BLUETOOTH BASED VISUALIZATION FOR REAL TIME ECG MONITORING

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Abstract — This paper investigates a portable system for remote monitoring of cardiac activity. In this paper we present a low cost, handheld device with wireless transmission for real time ECG acquisition, archiving and visualization both in a mobile phone and a PC. With the recent advance in technology, we create small size wireless ECG system capable of transmitting ECG signal via Bluetooth technology to laptop.
Keywords— Wireless, ECG, Bluetooth.

I. INTRODUCTION

Mobile telemedicine systems are becoming more important all the time, especially in the care of patients that are isolated or traveling, far from a reference hospital. According to an estimate, given by the World Health Organization (WHO), cardiovascular disease kills almost seventeen million people around the globe each year along with twenty million people at a risk of sudden heart failure [13] .Some of these lives can often be saved if acute care and cardiac surgery is provided within the so-called golden hour. So the need for advice on first hand medical attention and promotion of good health by patient monitoring and follow-up becomes inevitable. Hence, patients who are at risk require that their cardiac health to be monitored frequently whether they are indoors or outdoors so that emergency treatment is possible. Telemedicine is widely considered to be part of the inevitable future of the modern practice of

medicine.Telemedicine [4] can make available the benefits of new technologies, especially information and communications, in providing medical care. These systems must be embedded in low cost, small devices with low power consumption, and should have an interface that is usable by the patient.

Wireless technology [1] is to reduce the number of cables and wires which may be tedious and often even hazardous. Scientists and Engineers have been exerting, both a lot of time and money on these technologies, and hence we have the beginning of what many are calling the Wireless Age. Wireless technologies such as Bluetooth, GPRS, GSM or Wi-Fi to these systems allow the wireless transmission to health or control centres. Bluetooth and GSM/GPRS, and the development of software tools both for a computer and for mobile devices enable a large range of application scenarios. Advantages of this are a low cost, portable system with wireless transmission capabilities for the acquisition, processing, storing and visualization in real time of the electrical activity of the heart to a mobile phone, a PC.

One such place where wireless technology could be implemented is inside a hospital, where there are several electrical devices using long wires and cables. An Electrocardiogram (ECG) Monitor which ideally has 12 cables connected to a patient could potentially be implemented as a wireless system. An ECG reading is proven worldwide to be the most accurate data used to determine a patient's heart condition. Therefore many studies have been focused in the design of a highly intelligent, extremely friendly and easy to use, personal portable device for the early detection and interpretation of ECG.

The wireless mobile healthcare system is a kind of flexible system that permits users real-time monitor the important biological signals and transmits the analysis results to the remote hospital central by mobile wireless communication device. The use of wireless communication between mobile users has become increasingly popular due to the advancements in computer and wireless technologies. Implementation of wireless technology in the existing ECG monitoring system eliminates the physical constraints imposed by hard-wired link and allows users to conduct own check up at anytime anywhere. The usage of mobile phone has been recognized as a possible tool for telemedicine since it has become a commercially available household article.

II. LITERATURE SURVEY

Different Methods of Wireless ECG Systems

There have been different methods to develop a wireless ECG monitoring system where the patient being examined is to be free of wires. The following methods use a slightly different implementation in that electrodes are physically connected together, and then an ECG signal is calculated. This processed data is transmitted wirelessly from the patient to a mobile base station. The final implementation uses Bluetooth technology.

(i)Heart monitoring of clothed Person

The first implementation encountered during research used a completely different idea for a wireless ECG monitor. It uses a completely wireless system where a heartbeat sensor was devised that works without electrical connections to the patient.

Figure1.1: Monitoring the heart of a fully clothed person

The patient is fully clothed and the sensor device scans from about one metre away. The device measures displacement current, which is a measure of the changing electric field in the air, generated by the shifting voltages on the skins surface.

(ii)FM Based ECG system

Another ECG system encountered is where several nodes are connected as a system (placed on the patients chest) to calculate the patients ECG and relays this through the tissue of the body (using FM modulation) to a transmitter located on the patients wrist and is transmitted to a base station. Figure 1.2 illustrates this concept.

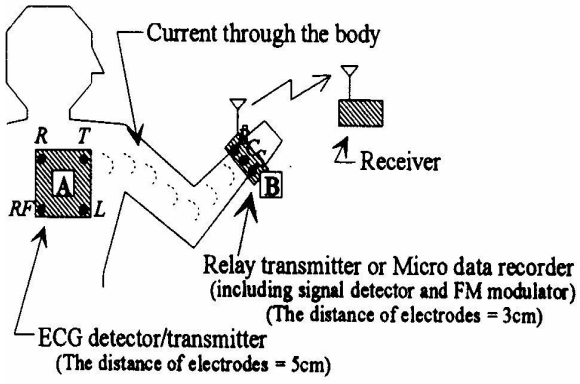

Figure 1.2: FM based ECG

This implementation obtains extremely low power consumption due to the method used for signal transmission; however it suffers from the method of producing the ECG wave before transmission.

(iii)Micromedical

Micromedical [7] has also attempted to implement a wireless ECG monitor where a three-node system (as a single device) takes the ECG reading and is capable of connecting to a mobile phone. The ECG wave is then transmitted to the treating Doctor. Although this implementation is not ideal for hospital situations, it can be used as general checkups for patients in remote locations.

(i v)Bluetooth based Solution

This system expands on a previously developed Internet based database which collects ECG data from patients. The Bluetooth communications protocol is used in the system to send the digitised ECG data to a WEB server via GSM phone modem

(v)BlueNurse

In this, Bluetooth wireless communications protocol is used to send an ECG signal from the patient to mobile station (laptop). The architecture used for this implementation involved using conventional ECG signal acquisition circuitry (ECG system which measures and filters an ECG signal with analogue circuitry before A/D converting). Also, the node meant for transmitting the ECG signal consisted of three electrodes [8] all of which returned to this node. Still the system was unable to show an ECG reading of a patient wirelessly. That is, the Bluetooth wireless link was functional; however the ECG application was not interfaced to the communications link.

Electrocardiograms (ECG):

Electrocardiography (ECG or EKG) is a transthoracic interpretation of the electrical activity of the heart over time captured and externally recorded by skin electrodes It is a noninvasive recording produced by an electrocardiographic device. The etymology of the word is derived from the Greek *electro*, because it is related to electrical activity, *cardio*, Greek for heart, and *graph*, a Greek root meaning "to write".

The ECG works by detecting and amplifying the tiny electrical changes on the skin that are caused when the heart muscle "depolarises" during each heart beat. At rest, each heart muscle cell has a charge across its outer wall, or cell membrane. Reducing this charge towards zero is called de-polarisation, which activates the mechanisms in the cell that cause it to contract. During each heartbeat a healthy heart will have an orderly progression of a wave of depolarisation that is triggered by the cells in the sinoatrial node, spreads out through the atrium, passes through "intrinsic conduction pathways" and then spreads all over the ventricles. This is detected as tiny rises and falls in the voltage between two electrodes placed either side of the heart which is displayed as a wavy line either on a screen or on paper. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle.

An ECG is the recording of the heart electrical potential versus time [2]. In other words, an ECG is simply an electrical recording of the heart. The ECG signal is used by the medical profession in determining present or upcoming heart problems. ECG is among the most commonly performed tests in

medicine. Figure 1.3 [9] shows an ideal ECG signal frame identifying typical features.

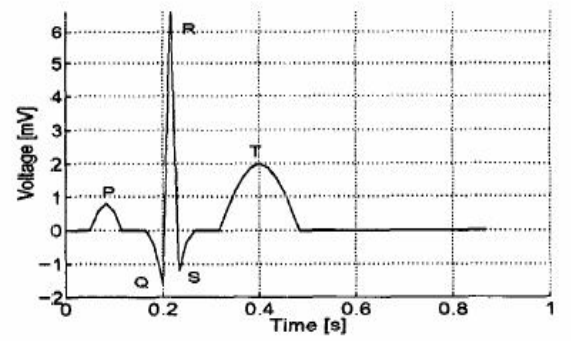

Figure 1.3: Ideal ECG frame with typical features

As shown in figure 1.3 ECG is characterized by a recurrent wave sequence of P, QRS and T- wave associated with each beat. The QRS complex is the most striking waveform of all, caused by ventricular depolarization and atrial re-polarization. Once the positions of the QRS complexes are found, the locations of other waveforms of ECG like P, T waves and QT, ST segment etc. are found relative to the position of QRS, in order to analyze the complete cardiac period.

An electrocardiogram [12] is generated by a nerve impulse stimulus to a heart, whereby the current is diffused around the surface of the body surface. The current at the body surface will build on the voltage drop, which is a couple of µV to mV with an impulse variation. This very small amplitude of impulse needs to be amplified to enable the recording and displaying. Usually, the electrocardiograph needs a couple of thousand times of amplification.

ECG signals

The electrocardiograph is constructed to measure the electrical potential between various points of the body. In a standard ECG recording there are five electrodes connected to the patient:

1. Right arm, RA
2. Left arm, LA
3. Left leg, LL
4. Right Leg, RL
5. Chest, C

Depending how the electrodes pairs are connected to the ECG sensor different waveforms and amplitudes can be obtained. Each pair contains unique information of the heart activity that can not be obtained from another pair of leads. Using real time ECG waveform data is a good “stress test” for this transmission protocol.

	Zigbee	Bluetooth	Wi-Fi
Application	Remote Monitoring and Control	Virtual Cable	Multimedia streaming, Web
Max. N. Nodes	Up to 32000	1 to 7	1 to 5
Transmission Speed (KB/s)	25-250	728	54000
Power Consumption (Radio)	25-35 mA	40 mA	> 400 mA
Power Consumption (Stand By)	3µA	200µA	20mA

Figure 1.4: Transmission protocols.

With the increasing use of ECG Monitors [9], it is anticipated that such instruments will be used in determining other health related issues. However, existing ECG monitoring systems are relatively bulky and hence are less portable. This bulkiness is due to electronics involved in obtaining high quality signals from the confounding effects of patient movement and electrode attachment artefacts. Also, patients are confined to remaining near the ECG Monitoring machine as they are attached to the ECG Monitor via the leads. The entire process of obtaining ECG signals from

Patients can be greatly eased with the use of portable system that allows remote monitoring.

Wireless communications protocols on the market for which an application such as ECG monitoring can be used. Figure1.5 [9] shows a comparison of several Wireless protocols.

Technology	Ideal Application	Range (m)	Data Rate (Mbps)	Current Required	Cost ($)	Connection Type
IR	Device synchronization, data transfer	1	16	Low	10	Single Freq
Bluetooth	Cable Replacement, Ad hoc PAN	10-100	< 1	Medium	10	FHSS
HomeRF	PCs to consumer goods	50	1-2	High	45	FHSS
802.11b	High speed LAN	100+	11	High	45	DSSS

Figure 1.5: Comparison of Wireless Protocols

The above figure 1.5 presents protocols where the throughput is high. However, in an attempt to make the electrode nodes wireless, this is not the only consideration. It is also noted, that the protocols presented above consume a considerable amount of power.

Zigbee

The Zigbee [9,6] protocol operates in the three different frequency bands (2.GHz, 915MHz. USA ISM band and 868MHz-Europe), which employs DSSS for transmission and reception of data.

Protocol features include

- 28kbps and 250kbps data throughput
- Power management features
- Master / Slave topology
- Dynamic slave device addressing
- Up to 254 (+ master) network nodes
- Automatic network configuration
- Full handshaking for packet transfers.
- TDMA slots can be allocated.
- CSMA/CA channel access mechanism.

Bluetooth

In 1998, five major companies (Ericsson, Nokia, IBM, Toshiba, and Intel) formed a group to create a license-free technology for universal wireless connectivity in the handheld market. The result is Bluetooth, a technology named after a 10th-century king who brought warring Viking tribes under a common rule. The Bluetooth specifications, currently in version define a radio frequency (RF) wireless communication interface and the associated set of communication protocols.

Bluetooth [2] standard offers important advantages: low cost, low EM interferences, reduced power consumption, confidentiality of the data, dimensions of the transmitter and are capable of generate small pico-net of some devices. Also it is embedded in most of portable, palm computers and mobile phones and already used in a great number of wearable devices (e.g. mobile phones wireless headsets). The emerging ZigBee standard offers enhanced capabilities especially in term of power consumption, number of connected devices, etc. but, currently, it is not so widespread as Bluetooth.

The Bluetooth [3] protocol enables short range, low power wireless communications between Bluetooth devices. Designed primarily as a cable replace technology, it enables ad-hoc wireless networking, which allows formation of a network without base stations. The Bluetooth radio uses a low-powered transceiver that supports digital wireless communications at the 2.4GHz ISM band allowing data rates of 721kbps.

Reliable and secure transmissions:

Bluetooth technology also provides fast, secure voice and data transmissions. The range for connectivity is up to 10 meters, and line of sight is not required. The Bluetooth radio unit

- Functions even in noisy radio environments, ensuring audible voice transmissions in severe conditions.
- Protects data by using error-correction methods.
- Provides a high transmission rate.
- Encrypts and authenticates for privacy.

CONCLUSION

This system has many advantages including efficiency, accuracy, and simplicity. It is very suitable for ECG detection in clinical practice. A low cost system for ECG is used for acquisition and visualization in mobile devices which is easy to install for a patient, as well as for a physician with little previous knowledge. Incorporating technologies such as Bluetooth and GSM/GPRS, and the development of software tools both for a computer and for mobile devices enables a large range of application scenarios.

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