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A portable wireless biometric multi-channel system

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ABSTRACT

This article presents an 8-channel system for capturing bioelectric signals and transmitting them by the ZigBee protocol. It is a small, portable system with optimised power supply so that it can be battery fed. One of its main advantages is its versatility, since it enables each channel to be configured, in a dynamic and individualised way. This makes it possible to capture diverse bioelectric signals simultaneously, such as electrocardiogram (ECG), electroencephalogram (EEG), electrooculogram (EOG), etc. The developed system can be easily integrated into a Wireless Sensor Network based on ZigBee technology.

1. Introduction

Technological advances now mean that biomedical instrumentation systems can be implemented at a low-cost with high effectiveness. This new instrumentation may be used in hospitals, healthcare centres, patient's homes and could also serve for research purposes. In general they are small, portable systems with autonomous power supply. The performance features of many of the bioelectric signal capturing systems can be enhanced by connecting them up to a personal computer (PC), thereby obtaining the following benefits:

- A personal computer will be available in the great majority of laboratories and healthcare centres. Many of the computer's functions can be implemented with a PDA or even a mobile phone.
- The instrument user interface can be implemented with screen data display or the system functioning can be adjusted by working on the PC, which sends the commands onto the device.
- One single PC can serve as host for several biomedical instruments, centralising various information from the same patient (ECG, EEG, etc.) or even from different patients on the same database [1].
- The information management possibilities are similar to those of PC data: printing, internet transmission, mobile telephony, other communication networks, databases, etc.
- Cost saving on the strength of using simple signal pickup systems sharing the same PC.

Publications before this work reflect the abovementioned advantages, in single-lead electrocardiograph systems [2] or in electroencephalograph capturing systems [3], both cases connected by an RS232 serial port to a PC. A long-term portable recorder for physicological signal has been implemented in [4]. One of the most representative commercial systems of this working philosophy is BIOPAC, which enables different types of biological signals to be captured and sent on to a computer by USB [5].

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The rapidly growing market for wireless technologies in medical environments has led to a critical need for effective cable replacement solutions. Special mention must go to those systems using a wireless communication system [6–9], since they provide flexibility (they are mobile systems that need no cables) and safeguard the physical safety of patients, keeping them isolated from the electricity network. This will enable widespread use of wireless body sensors, utilising both an effective transmission protocol as well as providing proper infrastructure support [10].

1.1. Related work

The system proposed in this manuscript deals with aspects of biomedical instrumentation and wireless communications in medical systems.

The ECG constitutes one of the most powerful and information-rich physiological signals, while being also of straightforward acquisition. This relevance, associated with a relatively high amplitude (up to units of milli Volts, when measured through surface electrodes) translates to a rich literature dealing with the capture and processing for cardiac signals. For example, Shih et al [11] present a telemedicine system (a three-lead electrocardiograph based on an 8-bit microcontroller) that integrates ECG signal reasoning and RF identification together to monitor an elderly patient. In [12] the authors present a single lead system method for on line acquisition of the ECG signal for storage and processing using a MATLAB™-based Graphical User Interface. The Holter system discussed in [13] counts on communication via MMS (multimedia messaging service) and internet for transmitting information to a server. If on one hand the availability of the raw data is sometimes critical, depending on the final application, on the other hand certain parameters from the signal can be immediately obtained (through automated algorithms, with no human intervention) and be of great benefit for a medical diagnostic. Examples of such parameters for the EKG system are the RR interval [13], T-normal amplitude [14], and the QRS width [15]. An overview of telecardiology systems via wireless and mobile technologies is provided in [16].

The electroencephalogram (EEG) is another valuable physiological signal. The EEG presents challenges such as lower amplitude (microVolts through surface electrodes) and higher number of channels needed than a typical ECG. The system discussed in [3] allows for the capture of two channels and signal transmission to a PC via a serial communication interface. In [17] the authors developed a low cost system which allows for much higher transfer rate, of up to 8 EEG channels, and transmission over short distance through a ZigBee protocol to an internet gateway. An up-to-date review on the potential uses of wearable EEG technology is presented in [18].

Other less frequently captured physiological signals are the electrogastrogram [4], the galvanic skin response (GSR) [19] for assessing user stress, and the electromyogram (EMG). The EMG can help diagnose neuromuscular diseases, or in assessing low-back pain, kinesiology, and disorders of motor control. Finally, EMG signals can be used for the control of prosthetic devices [20].

1.1.1. Wireless biomedical systems

Wireless devices have expanded the medical area with a wide range of capabilities. Not only improving the quality of life of patients and doctor-patient efficiency, wireless technology enables clinicians to monitor patients remotely and give them timely health information. The literature abounds with systems and novel applications in wireless sensors for healthcare. Some example papers describing the state-of-the-art in these two areas are provided below [21–25].

Some of the most commonly used protocols in wireless communication biomedical systems are: Bluetooth [26–30], ZigBee [31–33,17], WiFi [30], ad hoc protocols [7,34], MICS (Medical Implant Communication Service) [8] or mobile telephony [15,35].

In order for a protocol to satisfy these medical applications, it must be low power, highly portable, affordable, and reliable. The two most obvious choices for these technologies are ZigBee and Bluetooth. Bluetooth, however, is more expensive and requires more battery power, and is better suited to situations in which connections are persistent, rather than short quick bursts in spread out time intervals [36]. Therefore, ZigBee protocol can be a good election for applications where the data rate is low and the data package is small.

A recent development in the literature of wireless protocols is the combination of two or more of them in one single system. The advantages are that the strength of protocols for short distance can be combined with the ones for long distance and therefore one system can leverage both protocols jointly. For example, Bluetooth can be used for short distance and GPRS for long distance communication. In [11] a patient unit is fitted with a module for acquiring ECG signals, an RFID tag for patient identification, and a GPRS module. A second example ([37]) leverages ZigBee and internet within a system designed to improve healthcare and provide assistance to dependent people at their homes. In general, the factors influencing the decision on the communication protocol to be used depends on three factors: availability of hardware components, infrastructure of the medical environment, and conditions of use of the system.

Currently, most commercial medical devices use Bluetooth and/or WiFi to transmit data to the existing infrastructure in the medical environment [38] because these technologies allow more data transmission (high data rates) and power consumption is not a problem since the battery life is not an important factor in its design. However, many of them report the possibility of including Zigbee communication. The ZigBee Alliance [39] is a group of companies that maintain and publish the ZigBee standard. The Alliance publishes application profiles that allow multiple OEM vendors to create interoperable products. In this regard note that several manufacturers of electronic components and electronics devices such as Texas Instruments are beginning to develop portable medical applications such as blood glucose metre, digital blood pressure metre, blood gas metre, digital pulse/heart rate monitor or even a digital thermometer, which use a ZigBee wireless networking for remote monitoring, control and sensor network applications [40].