

Portable Telemedicine System for High-risk Patients

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Abstract - Telemedicine has been an active area of research for over 15 years. In the past, several telemedicine applications using wired communications were presented whereas nowadays the evolution of wireless communication means enables telemedicine systems to operate everywhere in the world thus expanding telemedicine benefits, applications, and services. A low-cost, portable, wireless health monitoring and alarm system is proposed in this paper. Human's electrocardiogram (ECG) is acquired and analyzed. If an emergency situation occurs, the analyzer sends alarm signal and 10s epoch to the central server, using GSM/GPRS wireless technology.

Keywords – Wireless ECG, Telemedicine

I. INTRODUCTION

Heart diseases are at the top of the world death cause list and every year 7.2 million people die because of these diseases. As result of the advances in wireless communication and embedded computation technologies, remote health monitoring and telemedicine topics become a very active research area recently. Therefore, developing low-cost, portable and wearable remote health monitoring systems enable observing of some diseases outside from the hospitals.

Telemedicine can be defined as the delivery of health care and sharing of medical knowledge over a distance using telecommunication means. It aims to the provision of expert based medical care to any place that health care is needed. Telemedicine as a concept was introduced about 30 years ago where telephone and fax machines were the first telecommunication means used. In recent years, several telemedicine applications have been successfully implemented over wired communication technologies like POTS, and ISDN. However, nowadays, modern wireless telecommunication means like the GSM and GPRS and the forthcoming UMTS mobile telephony standards, as well as satellite communications, allow the operation of wireless telemedicine systems freeing the medical personnel and / or the subject monitored bounded to fixed locations.

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Different monitoring systems are commercially available and some of the research proposals about monitoring systems are classified in respect of the following features [1].

- *Systems that record signals and perform analysis off-line.* These systems only record the vital signals and no real time classification is done e.g. Holters.

- *Systems that perform remote real time monitoring.* Here the ECG signals and additional parameters [7] are captured and sent to a monitoring centre through mobile phones. The limitation here is that the analysis is not performed in the place where the signal is acquired.

- *Systems that provide local real-time classification.* These systems use intermediary local computers between sensors and the control centres or a hospital. These computers perform local real time monitoring. If some anomalies are detected, it sends alarms to the hospital.

In 2001 there have been notion of telemedicine using the mobile phone by Negoslav Daja *et al* [2]. In 2002, F Gouaux *et al* [3] did propose a smaller and feasible device for telemedicine. However, it was still insufficient due to the lack of processing of the raw ECG signals on their devices. E Kyriacou *et al* [4] designed a telemedicine framework yet it did not discuss the issue of processing raw ECG signals on the mobile device. Guidelines for designing telemedicine for the future were given by B. Woodard *et al* [5] and P Rubel *et al* [6].

In this paper we proposed a solution of portable telemedicine system for high-risk patients with cardiovascular diseases. It differentiates with the following factors:

- Online service for ECG signal processing on wearable personal analyzer and transmission of abnormal data upon its detection, using GSM module.
- Transmission of only abnormal ECG data, thus saving transmission costs and preventing network congestion.
- Continuous monitoring of patient's cardiac status anytime, anywhere.

II. HARDWARE SYSTEM

The ultra-portable wearable device, named Personal Analyzer (PA), is given in Figure 1. It acquires and process ECG signal in real time. If an emergency occurs, the alarm message and 10s epoch of the signal transmitted via Bluetooth wireless communication technology to GSM module. An emergency recognizes as a number of abnormalities for predetermined period.



Figure 1. Personal Analyzer

With the developed system, long term monitoring, real-time transferring of the data to the central server and informing - alarming of the related institutions on an emergency situation are achieved. In this way, patients obtain more freedom while they are doing their daily activities. General diagram of the proposed approach is given in Figure 2.

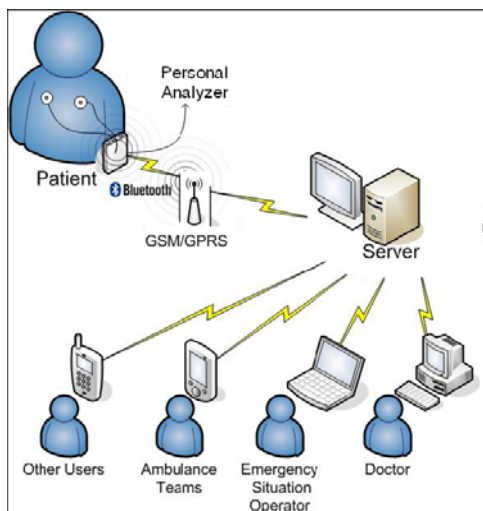


Figure 2. Diagram of the system

ECG AMPLIFIER

The amplitude of the ECG signal varies between 0.05 mV - 10 mV and must be amplified with an amplifier. In our decision, a 2-electrode, ground-free ECG amplifier was used. The signal taken from Ag-Cl electrodes is amplified by Analog Device's INA122 operational amplifier which is being used as an rail-to-rail instrumentation amplifier. Then, a simple 0.05 Hz - 35 Hz band pass RC filter is employed. In final step, for adapting the signal to microcontroller's sampling range, a MCP602 operational gain amplifier by Microchip is used. The block diagram of the sensor is given in Figure 3.

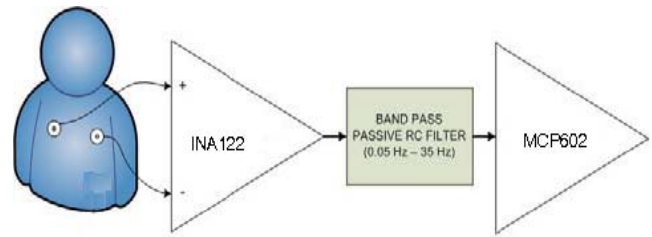


Figure 3. ECG Amplifier

PERSONAL ANALYZER

For sampling, analyzing and transferring the ECG data to GSM a microcontroller PIC18LF458 is used. It samples the analog signal that received from the ECG amplifier with 256 Hz, 8-bit resolution. To suppress the base line drift and the 50 Hz power line interferences completely we designed an averaging filter FilterDxN, according to equation (1). It embodies two variables allowing to adjust its amplitude-frequency response: (i) D is the distance between the averaged samples (as a number of samples); (ii) N is the number of the averaged samples (an odd number is required to prevent against phase shift between the input and the output signals).

$$SF(i) = S(i) - \frac{1}{N} \sum_{j=-(N-1)/2}^{(N-1)/2} S(i + jD), \quad (1)$$

where S is the input signal, SF is the filtered signal, i is the sample index.

The amplitude-frequency response of the designed $FilterDxN$ (Figure4) resembles a comb-filter. The upper x-axis in Figure 4 corresponds to the ratio between the sampling frequency (F_s) and the distance D . The zeros of the filter are occurring at integer ratio F_s vs D . The number of the ripples between the zeros, is determined by the number of the averaged samples N . The higher the number of the ripples is, the smaller are their amplitudes, as well as the steeper they become. The analysis of $FilterDxN$ response gave us the opportunity to choose N and D values adequate for filtering of ECG signals sampled at $F_s=250\text{Hz}$, i.e. $D=10$, $N=17$.

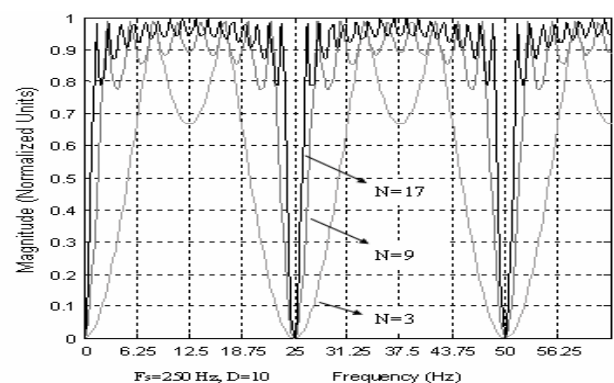


Figure 4. $FilterDxN$ - amplitude-frequency response
After filtration, ECG signal is analyzed, applying software procedure. The main steps are:

- QRS identification;

- QRS classification – normal or extrasystolic activity;
- Heart rate determination;
- Abnormalities detection;

When a type of predefined abnormalities is detected, an alarm signal and 10s epoch of the signal transferred from PA to GSM module via Bluetooth.

GSM/GPRS MODULE

We used GSM module to send date to central service localized at Hospital (Department of Cardiology of Medical University – Sofia). The MC35i module (figure 5) is used in the our system.



Figure 5.

The main features of MC35i are:

General features:

Dual-Band GSM 900/1800 MHz
 GPRS multi-slot class 8
 Compliant to GSM phase 2/2+
 Output power:
 Class 4 (2 W) for EGSM900
 Class 1 (1 W) for GSM1800
 Control via AT commands
 SIM Application Toolkit
 Supply voltage range: 8 ... 30 V
 Temperature range
 Normal Operation: -20°C to +70°C
 Restricted Operation: -25°C to +75°C
 Switch off: +80°C
 Storage: -40°C to +85°C
 Dimensions: 65 x 74 x 33 mm
 Weight: 130 g

Specification for GPRS data transmission:

GPRS class 8: max. 86 kbps (DL)
 Mobile station class B
 PBCCH support
 Coding schemes CS 1-4

Specification for CSD data transmission:

Up to 14.4 kbit/s
 V.110
 Non-transparent mode.

The MC35i is a terminal, offering high level GSM/GPRS features in compact plug-and-play housing with all the standardized interfaces. Together with its small size, this makes it easy to integrate into all kinds of machines. The Dual-Band GPRS Class 8 technology is incorporated into robust housing and includes a range of common interfaces as well as an integrated SIM cardholder. MC35i receives

data from PA by Bluetooth module connected to the serial port. The idea for separation between the Personal Analyzer and communication module (GSM) based on the previous experience showed the influence of the GSM placed close to the ECG amplifier.

III. CONCLUSION

In this study, a portable telemedicine ECG monitoring and clinical alarm system is presented. Human's ECG information is acquired and if an emergency situation occurs the information sends to the central server using GSM/GPRS wireless technology. Furthermore, PA and GSM are separated devices. PA-GSM and GSM-central server communication is realized by wireless technologies. Therefore, whole system constitutes a distributed architecture and the system increases the patients' movement freedom. Additionally, PA's integrated technologies like Bluetooth. So, there is no need to implement extra hardware for communication. Also, PA's physical size becomes smaller. On the other hand PA can communicate any device that uses Bluetooth e.g. smartphone, laptop or desktop PC not only with the PDA.

Easy usage and portability of the system with alarming features has an important role in diagnosing the cardiac diseases and treatment. Also this system can be used to record events for some diseases like cardiac arrest, ventricular tachycardia or arrhythmia. The main advantage of the proposed system is decreasing the intervention time to the patient in an emergency situation.

ACKNOWLEDGMENTS

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