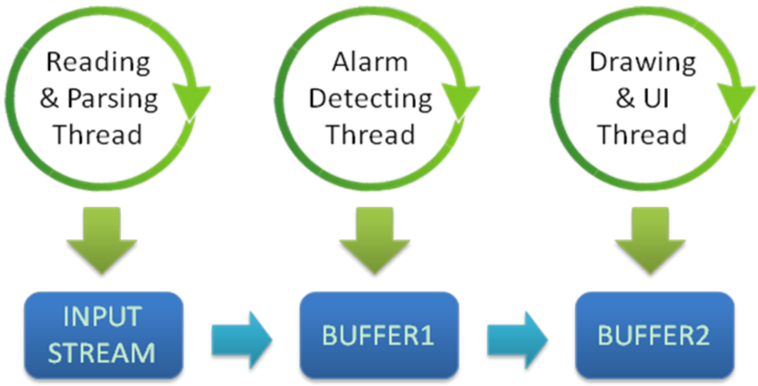

Figure 2. Processing of ECG data.

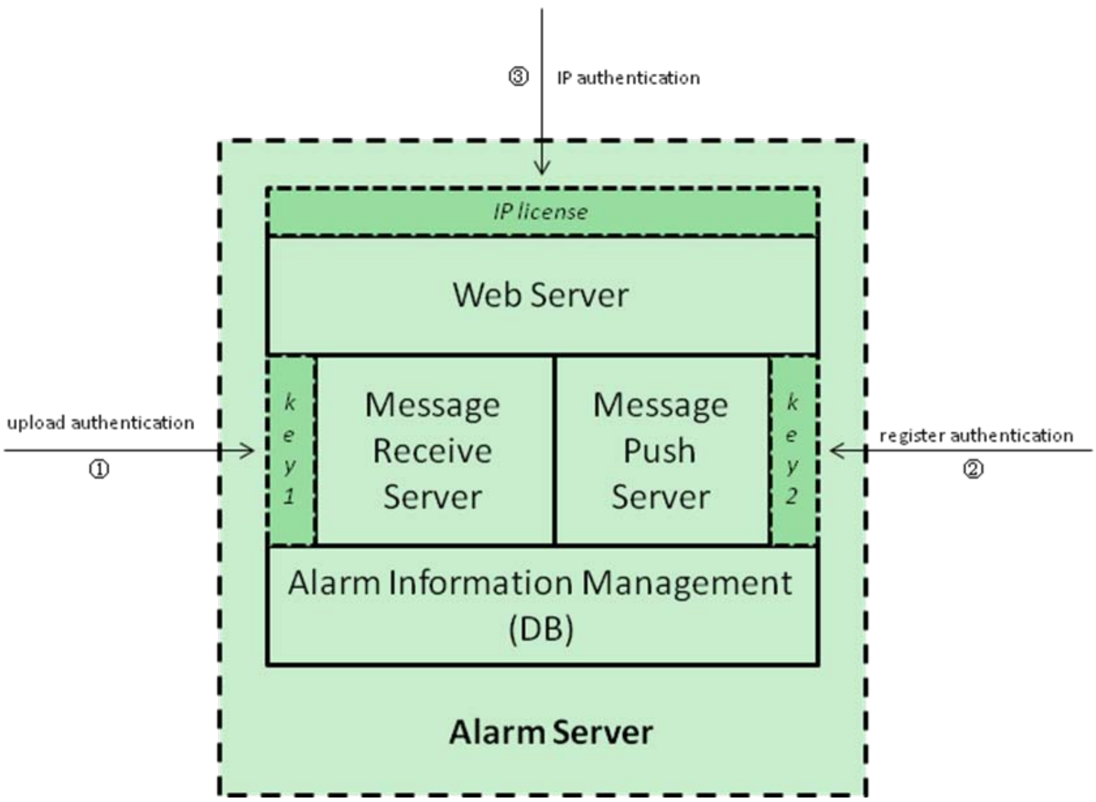

Figure 3. Alarm Server Architecture.

Alarm message could be defined in xml format, like:
<? xml version = “1.0” encoding=“UTF-8” ?>
<AlarmMessage>
<type>**alarm type**</type>
<time>**alarm time(UTC)**</time>
<location>**City/District/Street/Number**</location>
<locationUrl>
http://api.map.baidu.com/geocoder?location=⋯
⋯</loactionUrl>
</AlarmMessage>

The Android phone requests a TCP connection to Alarm Server to send this message. After validating its identity, Alarm Server establishes the connection. Then the alarm message is sent through the channel. After that, the ECG image is uploaded to a specified directory under the Web Server. We use TCP protocol to transport the alarm messages and ECG images to alarm server, because TCP is a reliable protocol that could make sure alarm messages and ECG pictures arrived safe and orderly. Between Alarm Server and doctor’s phone, a long IP connection is maintained so that the Push Server could push the message and the ECG image URL to doctors’ phone in time. When the doctor read the message on his phone, an Android WebView could be used to show the ECG image by the URL. So an HTTP connection is built to transport high resolution ECG image. The whole process of alarming in the system is shown in **Figure 4**.

Taking into account that the message receiver is a mobile phone but not a PC, the power and network resource is limited, instead of making the phone pull messages from alarm server initiatively, we must use a reasonable mode to push messages to the client phone. So we integrated the open source project Androidpn in the Push Server [8]. Androidpn implements an excellent push mechanism on Android platform. In our system, it was reformed to adapt to our needs, and it showed good performance on maintaining IP long connection, multi-user management, and resource consumption.

4. Experiment Results

Figure 5 shows the actual test environment, and a scene of ST segment abnormalities alarm. We used Samsung GT-N7000 as the test Android processing center. It catches the alarms and sends them to Alarm Server. The Motorola phone is the client phone to receive alarm messages. It receives the message as a Notification with ringing and vibrating, as is shown in **Figure 6**. When the Notification is displayed, the details about this alarm and the ECG image are shown on the screen. **Figure 7** shows the operating results on doctors' phone.

In this test environment, we performed 10 times alarms both under China Mobile (CMCC) and China Unicom's (CU) mobile networks to test its reliability and time delay. **Table 1** shows the results. From the test results, we can see the system's reliability and alarm time delay is good enough for being applied in a practical application.

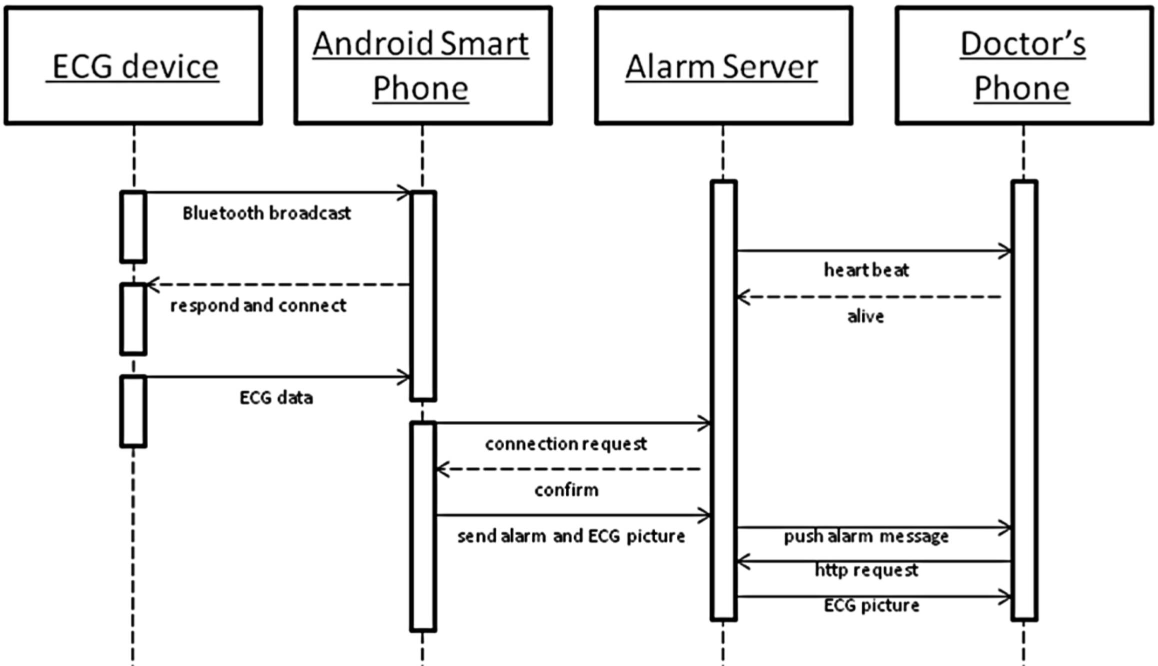

Figure 4. Process of an alarm in the system.

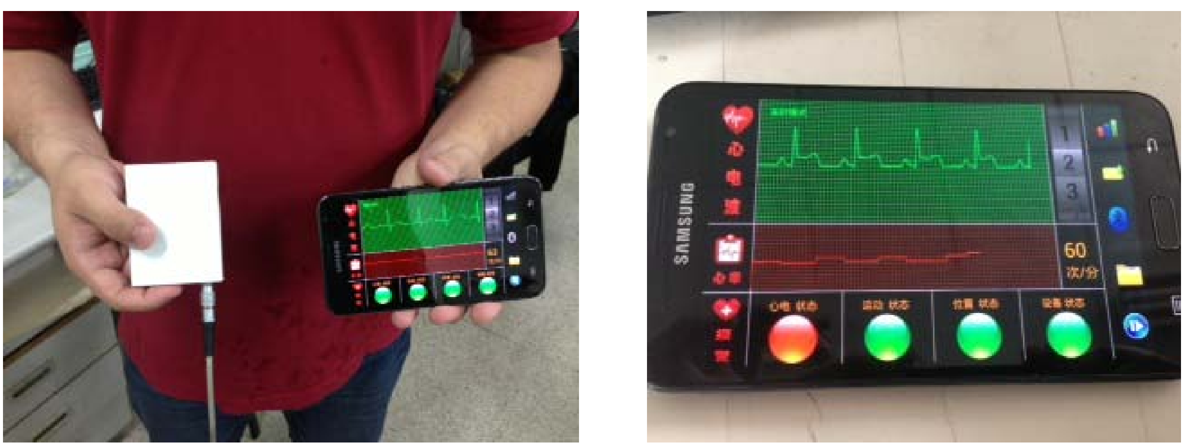

Figure 5. ECG Device and Android smart phone.

Figure 6. Alarms come as Notifications.

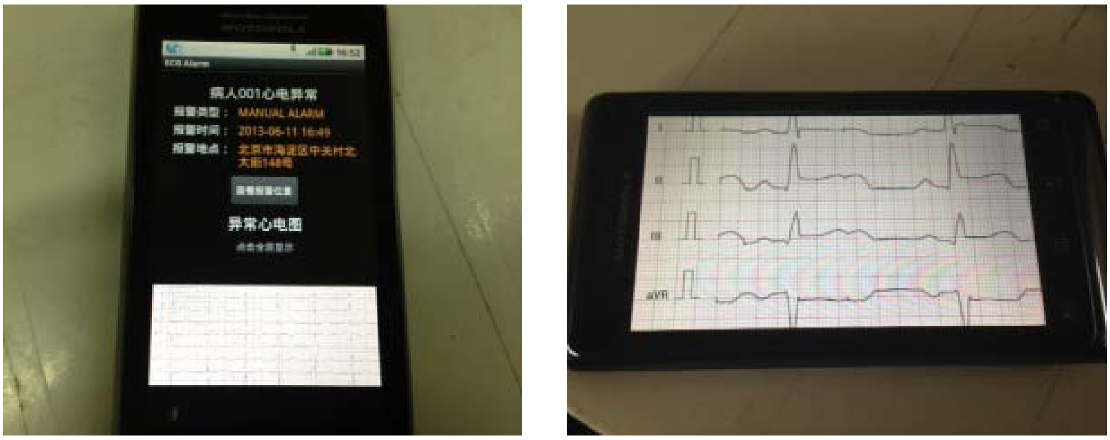

Figure 7. Browse the alarm details.

Table 1. Alarm reliability and time delay test.

CU/WCDMA		CMCC/EDGE	
No.	Time delay (ms)	No.	Time delay (ms)
1	**762**	1	**2360**
2	**3165**	2	**1620**
3	**5906**	3	**1981**
4	**472**	4	**1613**
5	**3226**	5	**1943**
6	**388**	6	**7379**
7	**440**	7	**1635**
8	**2674**	8	**1636**
9	**2439**	9	**1903**
10	**2844**	10	**1707**

5. Conclusion

In this paper, we designed and developed an Android based ECG monitoring and alarming system, which focuses on the system architecture and alarm processing, also we tested its reliability and time delay in a real environment. From the result, we could see the system reflects user-friendly design and strong reliability. Of course, it based on a stable mobile operators network environment. And on the side of client Android phone to receive messages, there is some room for improvement in power consumption. Anyway, we believe it has a certain application value for medical professionals to treat cardiovascular and heart disease.

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