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Biosignal Monitoring Using Wireless Sensor Networks

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1. Introduction

The continuous search for people welfare through various mechanisms, has led medicine to seek synergy with other disciplines, especially engineering, among many other developments allowing the application of new techniques to monitor patients through their own body signals. The application of new developments in areas such as electronics, informatics and communications, aims to facilitate significantly the process of acquisition of biomedical signals, in order to achieve a correct approach when developing diagnostic or medical monitoring, to optimize the required care process and sometimes to reduce the cost of such processes.

In some specific situations it is desirable that the patient under monitoring does not lose his mobility by the wire connection to the device that captures any particular signal, since this state may interfere with the study. For example, in case you need to measure the heart effort of a person taking a walk or a sprint. It is in this type of environment where new ICT technologies such as Wireless Sensor Networks (WSN) can support the development of biomedical devices allowing the acquisition of various signals for subsequent monitoring and analysis in real time.

Telemedicine also called e-health is everything related to electronic health data for monitoring, diagnosis or analysis for the treatment of patients in remote locations. Usually this includes the use of medical supplies, advanced communications technology, including videoconferencing systems (Enginnering in Medicine & Biology, 2003).

Telemedicine systems can establish good and emerging technologies such as IEEE standards 802.11, 802.15 and 802.16, which these bases are characterized by the distribution networks for medical information, and provision for life-saving services. These systems have certain restrictions in the sense that when these wireless communications may be affected by a storm, or in conditions where the signal to transmit is not the most appropriate spots, then due to these problems, which solutions were sought resulted in great advances in wireless networking technologies providing vital routes for the restoration of services in telemedicine.

The efficiency of telemedicine systems are widely affected by the design of systems, such as standardization, which in this case would not only rapid deployment, but also easy access for maintenance and renewal future systems that support care services.

The constant study and monitoring of biomedical signals, has been an important tool in the development of new medical technology products. However, these over time begin to see that they are useful and important in industries that formerly had not been implemented but that scientific advances are essential. Over the years, monitoring of such signals have been putting more importance and trust in the medical corps, allowing them to exploit technological advances to benefit human care.

Within each wireless sensor network, sensors are one of the most important components of the network. There are several sensors based on the applications we want to use. An example is the temperature sensor, which is a component that is mostly composed of semiconductor materials that vary with temperature change. In the case of biomedical environments, it senses the temperature of the skin or skin temperature, which enables us to monitor it in the patient, allowing for immediate assistance.

We are not too far from the meaning stated above, to make a comparison, we found that both conditions vary only in the ability to sense, as this requires certain conditions of the system or agency is analysing nevertheless remains a fundamental part at the time to learn about processes that is "easy" observe or with our senses is impossible to understand.

However, biomedical sensors, should be chosen under certain parameters that are vital to the development and smooth operation of the same, they should be able to measure the signal in particular, but also to maintain a single precision and replacement capacity fast enough to monitor living organisms. Additionally, these sensors must be able to adapt to variations in the surface bioelectric be implemented (Bronzino, 1999).

This chapter is organized in the following sections. Section 2 shows the main characteristics of wireless sensor networks. We present the essential information about Body Sensor Networks as a WSN specialization in medical environments in Section 3. Section 4 shows our methodology for the development of applications of biomedical signals acquisition. We conclude this chapter with section V.

2. The wireless sensor networks

The wireless sensor networks are formed by small electronic devices called nodes, whose function is to obtain, convert, transmit and receive a specific signal, which is captured by specific sensors, chosen depending on the sensing environment. This technology, due to its low cost and power consumption is widely used in industrial process control, security in shopping malls, hotels, crop fields, areas prone to natural disasters, transport security and medical environments, among other fields.

A sensor network can be described as a group of nodes called "motes" that are coordinated to perform a specific application, this lead to more accurate measurement of tasks depending on how thick it is the deployment and are coordinated (Evans, 2007).

2.1 General features

In a wireless sensor network, devices that help the network to obtain, transmit and receive data from a specific environment, are classified according to their attributes or specific performance in the network (Cheekiralla & Engels, 2005).

A wireless sensor network consists of devices such as are micro-controllers, sensors and transmitter / receiver which the integration of these form a network with many other nodes, also called motes or sensors. Another item that is extremely important in any classification, is to know the processing capacity, due to its necessary because communication being the main consumer of energy, a system with distributed processing features, meant that some of the sensors need to communicate over long distances This leads us to deduce that higher

energy consumption needed. Hence the rationale for knowing when to be processed locally as much energy to minimize the number of bits transmitted (Gordillo & al., 2007).
A node usually consists of 4 subsystems (See Fig. 1):

- **Computing subsystem:** This is a micro controller unit, which is responsible for the control of sensors and the implementation of communication protocols. The micro controller is usually operated under different operating modes for power management purposes.
- **Communications subsystem:** Issues relating to standard protocols, which depending on your application variables is obtained as the operating frequency and types of standards to be used (ZigBee, Bluetooth, UWB, among others.) This subsystem consists of a short range radio which is used to communicate with other neighboring nodes and outside the network. The radio can operate in the mode of transmitter, receiver, standby, and sleep mode.
- **Sensing subsystem:** This is a group of sensors or actuators and link node outside the network. The power consumption can be determined using low energy components.
- **Energy storage subsystem:** One of the most important features in a wireless sensor network is related to energy efficiency which thanks to some research, this feature has been considered as a key metric. In the case of hardware developers in a WSN, it is to provide various techniques to reduce energy consumption. Due to this factor, power consumption of our network must be controlled by 2 modules: 1) power module (which computes the energy consumption of different components), 2) battery module (which uses this information to compute the discharge of the battery.)

When a network contains a large number of nodes, the battery replacement becomes very complex, in this case the energy used for wireless communications network is reduced by low energy multiple hops (multi-hop routing) rather than a transmission high-tech simple. This subsystem consists of a battery that holds the battery of a node. This should be seen as the amount of energy absorbed from a battery which is reviewed by the high current drawn from the battery for a long time (Qin & Yang, 2007).

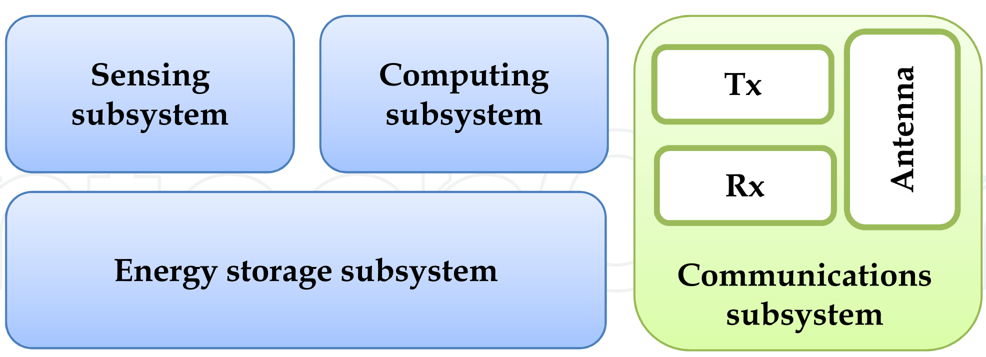

Fig. 1. Wireless Sensor Networks subsystems

2.2 WSN classification and operation mode

A wireless sensor network can be classified depending on their application and its programming, its functionality in the field sensing, among others. In the case of a WSN (Wireless Sensor Networks), is classified as follows:

- **Homogeneous**, refers when all nodes have the same hardware, otherwise it is called heterogeneous.

- **Autonomous** referenced when all nodes are able to perform self-configuration tasks without the intervention of a human.
- **Hierarchical** referenced when nodes are grouped for the purpose of communicating or otherwise shut down, in this classification is common to have a base station that works as a bridge to external entities.
- **Static**, referenced when nodes are static and dynamic otherwise.

A WSN can also be continuous, hybrid, reactive. In the case of the reactive mode, is when the sensor nodes send information about events occurring in the environment and both are scheduled when the information collected under defined conditions or specified for the application that want (Ruiz, Nogueira, & Loureiro, 2003).

A WSN is designed and developed according to the characteristics of the applications to which the design or the environment is implemented, then to which must take into account the following "working models" (Egea-Lopez, Vales-Alonso, Martinez-Sala, Pavon-Mario, & Garcia-Haro, 2006):

- **Flexibility**. In this item, the wireless environment is totally changed due to interference from other microwaves, or forms of materials in the environment, among other conditions, that is why most of the nodes can fail at any time, because should seek new path in real time, must reconfigure the network, and in turn re-calibrate the initial parameters.
- **Efficiency**. This item is very important due to the network to be implemented must be efficient to work in real time, must be reliable and robust to interference from the same nodes, or other signals from other devices. This item is in relation to that should be tightly integrated with the environment where it will work.
- **Scalability**. This item talk about when it comes to wireless sensor network is dynamic, due to its topology or application to use, being a dynamic sensor network, adding nodes is an important factor for the smooth operation of data storage.

2.3 WSN functional levels

WSN network are classified into 3 functional levels: The level of control, the level of Communications Network and the Field Level, as shown in Figure 1.

The field level consists of a sensors set and actuators that interact directly with the environment. The sensors are responsible for obtaining data either thermal, optical, acoustic, seismic, etc. The actuators on the other hand receive orders which are the result of processing the information gathered by the sensors so it can be run later. In the communication network establishing a communication link between the field level and the level of control. Nodes that are part of a communications subsystem WSN are grouped into 3 categories: Endpoints, Routers, and Gateways. Finally found the level of control consists of one or more control and/or monitoring centres, using information collected by the sensors to set tasks that require the performance of the actuators. This control is done through special software to manage network topologies and behaviour of our network in diverse environments (Rodríguez & Tellez, 2009).

One way to consider wireless sensor networks is to take the network to organize hierarchically the nodes of the upper level being the most complex and knowing his location through a transmission technique.

The challenges in hierarchically classify a sensor network is on: Finding relevant quantities monitor and collect data, access and evaluate information, among others. The information

fulfilling predefined maximum quality standards taking into account that is not stopping the functioning of the body.

4.2 Processing & transmition

For optimum performance of a wireless sensor network, it must take certain variables or characteristics such as: Design the network topology sensing environment, energy consumption, distribution, formation of the network, which provide work a detailed selection of elements for optimum performance.

To get a sensing stability, we must be accurate when analysing signals, must turn to decipher and error-free data set give us a straight answer and correct what is a translation of a real situation. For this analysis, must take count that when handling and rely on signals, the noise and signals that alter our report as we may find situations where these noises are not important, as there spaces so. To overcome this obstacle, should be taken into account all types of filters that can regenerate the signal for the system to obtain an adequate response and follow the specifications with which the sensor reported the state of our system.

The next step is the routing of data, that we must consider how we get all this data, and network protocols that we use that are appropriate, including some that are feasible to use are the following: Internet, LAN, Bluetooth, RF, etc.

Can configure the data so that we know the environmental status according to the location of it and thus be able to see your progress. To have a comprehensive approach to what we see, we have three types of messages when creating a virtual environment that allows me to see the real situation. These three types of messages are control messages, which maintain stability in the system to monitor, we have messages of interest, which can give us an overall picture of what happens in reality and finally we have the data messages we give an independent report of the situation as external changes and variations as shown in control (Wassim & Zoubir, 2007).

The functionality of a wireless sensor network occurs in large part on the correct and accurate operation of the nodes that comprise it. For the acquisition of signals in a given environment using specific sensors, these sensors as was seen in the first objective, depending on the application and the environment in which you want sensing.

Based on the basic principles for designing a system for acquiring and processing of biomedical signals (Bronzino, 1999), the text provides 6 phases with which it must have the design of the data acquisition phase and later emphasizes the hardware design. The diagram is proposed as follows:

Fig. 6. General block diagram of a procedure analogue to digital (Bronzino, 1999)

The function of a node is to sense, process and communicate data from the signal for a more detailed study as the application that the network administrator requires. Depending on the

topology of the network, each node has a specific function, is the case router node, which can only send or receive a message, but cannot send messages or data to other router nodes. On the other hand there is the coordinator node which has a dependency on other nodes for the complete management of a network, unlike router node; this node can send data to different nodes regardless of their classification.
The components that make up a sensor node, are mostly very small devices made by MEMS (Micro Electromechanical Systems), which each plays a vital role in the performance of each node in the network. Some of these components are:

1. Sensing unit and unit performance
2. Processing Unit
3. Communications Unit
4. Power Unit
5. Other

These hardware components should be organized to conduct a proper and effective work without generating any kind of conflict in support of specific applications for which they were designed. Each sensor node needs an operating system (OS) operating system operates between the application software and hardware and is regularly designed to be used in workstations and PCs.
In the market there are several manufacturers of nodes. Currently there are 3 companies that excel in developing this technology. These are: CROSSBOW, MOTEIV, Shockfish. In the Table 2 shows some characteristics of the nodes of the manufacturers of this technology (Serna, 2007).

	Micaz	**Mica2**	**Mica2dot**	**Tmote**	**TinyNode**
Distributed by	Crossbow			Moteiv	Shcokfish
Clock frequency	7.37 MHz		4 MHz	8 MHZ	8 MHz
RAM	4 KB			10 K bytes	10k bytes
Battery	2 AA Battery		Coin cell	2 AA Battery	Solar
Microcontroller	Atmel	Atmega	128 L	Texas Instruments	MSP430 microcontroller

Table 2. WSN Nodes characteristics

Among the key parts of the performance of a WSN, it should detail the minimum consumption for the network. So for the design of a wireless sensor network have focused on the biomedical field to consider the following items (Melodia, 2007):

1. The collisions should be avoided whenever possible, since the relay produces unnecessary energy consumption and other potential delays associated. Must find an optimal solution to avoid overloading the network and avoid the maximum power consumption.
2. The delay of transmission sent data packets is very important because you are working in a biomedical signal, it should be broadcasting continuous time and with the highest possible quality.
3. The receptor of our network must always be in constant operation (On), for it provides an ideal or hypothetical situation where our network only mode when you need to send or receive packets, and minimize the monitoring efforts of our spots.

4. There are points in the design of our wireless system such as: efficient use of bandwidth, delay, channel quality and power consumption.
5. The adaptability and mobility of our network.

4.2.1 Design coordinators and Router nodes

Some new technologies in the design and manufacturing of communications devices, smaller devices and better yields have been able to develop more complete nodes to the field of sensing, transmission and reception of signals obtained. Currently there are several devices that meet the requirements demanded for the development of a wireless sensor network.

The use of communication modules, have helped to design the networks, both in reducing devices included in a node, and the integration of several functions at a level both hardware and software (i. e. Security Protocols) in a single device.

On the other hand a form of management and efficient use for the acquisition of signals and their subsequent communication can be handled through the use of communication modules and modem devices. This solution is temporary and that the management and programming of micro-controller installed in the module, you can get a bit complex due to the type of software from the manufacturer and type of programming. The stage design software, you must set the proper display and lots of useful information necessary for a proper analysis of the situation and a diagnosis of what is sensed.

4.3 Acquisition & visualization

In order to develop a software application that allows the correct visualization of the acquired signals, it must take into account multiple factors to identify the basic features to implement it.

One of the first tasks is the selection of the platform for software development, the parameters to consider are:

- A platform that has the ability to receive a high volume of data
- A platform that allows easy synchronization between hardware and software.
- A platform with virtual instrumentation tools.

After selecting the development platform begins the design phase of the application. This stage should establish the visual and information to be submitted for a proper medical diagnosis. In order to visualize the acquired biomedical signals must be designed the following modules:

- **Acquisition Module**: This module is responsible for taking the BSN biomedical signals gateway.
- **Separation Module**: This module is responsible for recovering the received frame, the different signals transmitted (if more than one)
- **Processing Module**: This module each signal must translate the information received in units of voltage to the unit required by the signal such as temperature and relative humidity among others.
- **Display Module**: Determine the way in which the signal must be represented.
- **Graphical User Interface**: This module is integrated display modules to facilitate the analysis of information by the end user.

Finally completed the respective designs, the following steps are implementing the software and then testing to check its proper functioning (See Fig. 8).

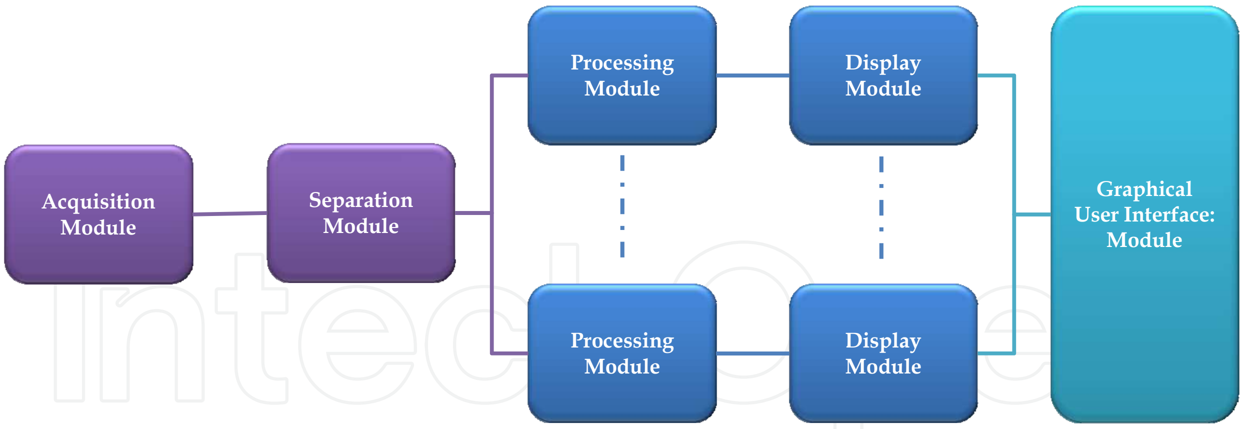

Fig. 7. General block diagram of biomedical signals visualization software

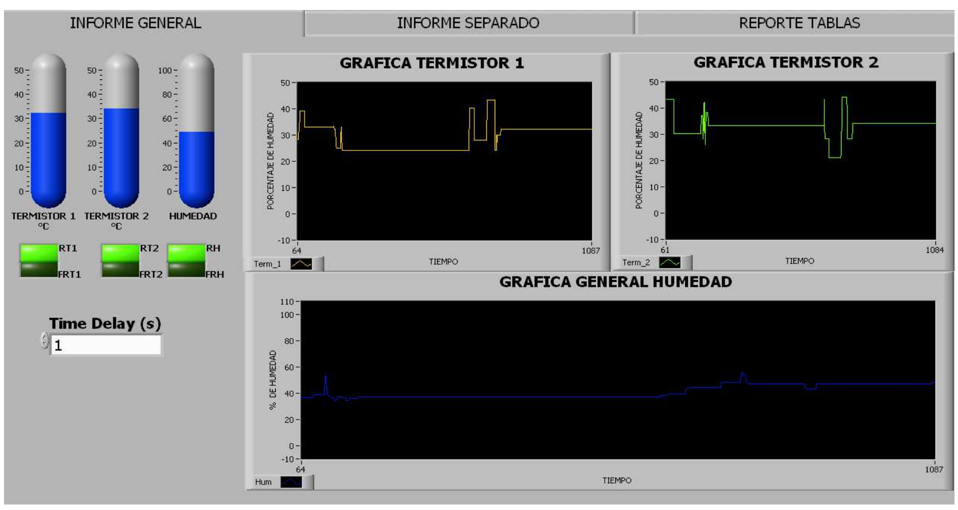

Fig. 8. Temperature and Humidity visualization software (Rodríguez & Tellez, 2009)

5. Conclusion

The impact generated by the use of wireless sensor networks in the quality of patient care is very high. The use of these devices in home care systems can reduce hospitalizations, health professionals timely interventions can extend patients life, and in some cases the use of biofeedback techniques in psychological treatments may overcome difficult phobias.
The development of such systems implies challenges to be faced in the area of engineering, such as minimizing energy consumption, since you want nodes lifetime in the network to be as long as possible. Another challenge is assuring the reliability of the information transmitted, since any slight variation may generate erroneous diagnosis. Finally, one of the biggest concerns is related to the potential impact of electromagnetic radiation to human bodies subject to the use of such devices.

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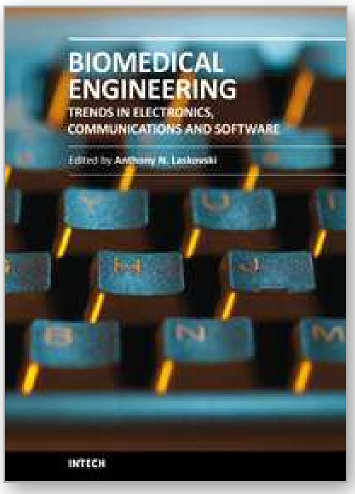

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Rapid technological developments in the last century have brought the field of biomedical engineering into a totally new realm. Breakthroughs in materials science, imaging, electronics and, more recently, the information age have improved our understanding of the human body. As a result, the field of biomedical engineering is thriving, with innovations that aim to improve the quality and reduce the cost of medical care. This book is the first in a series of three that will present recent trends in biomedical engineering, with a particular focus on applications in electronics and communications. More specifically: wireless monitoring, sensors, medical imaging and the management of medical information are covered, among other subjects.

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