Master Thesis

'Web interface development for healthcare oriented smart houses'

Staffordshire University – TEI of Larisa

Supervisor: Nicholas Samaras

Name: Panagiotopoulos Ioannis

Date: 21/06/2013

Abstract

A type of wireless sensor network is the wireless body area sensor network (WBASN). The wireless sensor nodes can be placed on, near, or within a human body. In a medical healthcare system, WBASNs continuously provide healthcare monitoring, especially of elderly or people with disabilities, wherever the patient goes. The medical sensors sense and process human vital signs such as blood pressure, heart rate and body temperature. Then the collected data is sent them to a medical center via personal server in order for medical professionals to monitor the patient's health. In the medical center, doctors and caregivers need web interfaces to process, analyze, and visualize the received data from WBAN-based systems. In this thesis, the main goal is the development of a web interface for medical healthcare systems, based on a WBAN, in order to provide security and better quality of life for elderly and disabled persons. In addition, the implemented web interface presents several features, including recording, displaying, and analyzing collected data from the medical sensors.

Abbreviations

WSN Institute of Electrical and Electronics Engineers

ADC Analog-to-digital converter

PDA Personal digital assistant

WPAN Wireless Personal Area Network

WLAN Wireless Local Area Network

WMAN Wireless Metropolitan Area Network

LED Light-Emitting diode

BP Blood Pressure

EMG Electromyography

UWB Ultra Wideband

HCI Human-Computer Interaction

MAC Medium Access Layer

TDMA Time division multiple access

RF Radio Frequency

ECG Electrocardiography

FTSP Flooding Time Synchronization Protocol

QoS Quality of Service

GPRS General Packet Radio Service

UMTS Universal Mobile Telecommunication Systems

CDMA Code division multiple access

Table of Contents

Table of Figures

1. Introduction – Wireless Sensor Networks

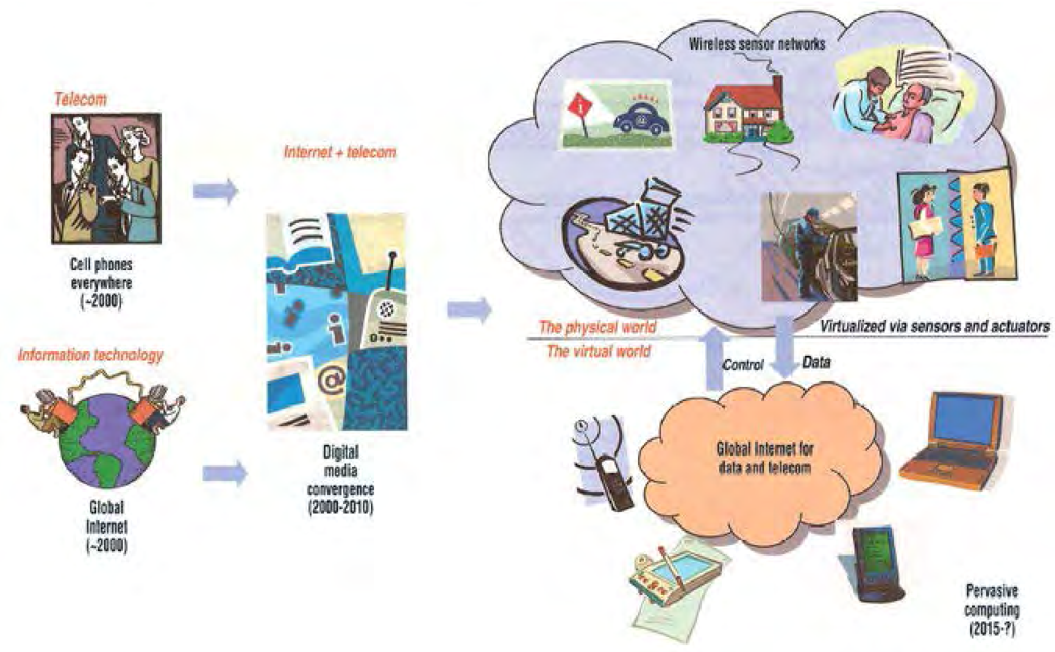

Figure 1 : Wireless Sensor Network

Wireless Sensor Networks consist one of the most promising and upcoming technologies of today. In fact they are categorized as one of the best 30 technologies of the last century. With their economical equipment they have managed to start invading our everyday lives and conquer our houses and our working environment aiming to facilitate and upgrade our lives.

Gordon Moore, the co-founder of Intel, suggested in 1965 what was later called Moore's law, that is, that the number of transistors fitted onto an integrated system would double their number every second year. What is really impressing is that this prediction came out to be true leading to today's possible miniaturization of hardware [1].

The increasing interest for wireless sensor networks can really easily be understood by just thinking that it is all about a number of small self – powered nodes that can take measurements or detect events and communicate, at the same time, with a base station in order to transmit this data. The basic principles upon which these sensors work are sensing, processing and communicating, and with these principles they can be used in a really large number of applications. As expected, they have to face many challenges such as their restricted energy. However, recent advances in low power VLSI, embedded computing, communication hardware, and in general, the convergence of computing and communications, are making this emerging technology a reality [27].

The main features of a WSN are scalability, self – organization, self – healing, efficiency, connectivity, low cost and low size of the nodes. Extended research in the field of wireless sensor networks started in the year 2000, after taking advantage of the first outcomes of the research conducted on this sector in previous years. Particularly the study of ad hoc networks attracted a lot of attention for several decades, and some researchers tried to report their skills acquired in the field of ad hoc networks to the study of WSNs [27]. As predefined ad hoc networks, form a dynamical, autonomous system of sensors using only a centralized administration and, of course, they can include WSNs.

Below we can see a description of the parts that compose a sensor node that participates in a wireless sensor network and is presented in figure

Figure 2 : MICAZ Sensor Node

- **Embedded Processor**

The role of the processor in sensor node is to schedule the tasks of the node, process the data received by the sensor and finally control the different hardware components of the node.

- **Transceiver**

The transceiver holds the responsibility for the node's wireless communication using Radio Frequency, Infrared or Laser technologies. Each transceiver operates in three different modes, namely receive, idle and sleep.

- **Memory**

Memory used in a sensor node is usually a RAM memory of a microcontroller, an in – chip flash memory and an external flash memory.

- **Power Source**

Power in a sensor node comes from being stored into batteries or capacitors. The batteries used are usually of 2 AA type. Latest researches are shifted into finding different ways of energy harvesting in a sensor node such as solar or wind power.

- **Sensors**

Sensors are mini devices that can transform a measurable response signal to a physical measurement such as temperature, pressure or heart rate. They sense an analog signal, then they digitize it in the ADC and finally they send it to the processor for any further process.
Sensor technology appears to be really appealing for a really large number of applications that vary from environmental monitoring, to agriculture and micro – surgery.
Through joint efforts of the University of California at Berkeley and the College of the Atlantic, environmental monitoring is carried out off the coast of Maine on Great Duck Island by means of a network of Berkeley motes equipped with various sensors [28]. The

same idea is also tested in a project conducted at the University of Hawaii, where sensors gather environmental data and directly send them to data server units on the Big Island of Hawaii.

In the field of agricultural monitoring Intel created a really interesting network called Wireless Vineyard, which was expected to collect and interpret data from the field and at the same time take the decision of injecting the appropriate kind of insecticide when needed. The Smart Kindergarten project of UCLA was a very interesting project that used sensors to supervise the learning process of the children and allow unobtrusive monitoring by the teacher [27]. Under the example of the Smart Kindergarten the School of Medicine of Boston University created the so called CodeBlue, which supports devices used to monitor patients that suffer from different diseases [29].

The technology of wireless sensor networks conquers the military field as well. DARPA [30], is a sensor network that uses peer – to – peer communication between anti-tank mines in order to respond to attacks or redistribute mines. Another application of this type is Urban Warfare, which detects enemy movements or chemical attacks [27].

2. Wireless Body Area Networks

2.1 Introduction

As technology keeps evolving, it comes up to the expectation of the aging population that demands technological enhancements in order to facilitate their everyday life and help them face their health problems. The latest advances in electronics present the below described system that facilitates each patient to receive treatment while being in his own private space enabling at the same time his mobility as he is no longer obliged to stay into a hospital. This is nowadays referred to as mHealth. In order to fully exploit the benefits of wireless technologies in telemedicine and mHealth, a new type of wireless network emerges: a wireless on-body network or a Wireless Body Area Network (WBAN) [2].

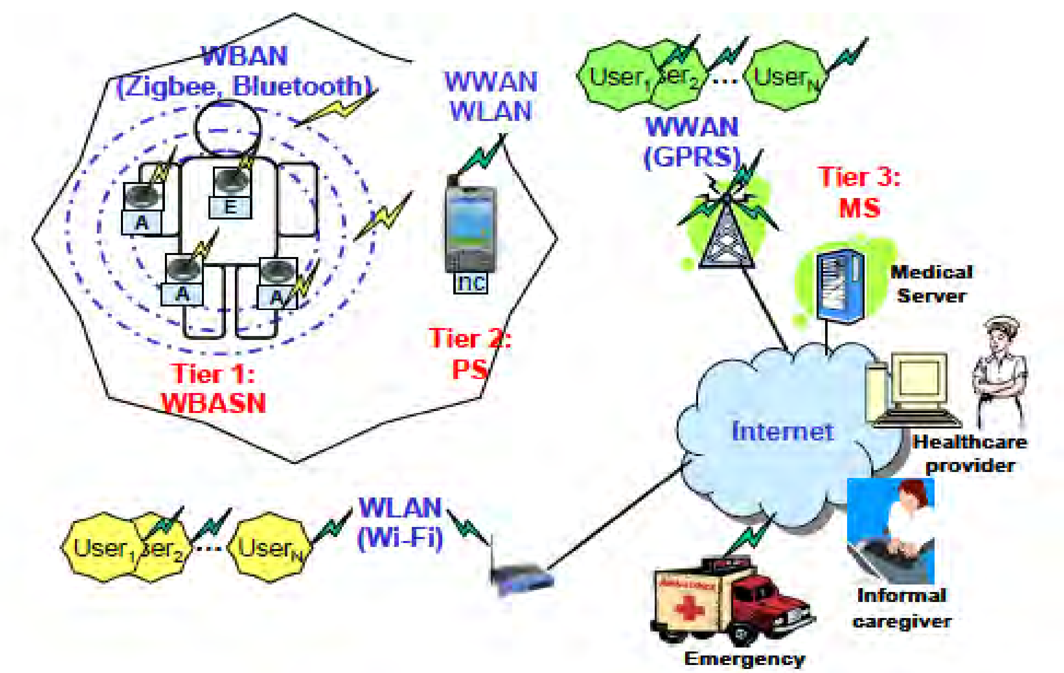

Figure 3 : Wireless Body Area Network

Body sensor networks were initially presented by T. G. Zimmerman in an article that he wrote introducing and presenting the term Wireless Personal Area Networks (WPAN) back in 1996 [3]. What this term really implies, is a system of tiny and intelligent sensors that can be either worn or implanted in the human body and take real time measurements of various health aspects. These sensors, in order to communicate with the environment, transmit, analyze and store data need a wireless communication interface and an external medical server to collect and further process all the necessary received data.

Wireless Body Area Networks consist of small and intelligent devices, attached or implanted in the human body that provide continuous health monitoring and real time feedback to the user or the medical personnel, and communicate with each other in a wireless way that permits the patient to feel free and move any way he wants in his own house. Furthermore, the measurements can be recorded over a longer period of time, improving the quality of the measured data [2,4]

In a WBAN we can distinguish three types of devices:

A. Sensors: They are used to take the requested measurements from the human body, such as heart beat, body temperature or even an electrocardiogram.

B. Actuators: The role of the actuators in this kind of systems is a little bit different as they are responsible for providing the patients with the necessary medicine or reacting when an abnormality is measured.

C. Personal Devices: This type of devices collects all the information acquired by sensors and actuators and informs all users about the prices monitored.

Usually, interaction among the user and the machines occurs by a personal device, e.g. a PDA or a smart phone that acts as a sink for the data received by the wireless devices.

WBANS have some specialties and, therefore, protocols designed for other types of wireless networks many times fail to support them. In the following, some main differences between WSNs and WBANs are presented [2]:

- Sensor nodes used have limited energy resources available as they have a very small form factor (often less than 1 cm3 [5]).
- All devices are equally important and devices are only added when they are needed for an application.

- An extremely low transmit power per node is needed to minimize interference and to cope with health concerns [6].
- The propagation of the waves takes place in or on the human body. As a result, the waves are attenuated considerably before they reach the receiver.
- The devices are located on the human body that can be in motion. Therefore we have really frequent changes in the network topology.
- The data mostly consists of medical information, thus reliability and high level of response is required.
- Stringent security mechanisms are required in order to ensure the strictly private and confidential character of the medical data [2].

When comparing a WBAN with other types of wireless networks such as Wireless Personal (WPAN), Wireless Local (WLAN), Wireless Metropolitan (WMAN) and Wide Area Networks we see that a WBAN operates closer to the human body, with a communication range of low values that in fact reach only a few meters. While a WBAN refers to the sensors attached to the human body, WPAN on the other hand represents a network that appears in the environment around a person with communication range up to ten meters when it comes to high data rate application and much more when it comes to low data rate applications. In the meantime, a WLAN has a communication range that can reach up to hundreds of meters. The communication protocol that uses each network is defined by IEEE, with WPAN using Bluetooth or Zigbee, WLAN Wifi and WMAN Wimax.

2.2 Sensors Used for Monitoring and Sensing

Technological advances in micro devices brought dramatic growth of interest in wearable and implanted technology. Tiny sensors constitute a new and revolutionary trend in many areas with a great variety of applications, from sports to battle field. Their appearance in the world of health and medicine promises a future of low cost with solutions that will monitor the patients all day and in any place. Due to this fact, a large number of companies have started investing in tiny sensors in order to provide reliable and, at the same time costless solutions to the health sector.

Sensors used in a WBAN are distinguished in two different categories depending on whether they are wearable or implanted. Below we can see these types of sensors as well as some examples of how these sensors are going to be used.

2.2.1 Wearable Sensors

Wearable sensors are mostly met in applications whose main goal is to take physiological measurements such as heart beat, respiration, oxygen levels etc. In fact they can nowadays be considered as ready for every clinical application. Mostly they are enclosed in patches, bandages, or clothes and what they require for analysis is a desired sample, usually a body fluid such as sweat, delivered to the sensor's active surface, whereupon a reaction happens and a signal is generated [7]. Their potential comes up to the point of monitoring individuals for periods of days, weeks or even months. Data collected by these sensors are wirelessly sent to recipients via a wireless LAN or internet connection.

Pulse Oximetry

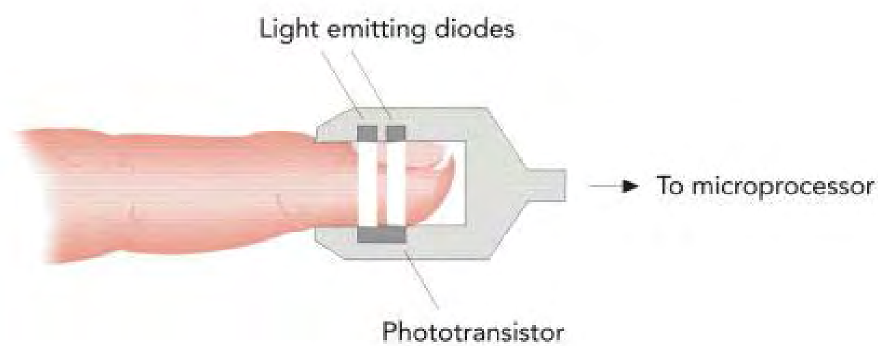

Figure 4: Pulse Oxymetry Sensor

Pulse oximetry is one of the latest methods used in order to measure heart rate and blood stream in a human body. Typically, a pulse oximeter is attached to a finger or an earlobe, and it consists of red and infra-red light-emitting diodes (LEDs) and a photodetector [31]. It is based on the use of two different small LEDs that operate at two different wavelengths, namely the one at the 660nm and the other at the 910nm. Each wavelength represents the red and infra – red light transmitted by the appearance of oxy and deoxy hemoglobin in the human body. Absorption on each wavelength differs significantly for the oxyhaemoglobin and deoxygenated haemoglobin [8] and can be used as a basis for the measurement of SpO2. This difference can be easily calculated as it comes as a ratio between the two types of haemoglobin which function in the human body as a carrier for the red blood cells. The different wavelengths chosen in the use of LEDs indicate the difference in the absorption of oxy and dexy haemoglobin by the human body. Oxy haemoglobin shows higher absorption and therefore is indicated by the higher wavelength of the 910nm. The almost periodic signal received by the above process is called photoplethysmograph and is used to determine heart rate.

- ***Electrocardiography***

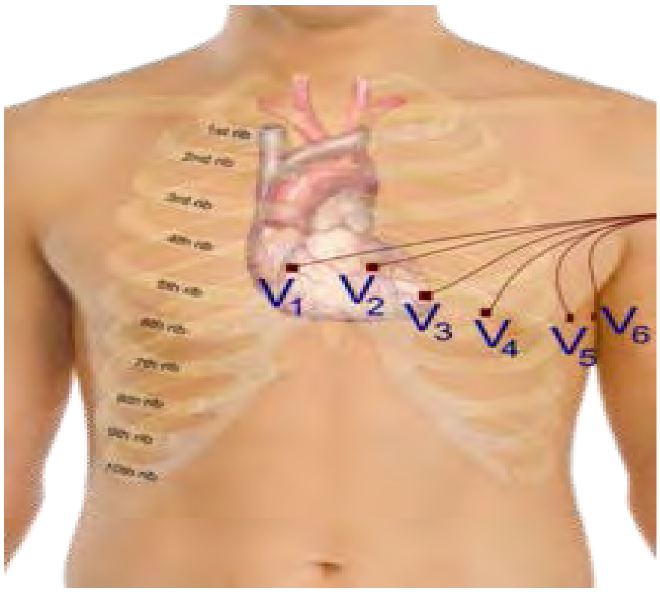

Figure 5: EKG Sensors

Heart is a really special muscle whose cells have the unique potential of being polarized, which means that they present concentrations of ions across their cell membranes. An excess of positive sodium ions on the outside of the membrane causes the outside of the membrane to have a positive charge relative to the inside of the membrane. The inside of the cell is at a potential that is about 90 millivolts (mV) less than the outside of the cell membrane. The 90 mV difference is called the resting potential [9]. Various actions made while the heart functions create an electrical field around each cell that by consequence causes a muscle contraction. This electrical field can be measured on the skin surface by an electrocardio sensor. ECG sensors are widely used in ambulatory applications.

Human++ project introduced by IMEC-NL [32] is a system that uses ECG/EEG and was developed to enable people to carry their personal body network. It uses a transmitter working on 2,4 GHZ and uses 2 AA batteries.

- ***Blood Pressure***

Blood pressure is a measurement that indicates the circulation of the blood on the walls of blood vessels and is divided into two categories. The systolic, the maximum pressure during a cardiac cycle and the diastolic, the minimum pressure at the same cycle. It has been observed that ambulatory BP is more closely related to target organ damage and cardiovascular events than BP readings taken in a clinical environment [30, 33]. Sensor applications regarding blood pressure obtain systolic and diastolic readings by placing the sensor around the wrist and read the results via the oscillometric method.

- ***Electromyography***

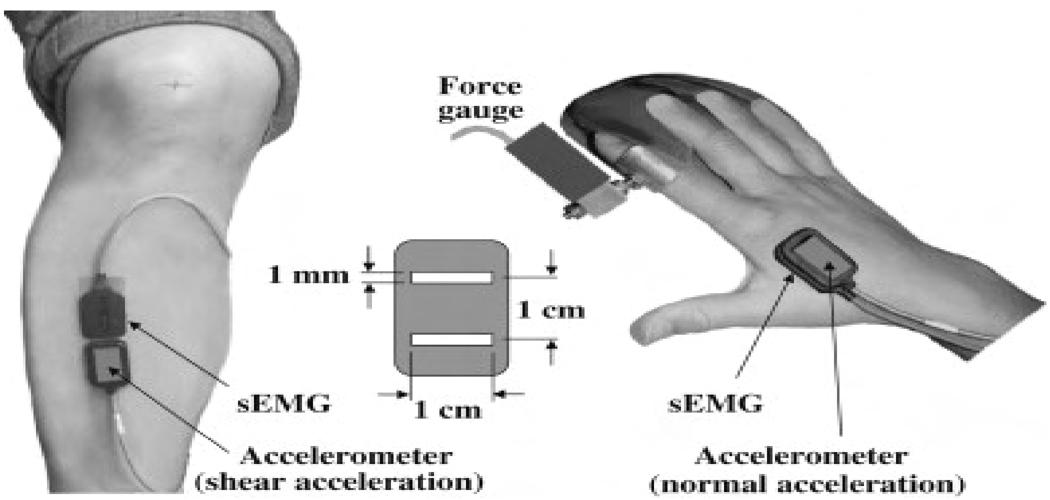

Figure 6: EMG Sensors

The term electromyography refers to the study of all muscle activities through different electrical signals derived from the muscles themselves. When a surface electrode is placed on the skin above a superficial muscle while it is contracting, it will receive electrical signals emanated from several muscle fibers associated with different motor units [30]. There are two types of sensors used when it comes to electromyography depending on the muscle that needs to be studied. The surface EMG that collects general activity and the needle EMG that is inserted inside the human body in order to acquire more specific information from the specific muscle. EMG sensors are generally used on persons who suffer muscle or skeletal problems.

- ***Motion Detection***

Motion detection sensors, usually called accelerometers, are used to sense changes in a body position that can be either linear or angular. The operational principle of accelerometer is based on an element named proof mass, which is attached to a suspension system with respect to a reference point and, when force is applied on proof mass, deflection is produced in it [10]. The produced deflection can be measured electrically to sense changes in body location [11]. An accelerometer is a sensor that measures acceleration with respect to gravity, and can be used to determine the orientation of a body part in the absence of movement [30]. The most common use of accelerometers concerns people that recently suffered a brain disease, stroke or Parkinsons, who need full control of the motion level of their body.

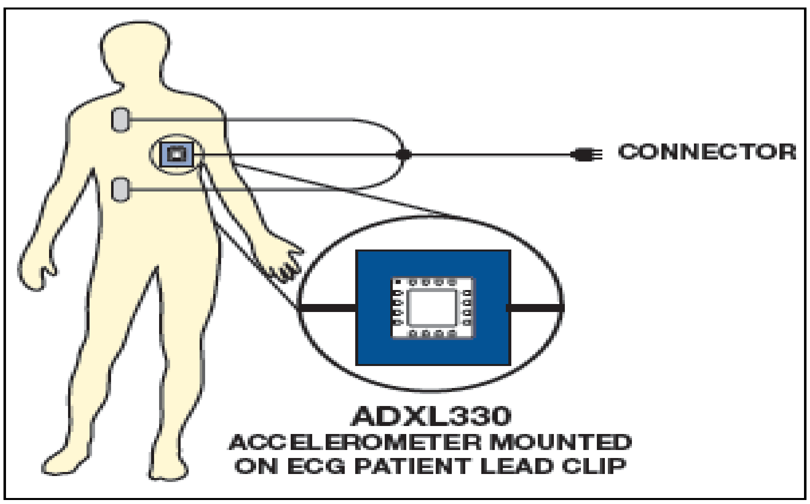

Figure 7 : Motion Detection Sensor

WBASN system is a solution that uses triaxial accelerometers in order to make posture and activity recognition on the tested field.

Electromagnetic Tracking System

This type of sensor belies on Faradays law of magnetic induction which means that each time the person who wears the sensor makes a motion the magnetic field of the sensor will change as well. This controlled magnetic field is generated by a fixed transmitter and detected by a receiver fixed on an object [10]. By using the above phenomena position and orientation of moving object can be calculated [12].

Electroencephalography

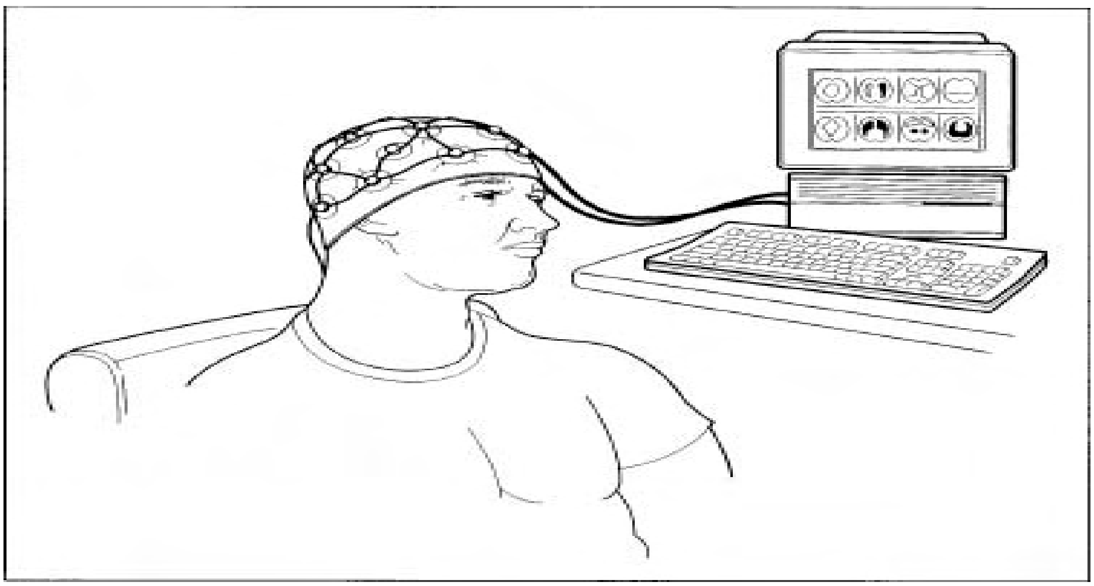

Figure 8 : Electroencephalography Sensors

The term electroencephalography refers to the detection of the electrical ability of the brain. The representation of this measurement is mostly called “brain waves”, and is used to assess brain damage, epilepsy or other brain damage and in some really rare cases brain death. Sensors used in electroencephalography are still in early stages, which brings science to the need of developing sensors that will have the potential to take daily measurements of the brain activities.

2.2.2 Implantable Sensors

Implantable biosensors need to be tiny, lightweight and compatible with the body mass in order for them to be accepted by the human body. Most importantly they must not decay over time and operate with the minimum possible power. Usually they necessitate an operation in order to be injected in the human body.

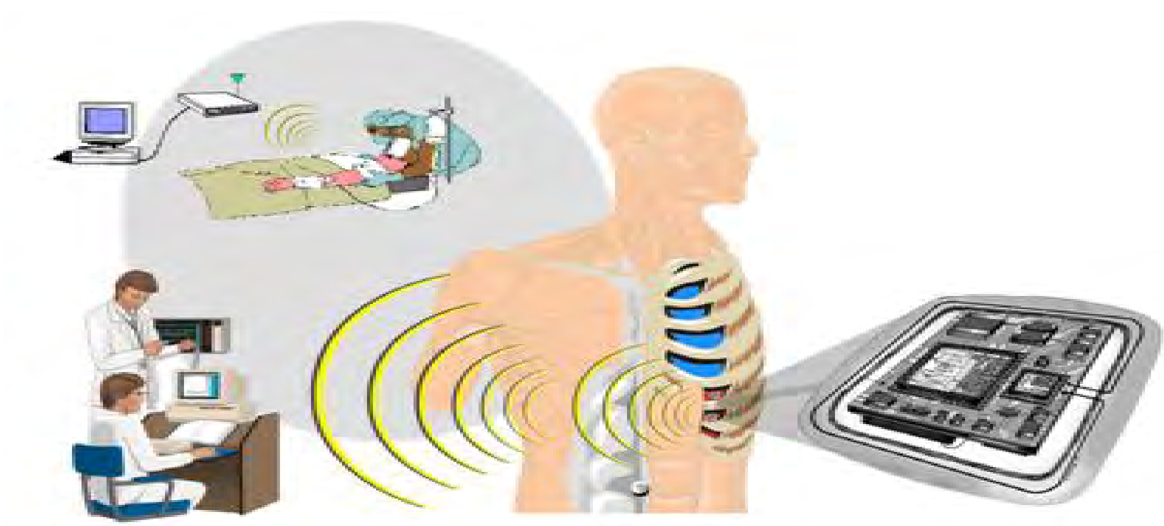

Figure 9 : WBAN with Implantable Sensors

- ***Glucose Monitoring***

In order for the doctors to understand and diagnose the problem of diabetes and therefore suggest a treatment they need to measure the concentration of glucose in the blood. People that suffer from diabetes type 1 need the existence of a sensor that will measure, on a daily basis, the glucose in their blood and will lower the risks of hypoglycemic episodes, which are caused by abnormalities in the production of insulin. This necessity was satisfied with the existence of implantable sensors covered with membrane that have the potential to transmit the levels of glucose every 5 minutes. If this sensor were to be combined with an implantable drug delivery system, a closed feedback loop would be formed for the control of blood glucose levels via the delivery of variable amounts of insulin [30].

- ***Sensor that broadens the Range of Brain Research***

Researchers in the University of Brown developed a sensor that has the potential to be fully implanted in the brain and, at the same time, powerful enough to convert the brain's subtle electrical activity into digital signals that could be used by a computer, and then boost those signals to a level that could be detected by a wireless receiver located some distance outside the body

[14]What researchers did in order to reach the desired result, was consult brain surgeons about the size and the shape of the sensor. After various trials they reached the point of a transmitting signal at the length of three feet, for a long period of time.

2.3 Data Rates

Wireless Body Area Networks can be met up in a great number of applications that vary a lot among them. The same type of variation is met in the data rate of each application that ranges from Kilobytes to Megabytes. The above table shows some typical examples of the most commonly known applications used regarding WBANs as well as their data rates, their bandwidth and their accuracy. Some of them appear to be really respectable according to their data rate as they reach the point of Mbps presenting at the same time a high level of accuracy.

APPLICATION	DATA RATE	BANDWIDTH	ACCURACY
ECG (12 leads)	*288 kbps*	*100-1000 Hz*	*12 bits*
ECG (6 leads)	*71 kbps*	*100-500 Hz*	*12 bits*
EMG	*320 kbps*	*0-10,000 Hz*	*16 bits*
EEG (12 leads)	*43.2 kbps*	*0-150 Hz*	*12 bits*
Blood saturation	*16 bps*	*0-1 Hz*	*8 bits*
Glucose monitoring	*1600 bps*	*0-50 Hz*	*16 bits*
Temperature	*120 bps*	*0-1 Hz*	*8 bits*
Motion sensor	*35 kbps*	*0-500 Hz*	*12 bits*
Cochlear implant	*100 kbps*		
Artificial retina	*50-700 kbps*		
Audio	*1 Mbps*		
Voice	*50-100 kbps*		

Table 1 Examples of medical WBAN applications [2,14,15,16]

2.4 Energy Consumed

Energy consumed in a WBAN is restricted by the size and the capability of the battery used although technological advances brought sensors to the point of being able to function for years without interruption. Research focuses on finding alternative ways to enlarge the lifetime of such sensor networks. One of the most discussed ideas is that of energy scavenging that could assist WBANs to work eternally. The overall energy in a body sensor network is consumed in the above three different domains:

1. *Sensing*
2. *Communication*
3. *Data processing*

2.5 Usability

WBANs are set up by engineers but in places such as hospitals or homes, where after the installation engineers stop existing. Therefore they must have the ability to self – organize and self – maintain, as the technical knowledge of the user will never be sufficient enough. Each node should automatically, when turned on, join the network and discover routes to communicate with the system without any further intervention. Furthermore, the network itself should be dynamic enough to add new devices instantaneously and react when a device stops sending signals. The exact location of a sensor nodes varies, depending on the environment or the type of application and thus the network could never be considered as a static one, as there are a number of applications that include body motion.

2.6 Positioning

Benoit Latre , Bart Braem , Ingrid Moerman, Chris Blondia , and Piet Demeester [2] propose two new and different classifications in communication among sensors on the body, data center and the internet. As shown in picture they introduce the intra-body and the extra – body communication.

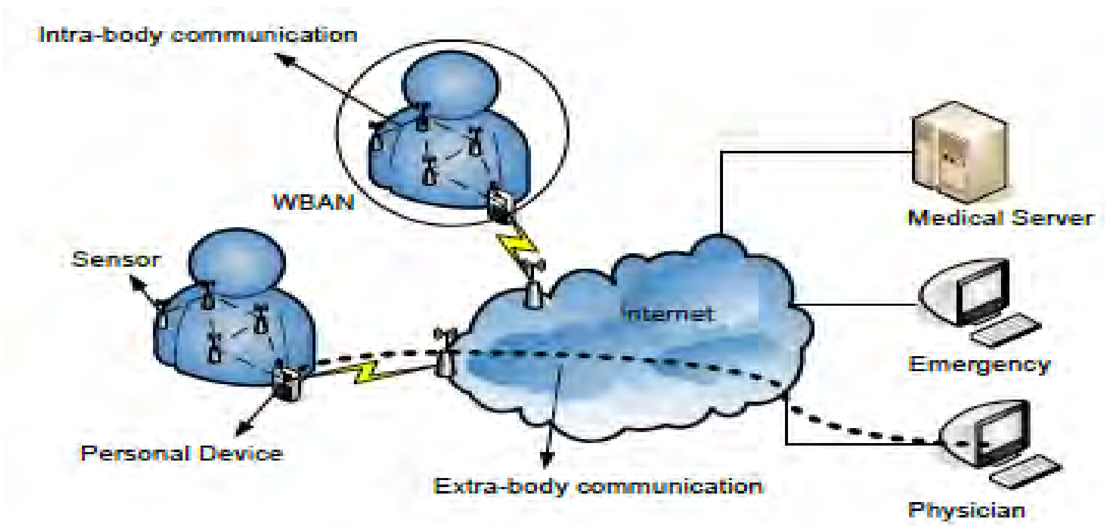

Figure 10 : Intra and Extra Body Communication

As they suggest, medical data received from the network should be addressed to a physician or stored in a database for further process. Hence they present a multi – tiered telemedicine system in which each tier represents a form of communication. Tier 1 encompasses the intra – body communication, tire 2 the extra – body communication and tire 3 the communication via internet with the medical server. The combination of intra-body and extra-body communication can be seen as an enabler for ubiquitous health care service provision [2].

3. Protocols and Architectures

3.1 Radio Technologies

Research of the recent years brought science to the point of characterizing the body area propagation environment in order to develop the best possible propagation models for an effective and reliable wireless sensor network. These works have been conducted in both the industrial, scientific, and medical (ISM) bands between 400 MHz and 2.45 GHz, and the ultra-wideband (UWB) frequency allocation between 3.1 and 10.6 GHz [17]. In each of the frequency bands, intra-body, on-body, and off-body channels have been studied [18].

Significant progress has also been made toward [18]:

- Identification of the propagation mechanisms that affect signal transmissions between nodes
- Assessment of the effects of multipath reflections from the external environment to signal transmissions between nodes
- Characterization of the fading statistics on body links that occur with body motion and
- Change of body position in both sparse and rich scattering environments
- Development of standard UWB channel impulse response models and evaluation of
- Typical modulation schemes utilizing them

Following we can see a short description of the existing protocols used for WBANs as well as some of their main characteristics.

3.1.1 Bluetooth LEE

Bluetooth technology was first introduced by Nokia back in 2004 with the aim to connect devices with terminals wirelessly. Its basic scope was to transmit data wirelessly with very low power consumption which makes Bluetooth one of the most appealing solutions for Body Area Networks. Bluetooth Lee was presented as a streamlined solution of Bluetooth as it uses an optimized radio. After further development under the project MIMOSA, which targeted cases including both WBANs and WPANs, LEE was released to the public with the name Wibree in 2006 [18]. It uses fewer channels which makes the synchronization faster, in fact at the level of milliseconds, and enhances of course power saving.

3.1.2 Bluetooth 3.0+ High Speed

Bluetooth 3.0+HS is a recently introduced standard that increases the data rate support from 3 Mbs to 24 Mbs and supports a great number of applications like transferring bulk data files. Together with its Low Energy extension, Bluetooth accommodates applications with different data rate, power consumption, and network coverage requirements. The limitation that this type of Bluetooth presents is the small number of slaves in every piconet and the indirect communication among them.

3.1.3 UWB

The term Ultra WideBand refers to radio technology introduced by Robert Scholtz for short range and low energy communications. Basically in the category of UWB belongs every transmission bandwidth that exceeds the lesser of 500 MHz or 20 percent of the arithmetic center frequency. UWB is used in many traditional applications that use sensors and therefore request low energy communication. Commercial products based on UWB provide extremely high data rates; for example, certified wireless USB devices work at up to 480 Mb/s, enabling short-range wireless multimedia applications, such as wireless monitors, wireless digital audio and video players, and other HCI use cases [18]. Recently UWB was proposed to take part in an emerging new standard for WBANs but until today no one knows when it is going to be communicated.

3.1.4 ZigBee

ZigBee or else named IEEE 802.15.4 is a communication protocol for small, low power and low data rate applications. Devices that take part in ZigBee networks form ad hoc topologies, with no centralized control. Its data rate can be defined up to 250kbit/s which is the most suitable data rate for a single signal transmitted by a sensor. Compared to Bluetooth and UWB, ZigBee/IEEE 802.15.4 devices can operate in three ISM bands, with data rates from 20 kb/s to 250 kb/s. ZigBee supports three types of topologies: star, cluster tree, and mesh [18]. This standard appears to be the most suitable to participate in home and industrial automation, while in the area of human bodies Bluetooth LEE appears to have the greatest potential.

3.1.5 Cross – Layer Protocols

The design of cross layer protocols is one of the ways to advance and improve efficiency using the interaction among protocols in a wireless network. However research in the area of Body Area Networks is still in early stages with Ruzelli et al. proposing a cross-layer energy efficient multi-hop protocol built on IEEE 802.15.4 [35]. According to their work the network is divided into two separate zones with fast and low transmission which almost doubles the networks lifetime compared with other traditional protocols.

3.1.6 Power Efficient Protocols

Power efficiency is one of the most critical issues in WBANs, as they function with small size and limited capacity batteries that restrict their lifecycle. Thus a well-designed and efficient in power protocol would assist these networks a lot and solve many of their problems. Most of the work conducted for power efficient protocols focused on MAC layer, however, there has been some research in implementing energy efficient methodologies in the higher layers of the ISO/OSI model [31]. In [35] we see one of these proposals. The authors suggested a multi – hop architecture which uses a TDMA – based MAC protocol ad, a gossiping strategy for the data dissemination through sensors and a gateway. Similar to that, in [36], the author studied the efficiency of two different protocols using TDMA for medium access in both cases. They applied cluster – based topology, assigning one sensor to be the cluster head of each cluster, and managed to save energy by getting only the cluster head node to make the long distance transmission and communicate with the base station. On the second protocol they applied a tree – based topology in which each node transmits data to the base station based on a tree hierarchy and following a specific root. The energy savings in this protocol come from the fact that no node is obliged to make long distance transmission.

The absence of an energy efficient protocol for WBANs, brought researchers to the point of investigating different solutions that could be both satisfactory and, at the same time, energy harvesting. [37] presents a MAC protocol designed for star topology that is composed of clusters, cluster heads and slave sensors as well. They use CCA / TDMA multiplexing to avoid collisions which, in combination with the above described network scheme, leads to network savings. H – MAC is a TDMA protocol proposed in [3-44], which improves energy efficiency by performing TDMA synchronization according to the heart beat rate. Energy consumption is also avoided due to the TDMA – based time slots assigned to each sensor, which avoids packet collision and guarantees free transmission. Similarly, Body MAC [38] uses three types of bandwidth allocation scheme that cope with different types of data transmission. Furthermore, researchers introduce a sleep mode mechanism being used by the protocol that turns off the radio using beacon and uplink or downlink periods in the most possible and energy saving way. One more protocol proposed for WBANs, is a TDMA – based protocol called MedMAC [39]. This protocol uses a TDMA synchronization mechanism that obliges the nodes to listen only the multi – super – frame beacon. Numbers of simulations showed that MedMAC is much more energy saving than the IEEE 802.15.4 for two classes of medical applications. Finally, authors in [40] propose a protocol called DQBAN, as an alternative for 802.15.4 that is a combination of a cross – layer fuzzy logic scheduler and energy aware radio – activation policies [31]. Fuzzy logic rules of this protocol determine the queuing of the packets, and the fuzzy logic algorithm used optimizes both quality of service and energy consumption, by considering cross – layer parameters wait time.

3.2 Network Layers

3.2.1 Physical Layer

The overall characteristics of the physical layer in a WBAN differ a lot when compared to a traditional sensor network because of the proximity to the human body. Tests with various types of sensors have proven that as devices get smaller communication among them becomes more and more difficult and, sometimes, even impossible and therefore we will have to come to the solution of complex network topologies.

3.2.1.1RF Communication

Research made in the transmission of signals inside the human body came to the conclusion that they suffer a great loss. As known from other types of wireless networks these losses are usually due to propagation which, in the case of WBAN, can be classified as inside the body and along with the body.

A. In the body

Human body has the ability to act as a communication channel in which we have a number of losses possibly happening due to absorption of power in the tissue. As the tissue is lossy and mostly consists of water, the EM-waves are attenuated considerably before they reach the receiver. In order to determine the amount of power lost due to heat dissipation, a standard measure of how much power is absorbed in tissue is used: the specific absorption rate (SAR) [2]. After a number of measurements researchers concluded that loss in the human body is a lot greater when compared to free space propagation.

B. Along with the Body

Taking into account that devices in a WBAN are mostly attached on the human body, the propagation along with the body can be divided into two different categories, that is, whether it is in a line of sight situation or not.

- Line of sight

Research conducted in [2, 14, 20] in both narrowband and ultra wideband signals came up with the results that the path loss exponent varies among 3 and 4, depending each time on the position of the device or the position of the human body. Furthermore, the study conducted in [41] proved that the position of the antenna is another key factor in the path long exponent because, as they proved, the closer the antenna is situated to the body, the higher path loss we meet.

- Non Line of sight

On the other hand, in non-line of sight situations, where there is no direct view between receiver and transmitter, waves are obliged to travel around the body and thus the path loss exponent reaches higher levels. Furthermore, the amount of radiation that the body can absorb or diffract, in non-line of sight situations, is quite large.

C. Body Movement

As anyone can assume, the movement of the body plays a really significant role in the strength of the received signal. For example, arm or knee motions can cause significant attenuation in the signal strength. In [2, 42] the researchers implemented an architecture in which the sensors communicate directly with the personal device and concluded that when the body was in motion the flow of the data rate was quite low.

3.2.2 MAC Layer

WBANs do not use a great number of MAC protocols. In fact, most implementations of WBANs use IEEE 502.15.4 or otherwise known as Zigbee. [19] tested IEEE's 802.15.4 response by creating a network in which the coordinator controls the communication through superframe structure. The coordinator also gathers feedback from all sensors and therefore can make dynamic adjustments in order to reach high energy efficiency levels. The conclusion retrieved from all studies is that ZigBee is an accepted solution for WBANs but it cannot be considered as the only one, and hence further research and combined MAC protocols are needed.

3.2.3 Network Layer

Efficient routing protocols in WBANs come as a hindrance because of the particularity of both network and environment. The limited bandwidth as well as the nodes that form the network cause severe problems in power surveillance and consumption. Research is shifted towards efficient routing schemes examining all the different solutions proposed. The most important element in such networks is the maximum throughput with the less possible energy consumption. Research, up to now, got to the point of finding techniques that will minimize energy consumption but not enhance the bit rate over a wireless link. A WBAN should be considered as a special case of network where all devices are mobile and have special requirements and therefore necessitate special protocols.

3.3 Architectures

In this subsection we are going to investigate some of the architectures proposed for WBANs based on their topologies and their network design.

3.3.1 Network Architectures

1. *Flat Architectures*

This type of architectures comprises of a single unit that gathers all network data and transmits them to the personal server, as described in [43], where the intelligent breathing telemetry sensor, armed with a thermistor based breathing sensor, is connected to a pc via a wireless link.

2. *Multi-tier Architectures*

Multi – tier architectures are broadly used in WBANs as they aim to achieve large data gathering from all sensors used in the network in the base tier, where a gateway is located as a communication gate among the sensors and the end user. In picture 11 we can see in detail how multi – tier architecture works and how the multiple tiers communicate among them. In [44] the authors described a multi-tier system that, being connected to the hospital's ZigBee network, records data from multiple WBANS and enhances the intercommunication through doctor and patient via IP phone, after it is connected to the hospital's core switch.

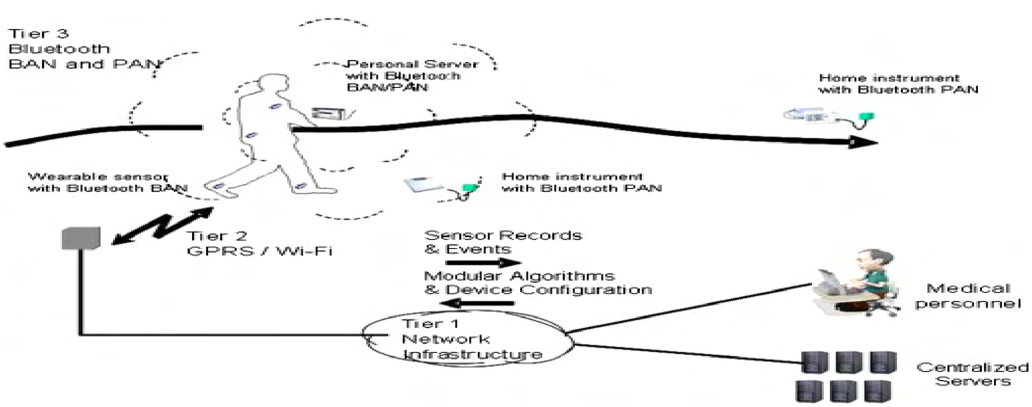

Figure 11 : Multi – Tier Architecture in a WBAN

3. *Security Centric Architectures*

Security Centric Architectures basically rely upon a commonly known and secure multi – hop protocol, named CICADA-S. This protocol has the ability to address MAC and Routing layers by ensuring collision–free medium access, low interference and avoidance of idle listening [2]. The way this protocol ensures security is through using a secure key generated for each node separately in each network session. Each time a node leaves the networks triggers automatically the system to reproduce codes, which ensures that the node leaving will not have any further access to the data in the network.

4. *Energy Efficient Architectures*

Multi – tier architecture is the one widely used in most sensor networks. In this architecture the cluster head node at the first tier collects all the tier's data and transfers them to the third and higher tier that processes data gathered from the network at user level. A research conducted by L. Roelens, S. Van den Bulcke, W. Joseph, G. Vermeeren, and L. Martens, in [44] present a WBAN that uses WISE sensors connected to a personal server and avoids over consumption by using a mobile gateway to establish the communication with the server. Efficiency is implemented when using efficient protocols and low power radio modules. Furthermore, the on board process of the data, while they are still on sensor nodes, reduces the size of the packets sent to the server. In the master – slave architecture that the authors selected the mobile gateway acts as the master and collects data from the slaves – WISE nodes when they are in its communication range. This type of architecture enables multiple communication sessions with the sensors, whose data are aggregated in a central device connected to all mobile gateways.

5. UWB Transceiver Design

Many researchers propose architectures that will include an UWB transmitter to achieve energy efficient operation in WBANs. UWB comes as an optimal solution because of the high interference and signal strength loss caused by the human body and its surrounding environment. Thus, what is really proposed is the development of a low power transceiver for the radios used by the sensor nodes. The use of UWB in sensor networks is thoroughly studied in [45] where a WBAN for capsule endoscopy is being studied. What they proved is that UWB appears to be really effective for both in – body and on – body medical sensors in the band of 402 – 405 MHz.

6. Network Design based on the Application

WBANs participate in various medical applications and therefore have many special and unique requirements based, each time, on the type of the application. In [46] researchers described a WBAN that uses bio – telemetry for elderly people. Typical protocols such as ZigBee and Bluetooth, due to their simple topology operation, proved out to be insufficient especially in this case where high data volume is required for monitoring physiological parameters. Therefore, the architecture chosen for this application contained sensors at the first tier, gateway at the second and finally monitoring and medical station at the third. Similarly in [47] authors present a hip rehabilitation WBAN named HipGuard. HipGuard uses ANT architecture, which means a master – slave framework with a central unit connected to all sensor units. Additionally, authors in [48] described a system that uses two types of tiers, namely the Actis and eActis tiers, with the eActis using the ECG and tilt sensor in order to enable the framework for Actis. For power consumption minimization the architecture uses ZigBee star topology, FTSP for accurate synchronization and sleep modes for sensor nodes.

7. Node Locations

This type of architecture rests upon the vicinity of the human to the network and upon the fact whether the sensor is implanted or attached to the human body. The pill camera is a famous example of WBAN, and what the camera basically does is that, after being ingested by the patient, it takes pictures of the inner human body and transmits them to a recorder. Similarly, unique characteristics, at this type of architecture, present the WBANs occupied with muscle stimulation. As described in [49], the best solution for a wearable WBAN is a multi – tier architecture, comprising at the first tier of sensors, of an application specific layer at the second, and of servers connected to the internet at the third. Sensium [50] is an application that monitors physiological signals and consists of a wearable digital plaster that measures different parameters. All Sensium devices are plugged into a PDA or a smartphone, with its first tier operating to collect data, and the higher one operating as a data base with the ability to connect to the internet. Authors in [51] made a really interesting suggestion describing an architecture that would base upon the data pulling paradigm instead of the traditional data pushing, which is now used for the WSNs. What the data pulling technique has to offer is a higher than usual throughput and elimination of collisions and overhead due to synchronization and timing. The base station, which is a unity with lager battery and processing time, collects the data through the pulling model and therefore saves power for the network.

3.4 Routing

Routing is not a commonly studied issue when it comes to WBANs because of the energy and power constraints that play the key role. Their unique characteristics necessitate a routing protocol that would support high mobility, high propagation, and low transmission power. In [49] the authors studied the behavior of WBANs at 2.2 GHZ and observed the following:

(i) Average packet delivery ratio (PDR) increases with increase in transmission power.
(ii) Increasing transmission power at regions with low multipath increases PDR even more.
(iii) Environments do have an impact on PDR. In a lab setting, more than 70% of links have PDR 90% or more; while, in an open setting (on the roof), about 50% of links have 90% or more PDR.

They measured channel symmetry and found that in a lab it reaches 3.9% compared to the 7.3% thatit reaches on a roof, while average PDR reached 94.9% on nodes situated on the left hand side and 94.4% on the nodes situated on the right hand side. Other studies proved that the multihop communication has some clear advantages, especially in open environments with low transmission power.

Research up to now has proven that there are two basic approaches when it comes to WBANs. The first approach suggests integrating routing functions to the MAC layer, while the second proposes designing a routing layer on top of the MAC layer, where link qualities are measured based on selected parameters, and taken into path computation [2].

4. Security and Quality of Service

4.1 Security

Like all traditional networks, WBANs, as well, have security issues regarding the data transmission from the network to the server. The most important aspects that need to be covered are data confidentiality, integrity, freshness, availability and privacy.

A. The term **data confidentiality** refers to information that can be accessed only by authorized persons, such as doctors. The way to achieve this is by encrypting the information and give the key to decrypt it only to certain people that need to have access to the data transmitted from the network.
B. **Data integrity** is the mechanism that ensures that the uses which the data disseminated through the network have not been corrupted.
C. **Data freshness** guarantees that the data received each time are the most recent ones.
D. **Network availability** signifies that all network resources should and must be available at any time because of the highly sensitive information that travels through the network.
E. Finally, **privacy** is a very important issue as well, because of the fact that medical data is one of the most sensitive types of data and therefore the system should have the mechanisms to ensure that they will not be stolen or published.

The unique characteristics of WBANs make it difficult for attackers to access directly the nodes, as they will be detected. The way to trespass such networks is to “steal” the data while they are being transmitted and that is a really critical issue when designing protocols for WBANs. One of the most crucial components to support, when it comes to security in their architecture, is the correct key management. CICADA – S is the mostly proposed protocol when we refer to security issues due to the fact that security mechanisms corporate with the communication protocols while addressing duty cycles to the sensors. The solutions of biometrics is proposed in [52] as a solution to the correct key management.

4.2 Ethic Issues

The development of a wireless healthcare application takes place with three major challenges in mind, that is, the need for reliable data transmission, fast event detection and timely delivery of data. Therefore, the privacy of a patient will be at risk if we don't take into account security while implementing new technologies in healthcare applications. Loss of their job or inability to obtain insurance coverage are two common negative consequences, should someone's disease information leak. Since a wide range of healthcare applications is covered by wireless medical sensor networks WMSNs share individual data with doctors, insurance companies or with the family.

Therefore, if someone's adversaries (for example insurance agents or personal enemies), without authorization, collect, use or make the patient's private matters publically available there may be life-threatening risks for them. There is always the possibility for an attacker to eavesdrop the patient's data while it is being transmitted by his/her body sensors to a doctor and so their privacy loses confidentiality. The stolen data can then be posted on social sites and thus the patient's privacy vanishes. Security and privacy should be major concerns and ethic issues should always be raised when healthcare applications are to be developed, as the physiological data of a patient are highly vulnerable when transmitted through wireless systems, which, otherwise offer a lot of advantages to patient monitoring.

Specific questions need to be answered when we deal with the challenges of electronic data and remote transmission of the information:

- Who should own the data? Who should have the authority to delete, edit, and add information to health data as well as enforce regulations surrounding it? Do individual patients own data collected on themselves? Do their physicians own the data? Do their insurance providers own the data? Are they all joint owners? Furthermore, there have been cases where Health Maintenance Organizations refused to cover a patient's expenses when the patient participated in clinical treatment protocols that were experimental. An additional question that is raised is whether the insurance provider can refuse to pay for expenses associated with the collection and storage of the data if he does not own the patient's data. Another question concerns third parties. If data is passed to a third party, do they have the same authority as the data owner, or are their rights more narrow? It is unclear what level of privacy and security protection must be maintained when data is transferred to a third party.

- The type and the quantity of the stored data is another important question. Some common data stored in a patient's paper based record are doctors' notes and lab test results. As for the quantity of the data things become more difficult in cases of remote patient monitoring using sensor networks. For instance, should the whole body of the raw data be stored locally at the patient's residence and only the data required for diagnosis and emergency response be transmitted back to the monitoring center, or not? The amount of sensor data stored in the central location should be just enough to safeguard the success of operations that have to do with the patient's health care. Any further information which has nothing to do with the patient's health care will just put his/her privacy issues at risk.

- Other crucial questions concern the storage of the health data. Should the storage be centralized or decentralized? Should data be stored in various databases with the ability to link with one another, or should it be stored in one central database? In the case of remote patient monitoring, should the sensor data be stored only locally or should it also be stored at the central monitoring station? What type of data storage will best accommodate the privacy and security needs?

- Who can a patient's medical record be viewed by? The users can be divided into two categories: 1) users with the read and write privileges (doctors, caregivers, nurses) who can not only view a patient's records, but they can also edit the records. 2) users with read only privileges (insurance provider), who can view the patient's records, but cannot edit it. The identity of the user accessing the patient's records might determine further restrictions on which portions of the data they can view. In the case of an insurance provider, their access might be limited to the part of the patient's records concerning the medical expenses. In another case, an elderly patient might want to authorize partial viewing of his/her medical record to certain relatives.

- Can the revelation of a patient's data without their consent ever be justified? Besides the afore mentioned users there might be need to reveal a patient's data to people who can save his life in case of an emergency, especially in cases of remote patient monitoring.

4.2 Quality of Service

The fact that WBANs present unique characteristics and their expansion is still in early stages prevents their inclusion in research concerned with matters of quality of service in all types of ad hoc networks which, otherwise, relies on quite good stages. The CICADA protocol seems to be the most reliable and qualitative solution, as it enhances reliability and energy savings at the same time. BodyQos, proposed in [53] uses asymmetric architecture, a virtual MAC and a resource scheduling strategy in order to offer the maximum QoS to the network. This protocol has been implemented on the top of TinyOS.

4.3 State of the art

The development of WMSNs in healthcare applications has enhanced the feasibility of patient monitoring. A lot of wireless healthcare projects aiming to provide continuous patient monitoring, in-hospital, in-ambulatory, in-clinic, and open environment monitoring, have been proposed recently. CodeBlue [21] is a popular healthcare research project based on a medical sensor network developed at the Harvard Sensor Network Lab. Several medical sensors (pulse oximeter, EMG, EKG) placed on the patient's body are contained in this architecture. These sensors have the ability to sense the data of the patient's body and transmit it wirelessly to the end-user devices (PCs, PDAs and laptops) for further analysis. The concept of CodeBlue is simple, a doctor or a medical professional issues a query for patient health data using their personal digital assistant (PDA), which is based on a publish and subscribe architecture. The relevant data are *published* by the medical sensors to a specific channel and the end-user *subscribes* the channel by using their hand-held devices (laptop and PDA). Moreover, the architecture of CodeBlue facilitates RF-based localization (MoteTrack), which is accurate enough to locate a patient's or medical professional's position.

Alarm-Net [22], was a heterogeneous network architecture designed at the University of Virginia. The research is designed for patient health monitoring in the assisted-living and home environment. Alarm-net contains body sensor networks and environmental sensor networks. There are three network tiers in the proposed assisted-living and home environment. In the first tier, a patient wears body sensor devices (ECG, accelerometer, SpO2) which sense individual physiological data. In the second tier, environmental sensors (temperature, dust, motion) are deployed in the living space in order to sense the environmental conditions. Finally, in the third tier, an internet protocol-based network is used which consists of Stargate gateways (AlarmGate). The idea of Alarm-net is very simple, individual physiological data is broadcasted by body sensors, using single-hop to the nearest stationary sensor. Then, the body data is forwarded by the emplaced sensor nodes, using multi-hop communication, to the AlramGate.

The AlarmGate is a gateway between the wireless sensor and IP networks, and is also connected to a back-end server. Any real-time data queries about physiological or environmental data are originated by the user that contains the source address, ID, and sensor type. For a single-shot query, the sensors sample the requested data and respond a single report to the query originator, and hence complete the query. In addition, authors have developed a circadian activity rhythms program to aid context-aware power management and privacy policies.

UbiMon [23], is a body sensor network architecture which is comprised of wearable and implantable sensors using an *ad hoc* network. The project's aim is to supply continuous monitoring of an individual's physiological states and capture transient as well as life threatening abnormalities that can be detected and predicted. The architecture of UbiMon contains: 1) *BSN node*: Each node is integrated with bio-sensors (ECG, SpO2, temperature). (2) *LPU (Local Processing Unit)*: LPUs can be portable devices (PDAs, laptop) used to the gather data from BSNs, and are known as the base station. The patient's abnormalities are detected by them and provide immediate warning to the physician. Moreover, the LPU works as a router between BSN nodes and the central server using wireless communication. 3) *CS (Central Sever)*: A CS provides the patient data to the Patient Database, and can analyze the patient's data on the basis of patient's condition, and detect potential life-threatening abnormalities. 4) *WS (Work-station)*: The WS is the patient's data monitoring terminal (PC, laptop), which is used by the doctors. Furthermore, the authors did not consider security for wireless healthcare monitoring, which is a major requirement for healthcare applications.

MobiCare [24], was a mobile healthcare project designed by Chakravorty. A wide-area mobile patient monitoring system is provided by MobiCare which facilitates continuous and timely monitoring of a patient's physiological status. MobiCare has the ability to improve the quality-of-patient care and save many lives. The proposed system consists of a body sensor network having wearable sensors (ECG, SpO2, and blood oxygen), a BSN manager (which is called MobiCare client) and a back-end infrastructure. The medical sensors sense the patient's body data and broadcast it to the MobiCare client. The MobiCare client gathers the body data and sends them, using GPRS/UMTS or CDMA, to the MobiCare server. The MobiCare server supports the medical staff for offline physiological analysis, and for patient care.

MEDiSN [25], is a system designed at Johns Hopkins University especially for patients' monitoring in hospital. It contains multiple physiological monitors (PMs), which are battery powered motes and equipped with medical sensors for collecting patients' physiological health information such as blood oxygenation, pulse rate and electrocardiogram signals. The PMs are mobile, temporarily storing sensed data and transmitting it to the relay points (RPs). Different RPs are incorporated by MEDiSN which are self-organized into a bidirectional routing tree, and forward PM data to the gateways and *vice versa*. A collection tree routing protocol (CTP) is used by the RPs in order to forward their measurements to the gateway. Furthermore, MEDiSN is connected with a back-end database that stores medical data and presents it to authenticated GUI clients. Specifically, this research focused on reliable communication, data rate, routing, and QoS.

SATIRE [26], is a wearable personal monitoring service which was designed and developed with the collaboration of the University of Illinois and the University of Virginia. Users of SATIRE are allowed to maintain a private record of their daily routine activities. Someone who is wearing a SATIRE jacket has the ability to record their normal daily activities. When the person comes into the vicinity of an access mote, the logged data is uploaded reliably to a private repository associated with that person. Then, this data may be used to reconstruct the activities and locations of the person. Although, authors properly address security and privacy issues in SATIRE, they did not implement any security and privacy for sensitive physiological data.

4.4 Open research issues and future trends

WBANs constitute a very interesting and, at the same time, really promising technological area that came into prominence in order to assist both patients and doctors into taking long distance measurements. Several researchers focused on the propagation of the electromagnetic waves in and on the body, while others made thorough research on MAC protocols that need to be developed taking into account the movement of the body. What is mostly interesting in such networks is the mobility of the nodes that, most of the time, requires a cross layer protocol in order to increase reliability and scavenge energy. Below we can see a brief description of the WBANs problems that need to be solved in the near future.

- Extension of the power supply

Fuel cell technology comes as a promising solution to the problem of restricted power that WBANs have, with the microfuels appearing really attractive for mobile applications. Solar energy also has the potential to support WBANs and extend their lifecycle.

- Lower power consumption

The maximum power consumption in a WBAN network occurs during the transmission of the data, and therefore research focuses on reducing this consumption by using ultra wide band transceivers or energy efficient algorithms that would reduce the number of bits that need to be transmitted.

- Biocompatibility

Biocompatibility refers to "the ability of a biomaterial to perform its desired function with respect to a medical therapy, without eliciting any undesirable local or systemic effects in the recipient or beneficiary of that therapy, but generating the most appropriate beneficial cellular or tissue response in that specific situation, and optimizing the clinically relevant performance of that therapy [31]." Implantable sensors face the problem of biofouling, which means that in some cases the biomaterial is not accepted by the human body that accumulates proteins and other unwanted biomaterials on the surface of the sensor and finally rejects it.

- Optimization of network resources

Sensors in WBANs are either wearable or implanted, and of course constructed to take physiological measurements. This is why they should use ultralow radio power levels for transmission and reception that are safe for human use [31].

- Preventative healthcare

Up to now WBANs are used to take particular physiological measurements or respond to specific requirements. Future trends insist that they should adopt dynamic programming in order to take various measurements on the body and assist, this way, preventive medicine by achieving faster diagnosis.

- Economic perspective

WBANs are basically wireless networks that perform special tasks, namely take measurements of physiological data, thus their cost poses limitations to their use. A really interesting challenge for the researchers would be to minimize their cost, to such a point that they would be accessible by all users.

- Routing

Routing in WBANs concerns the point of designing efficient protocols that would support mobility and ensure reliability. Up to now, research has proved that multihop communication enhances power savings and appears to be the most suitable one for body networks.

- Future applications

The basic principle under which WBANs were developed, was to assist the elderly and people suffering from certain diseases to take measurements from their body without their having to move from their house or the hospital room. Despite that, their development brought them to the point of finding different types of applications in many different sectors, especially now that personal computers are ubiquitous. WBANs have also the potential to pervade ecology or even military applications or even co-exist with other types of ad-hoc networks and the internet. The success of WBANs and their eventual widespread acceptance will be accelerated by merging it with existing technologies and creating frameworks with ease of data transfer and data access [31].

5. The Sensor Network

5.1 E – Health Sensor Platform for Arduino and Raspberry Pi

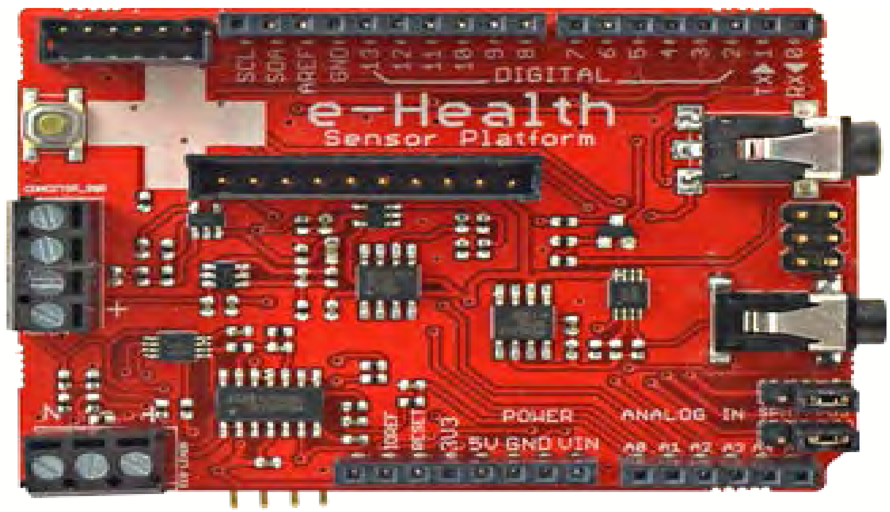

Figure 12 : E – Health Sensor Platform

The E – Health Sensor Shield presented above, gives Arduino and Raspberry Pi the ability to take medical measurements and perform medical applications in cases of WBANs, with the use of different types of sensors. The information retrieved from the measurements can be used in real time to indicate the state of a patient or analyzed for medical diagnosis and send wirelessly using connectivity options such as 3G, Wi – Fi, Zigbee etc depending on the type of the application. All the above data can be send to the cloud for further process and permanent storage as well or even to a smart phone in order to inform the doctor of the patient’s condition or the patient itself.

Figure 13: e – Health Sensor Shield over Arduino and Raspberry Pi

The e – health sensor shield can be powerd either by the pc or by an external power supply and can be combined both with Arduino and Raspberry Pi offering no matter what the choice will be the same reliable results.

5.2 Pulse and Oxygen in Blood

Pulse oxymetry is a method used in order to measure the arterial oxygen saturation in human blood based on the detection of Hemoglobin and Deoxyhemoglobin. These two sunstances come into two different wavelengths measured by the sensor and translated into percentages.

Figure 14 : Pulse oximeter Sensor

This type of sensors are really useful in cases where patients have unstable oxygenation and reach values from 88 to 94 percent when the acceptable normal ranges vary from 95 to 99 percent. The sensor has only one way of connection with the module in order to prevent errors and make the procedure easier. When a finger is inserted into the sensor, the button ON gets pressured and the indication appears on the sensor screen as shown below.

Figure 15 : Pulse oxymetry measurement

5.2 Electrocardiogram

The Electrocardiogram belongs to the category of the diagnostic tools used to access the muscular and electrical function of the heart. Sensors used for these measurements grow up to be the most commonly used in modern medicine as they provide the ability to diagnose myriad of cardiac pathologies. The accuracy of such sensors depends of course on the condition being measured as some problems may not always been shown.

In order to connect the sensor the user has to connect the tree leads (positive, negative and neutral) in the e – health board. After that, the plastic has to be removed and the electrodes must be placed on the human body.

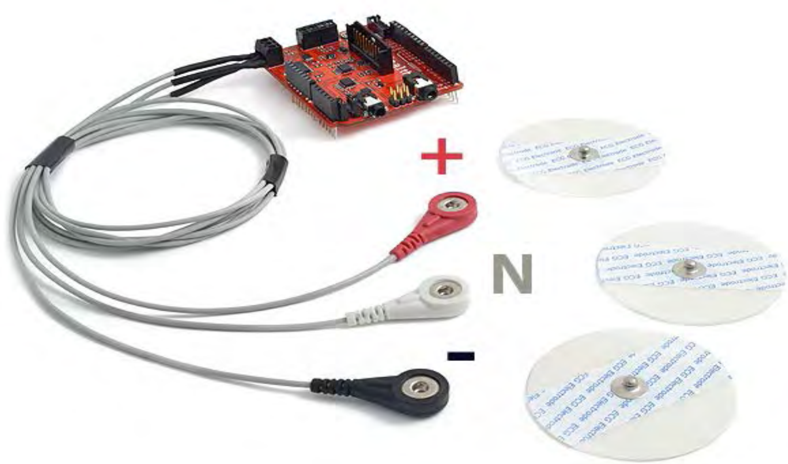

Figure 16:ECG sensor on e – Health sield

5.3 Blood Pressure

As blood pressure we characterize the pressure of the blood in the arteries as it is pumped around the body of the heart. It is recorded in two numbers, namely the systolic and the diastolic. As it is known measuring the blood pressure is really important for many people, especially those who face problems, as it is not stable all the time and is affected by various factors.

Classification of blood pressure for adults (18 years and older)

	Systolic (mm Hg)	**Diastolic (mm Hg)**
Hypotension	< 90	< 60
Desired	90–119	60–79
Prehypertension	120–139	80–89
Stage 1 Hypertension	140–159	90–99
Stage 2 Hypertension	160–179	100–109
Hypertensive Crisis	≥ 180	≥ 110

Blood pressure sensor is quite accurate and can be effectively used in a great variety of people. In order to connect it with the shield, the jumpers must be in the correct position. Then we connect the jack cable with the sphygmomanometer and the e – health Board. As shown in the picture, the sphygmomanometer must be placed on the wrist which is important to maintain in the horizontal plane. After pressing the ON button the sphygmomanometer itself starts taking measurements indicated on the sensor’s screen.

Figure 17: Sphygmomanometer

5.4 Glucometer

Glucometer measures the concentration of glucose in the blood. Only a small drop of blood that is obtained by picking the skin is enough to calculate the blood glucose level. Despite widely variable intervals between meals or the occasional consumption of meals with a substantial carbohydrate load, human blood glucose levels tend to remain within the normal range. However, shortly after eating, the blood glucose level may rise, in non-diabetics, temporarily up to 7.8 mmol/L (140 mg/dL) or a bit more.

In order to take a measurement we turn on the glucometer and place the test strip in the machine when it is ready. The glucometer will indicate the measurement and then store the value in the memory. After connecting the cable, data get extracted from the device and forwarded to the PC.

Figure 18 : Glucometer

6. Web Interface

The web interface application is used to collect data measured by the sensors and forward them to the doctor in order to inform him about the patient's condition. Measurements taken by this application are referred to heart rates, blood pressure and blood glucose. All data are stored into a database for further process and can be accessed either locally or via internet only by authorized users. Each user is allowed to access specific type of data which ensures the reliability and conformity of the system. The programming language used to code this web interface is C# and the development environment will be the Microsoft Visual Studio 2010 by using the ASP.NET. The database is SQL Server 2008 database and is implemented by the server explorer of the Visual Studio 2010. Finally, the platform used for the development and the testing of the application is the operating system Microsoft Windows 7.

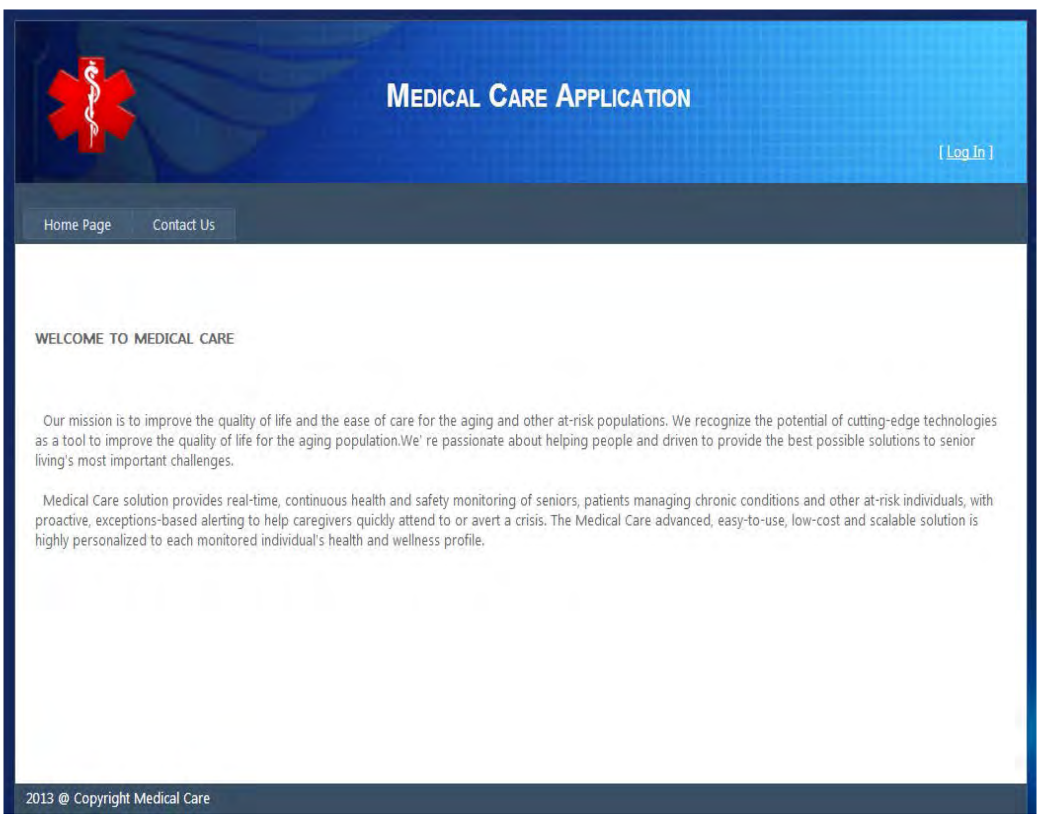

Figure 19 : Home Page

The figure below presents the application's home page where each user can be informed about some characteristics of the application.

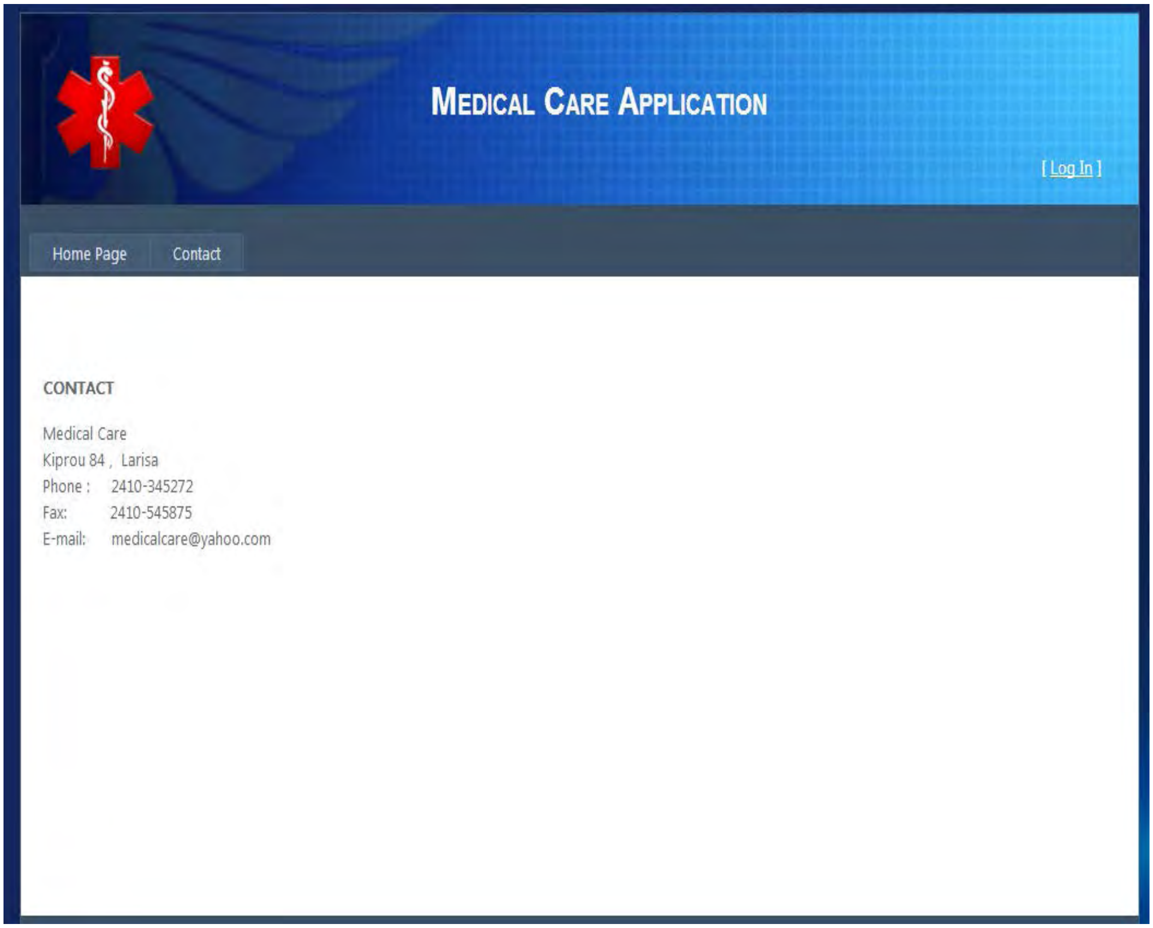

Figure 20 : Application's home page

Screen shots following present the login page where each patient or doctor can subscribe himself, or enter the application using username and password that was addressed to him via e - mail by the medical center. For security purposes, there is also the administrator account, probably belonging at one of the medical center's personnel, who has the responsibility of adding or deleting accounts to and from the application (Default Username: Administrator -Password: !234567).

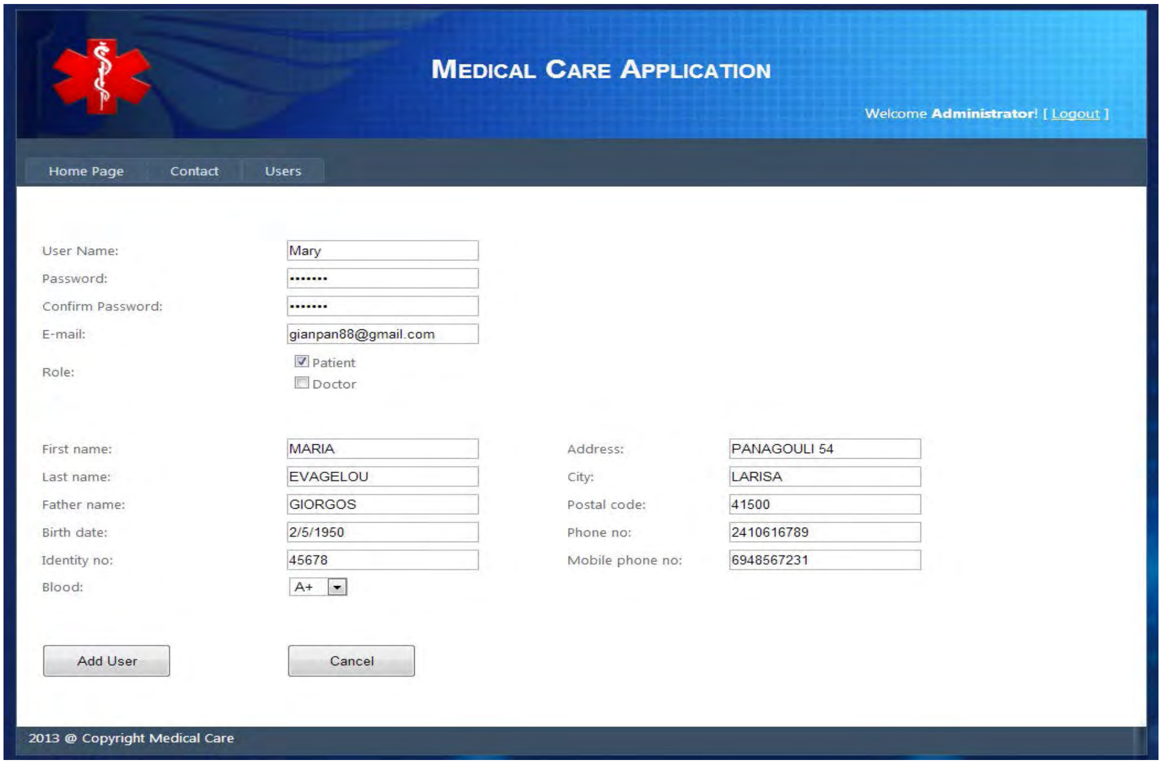

Figure 21 : Subscribe Page

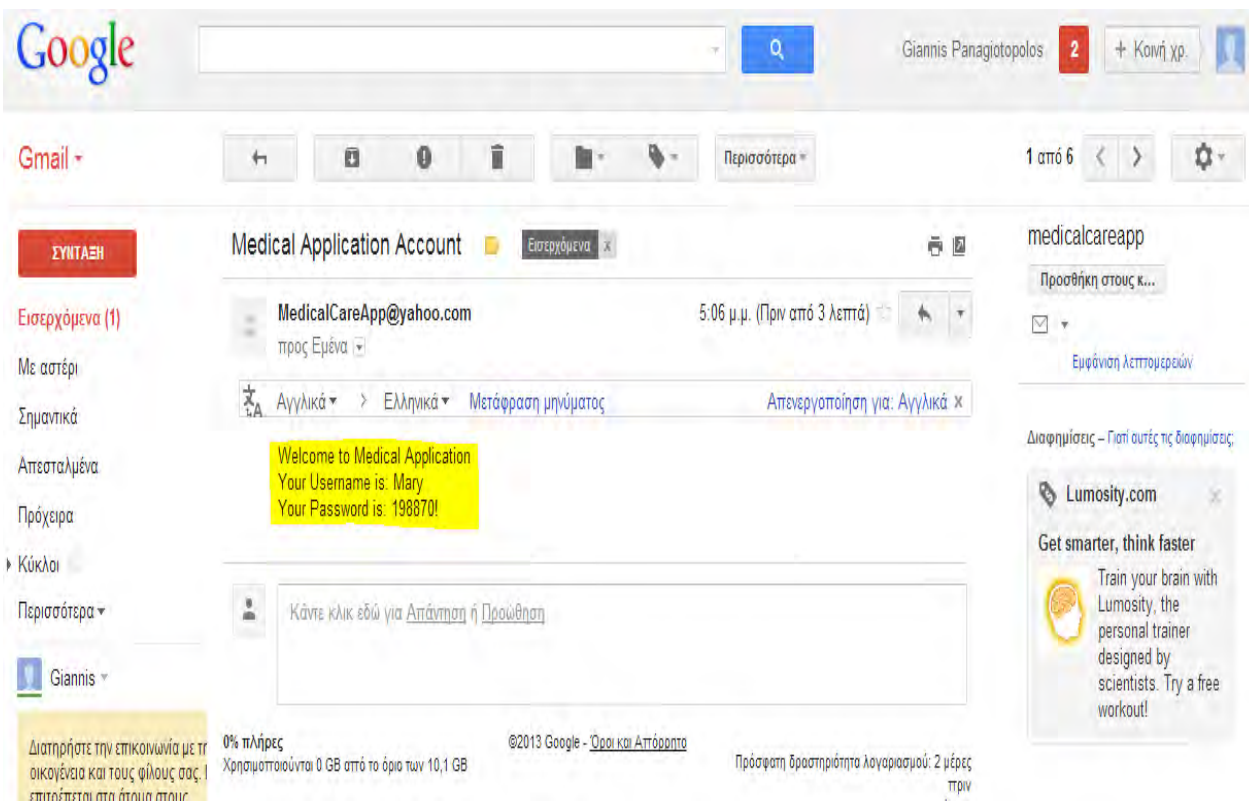

Figure 22 : E mail sent to the user that informs him of his username and password

6.1 Longing in as a doctor

Figures that follow present tha application's possibilities regarding the doctor. After longing in the the doctor has full access to the assigned to him patients' measurements taken by the sensors and stored to the application. As we can see the application also gives us a full profile of the doctor's personal data and communication details. Each time that a measurement tresspasses the predifined limits, the doctor receives an e – mail and a message in his cell phone that informs him about the problematic situation and requests at the same time his professional advice. Furthermore, the application has the storaging abilitity of the last fifteen measurements taken by the patient that are disposable to the doctor only by clicking the a dialog box at the left side of the main window. In advance there is also the ability of viewing each patient seperately, only by clicking the date or name filter, or a list of patients regarding a particular measurement, i.e. heart rate. (Default Username: doctor-Password:!234567)

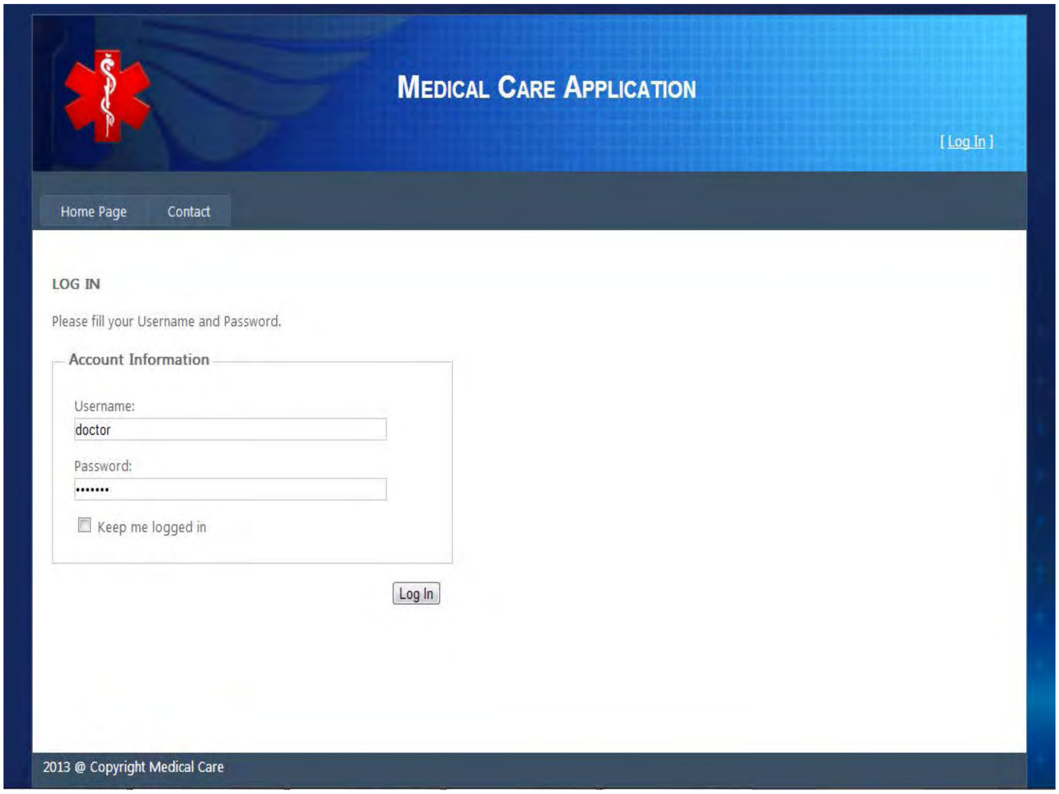

Figure 23 : Login Page

Figure 24 : Doctor's personal data

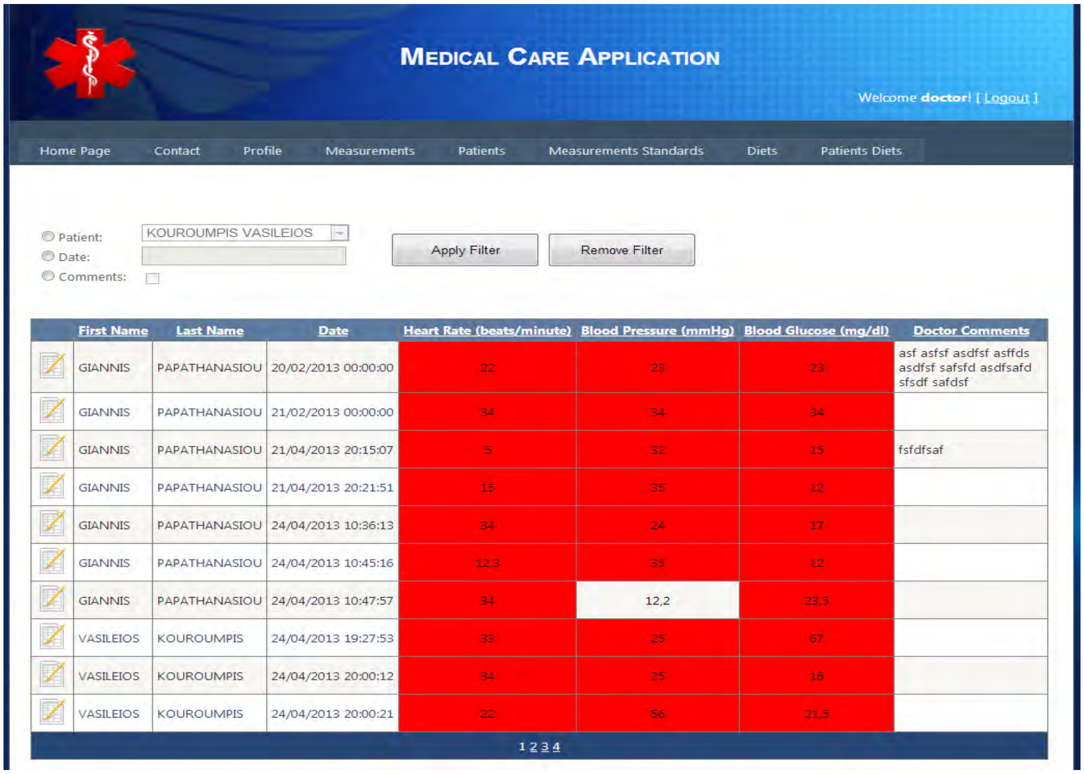

Figure 25 : List of measurements taken

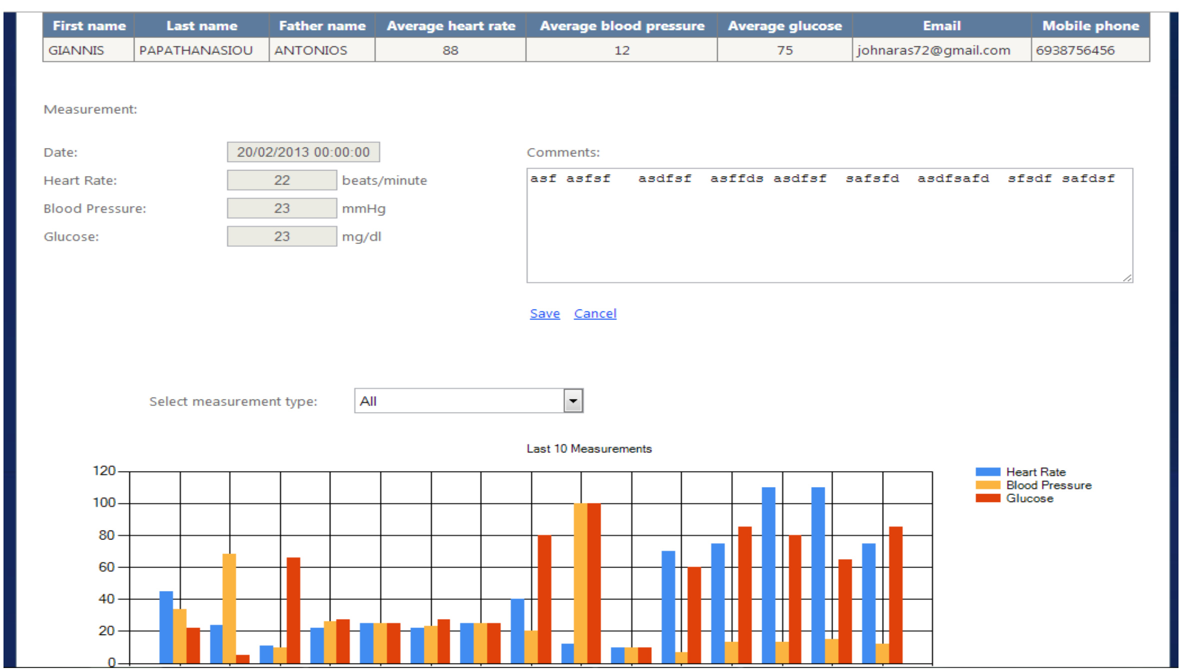

Figure 26 : Last 15 measurements taken

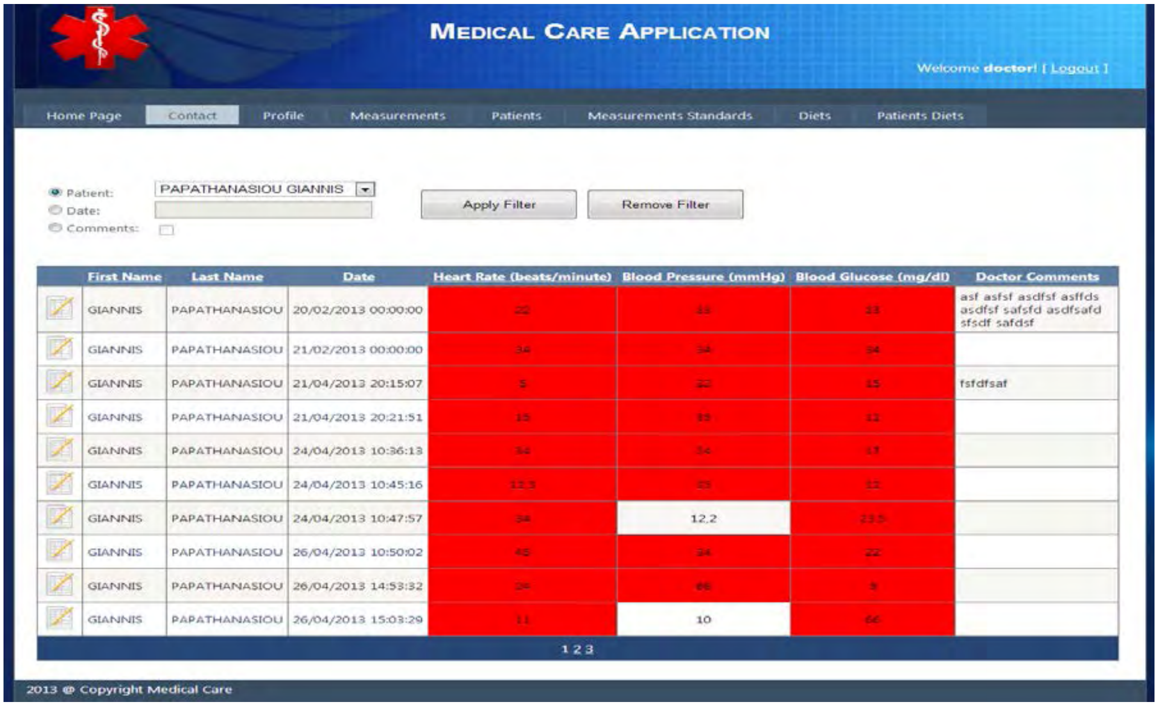

Figure 27 : List of patients regarding a particular measurement

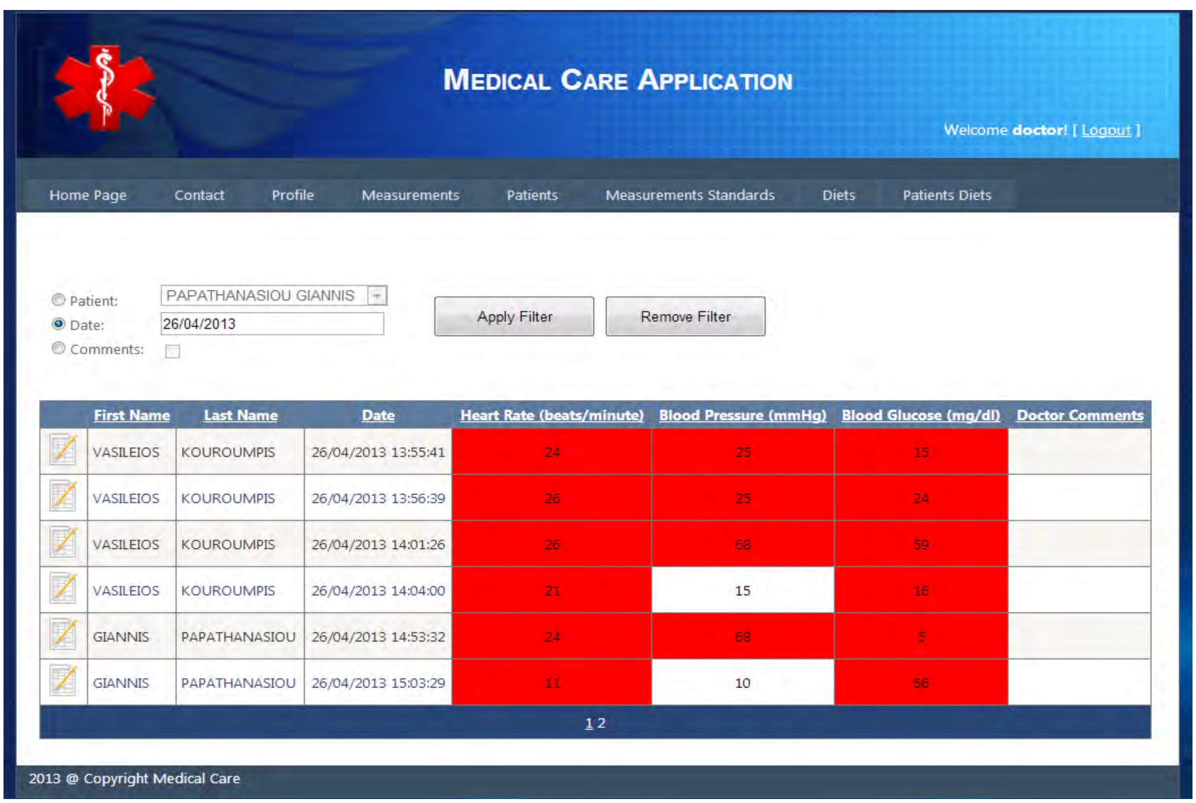

Figure 28 : Filter applying

Figure 29 : Messages sent to the doctor

Beyond all possibilities, each doctor has also the ability to trespass the application and change the ranges for each measurement, or even suggest an appropriate message that will be send to the patient as an advice

Figure 30 : Message send to the patient

What is really necessary at most of the times for a patient suffering from various diseases is a diet that will support and enhance his immune system. Medical care application gives the doctor the advantage to follow up his patient for 30 days and suggest a diet that will be send to the patients through an e – mail. Furthermore, as we can see below, the doctor can see all possible diets send the last 25 days in red color as well as when each patient started being on a diet.

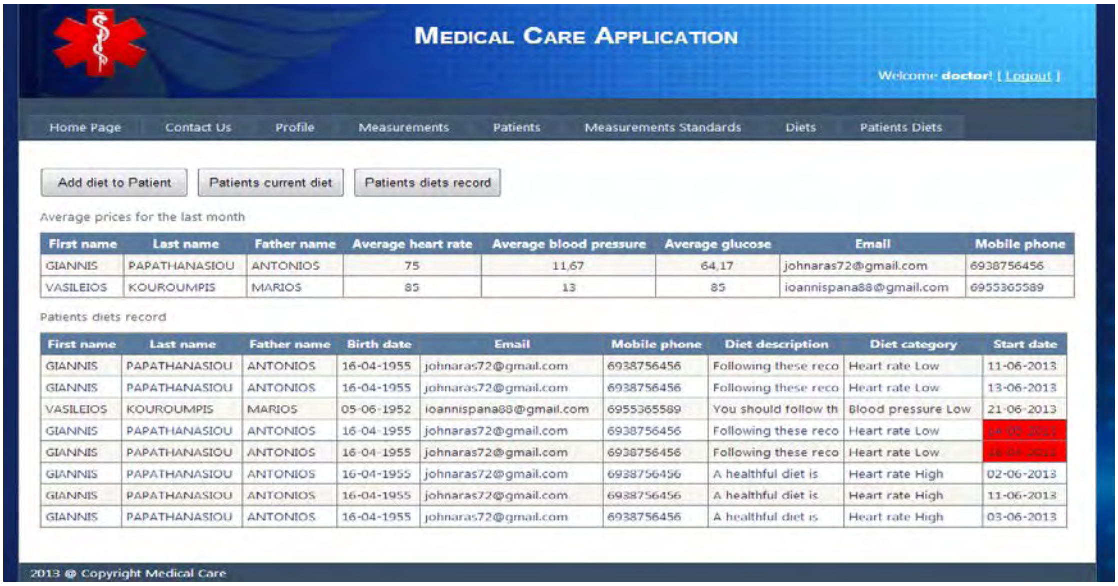

Figure 31 : Diets send to the patients

Figure 32: Diets send to the patients

6.2 Longing in as a patient

The second half of the above described medical care application belongs to the patient and to the effort to satisfy his needs. Each patient gets a user name and a password send to him via e – mail as described. Each patient has the potential to change his personal and communication data only by clicking the button edit. (Default Username: patient1-Password:!234567)

Measurements taken by each patient travel through a wireless network and get stored in the application's database. When a measurement exceeds its usual values the doctor gets immediately informed with both an e – mail and at the same time a message at his cell phone. What is really impressing is that the application provides the doctor with the ability to respond immediately to each patient through message or e – mail giving him all the necessary directions on what to do and how to protect himself.

If any type of measurement is far beyond normal the application provides the patient with the message '***The measurement values are out of range. Please check your sensor***'. If this message appears the patient should check the functionality of his sensor or contact with a technician.

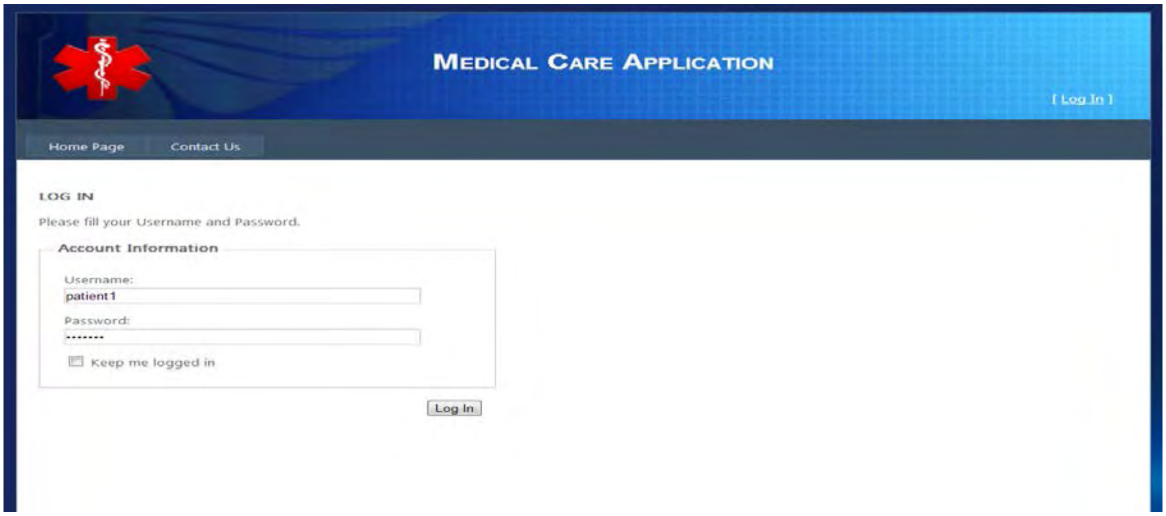

Figure 33 : Patient login page

Figure 34 : Patient's personal and communication data

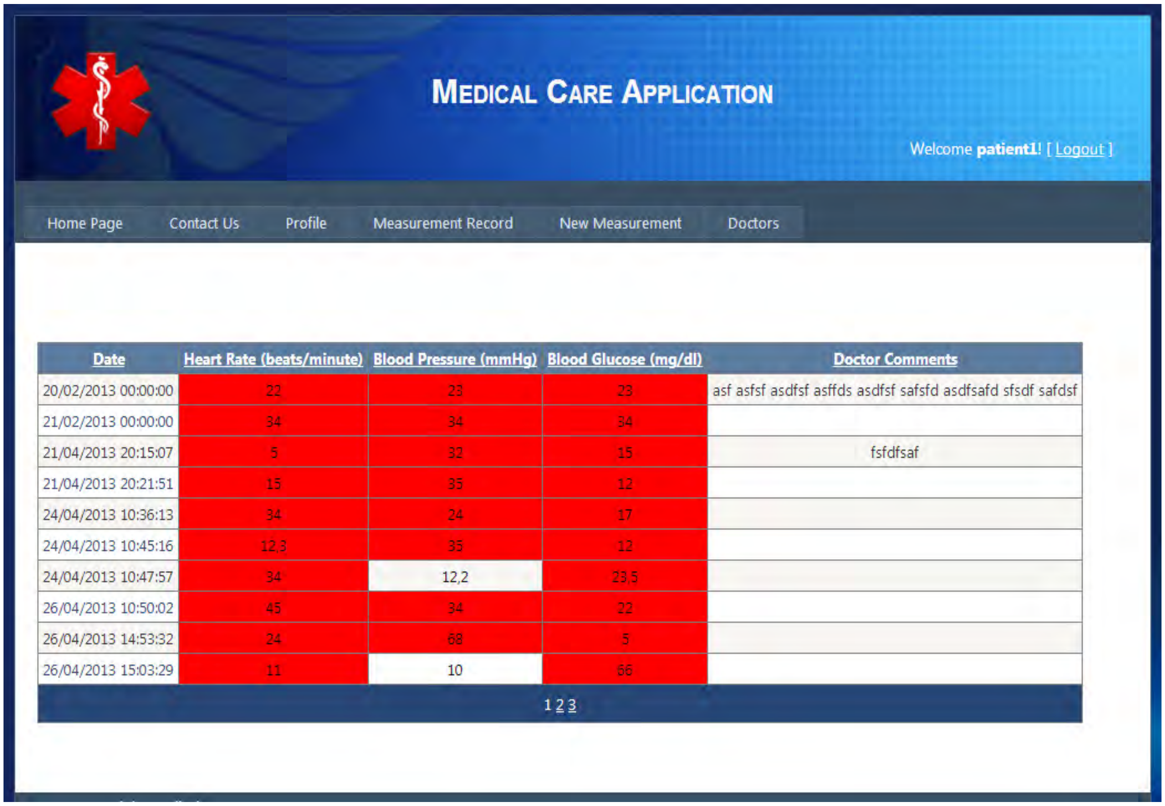

Figure 35 : Measurements

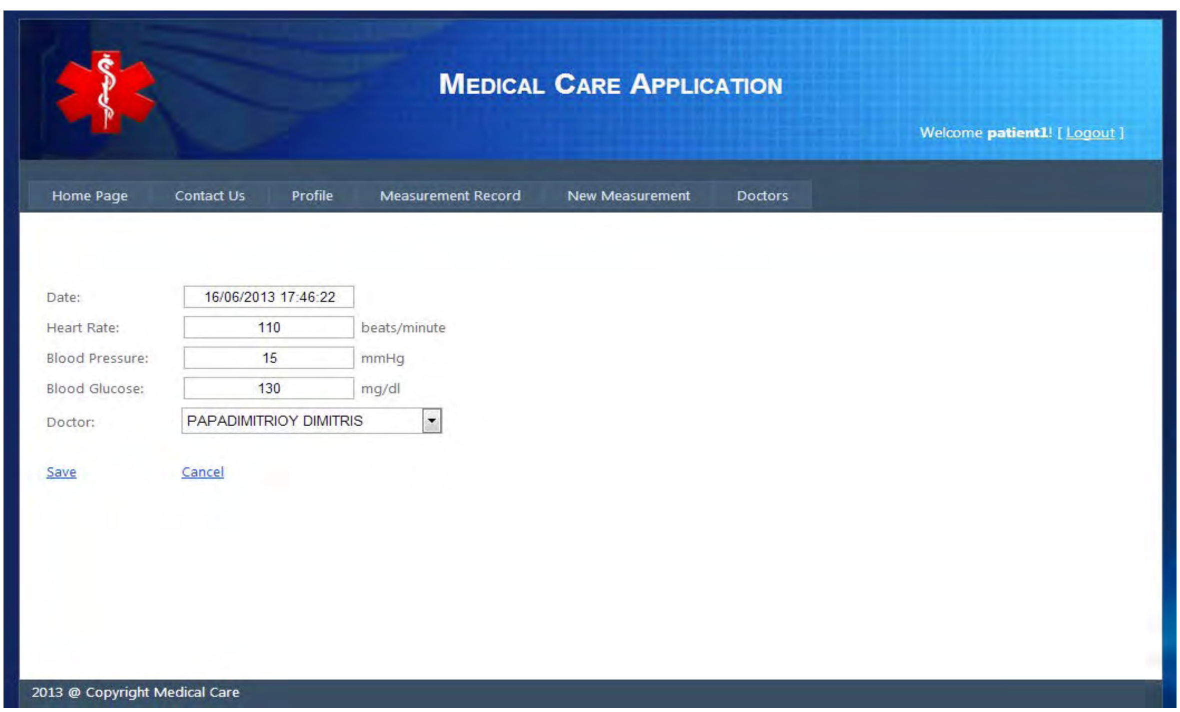

Figure 36: Personal measurements

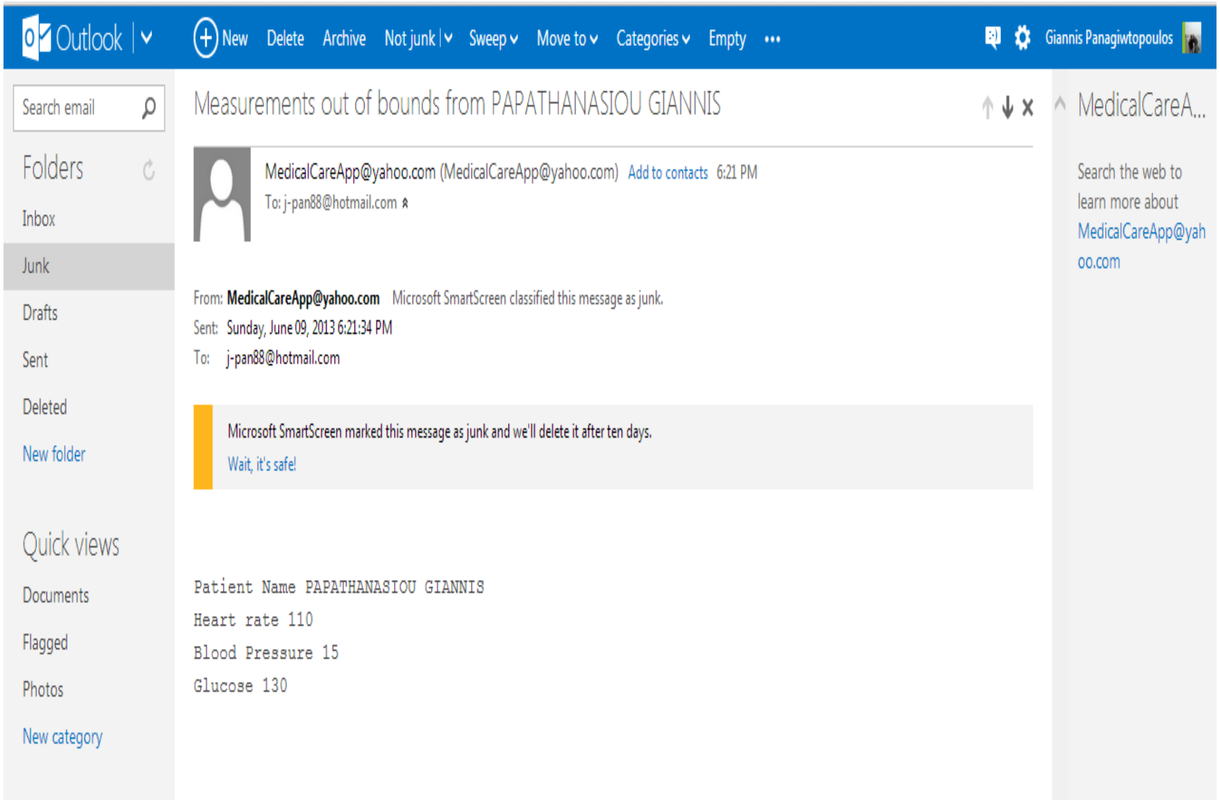

Figure 37: E – mail send to the doctor

Figure 38 : Message send to the doctor's cell phone

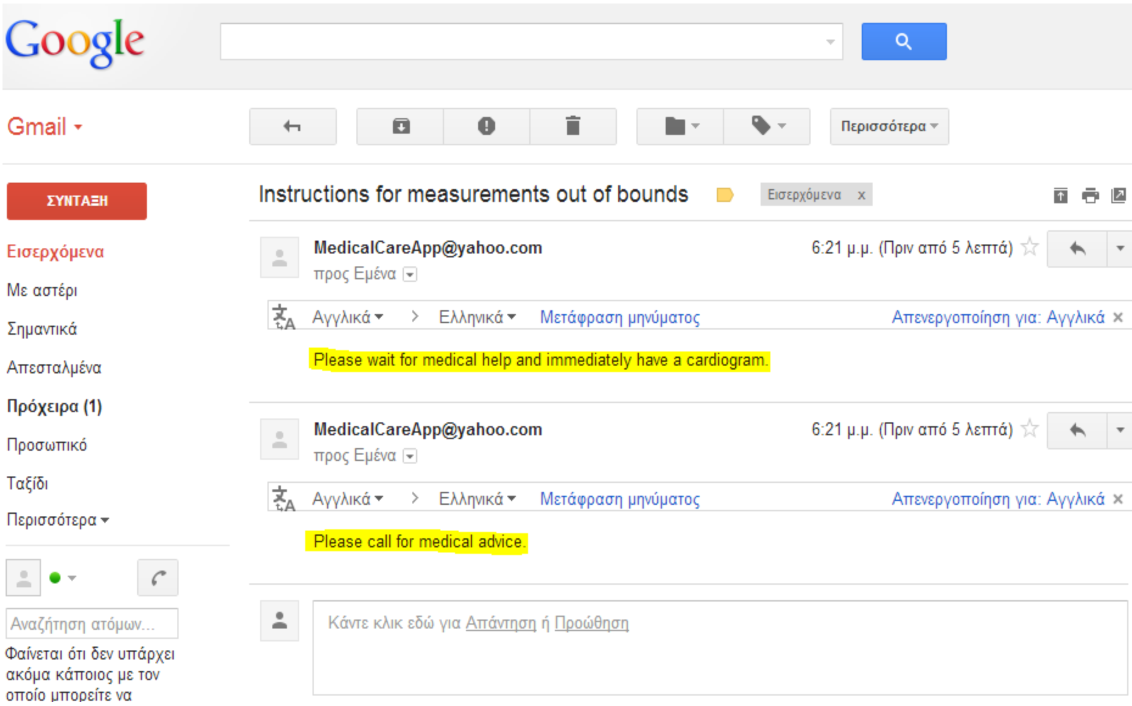

Figure 39: The doctor's response

Figure 40 : Problematic measurement

7. Conclusion and future work

The area of sensor networks used in mobile health in the form of systems that use biosensors is really broad and very promising. Research of the recent years tends on focusing on this area particularly in the forms that will assist and support especially elderly or disabled people.

Problems that this type of networks faces mainly focus on energy, lifetime, and the limited data that can be either collected or forwarded through the network and are expected to be solved in the near future as the technology of sensors tends to dominate everyday life. What we expect from them is to assist people making their life much easier and simpler with the least possible cost. In the area of life care, what people expect is future where patients will have to do nothing at all, and biosensor will do everything for them.

The above thesis refers to a system that will use all the high peak technologies with the aim to facilitate the patient's everyday life, enhance and quicken the communication with the doctor and reduce as well all possible costs. Expeditious development of implanted smart sensors to remedy medical problems presents clear benefits to individuals as well as society as a whole. For example implantable biosensors that monitor cancer help patients recover, take the appropriate treatment at the time needed or even maintain their health.

While world population keeps increasing, increases at the same time the necessity for such systems that will support and save communities. What we expect from medical care, is to become a really useful, easy to use and costless system that will have in the near future the possibility of taking, storing and processing more and more measurements and will have finally the ability of working as a first aid kit for every possible disease.

8. References

[1] Katrin Bilstrup , *A Preliminary Study of Wireless Body Area Networks*, Technical Report IDE0854, August 2008

[2] Benoit Latrie , Bart Braem , Ingrid Moerman , Chris Blondia , Piet Demeester
A Survey on Wireless Body Area Networks

[3] T. G. Zimmerman, *Personal area networks: near-field intrabody communication*, IBM systems Journal, 1996, vol. 35, no. 3 & 4, pp. 609-617

[4] S. Park and S. Jayaraman, *Enhancing the quality of life through wearable technology*, IEEE Engineering in Medicine and Biology Magazine, vol. 22, no. 3, pp. 41{48, May/Jun. 2003.

[5] B. Gyselinckx, R. Vullers, C. V. Hoof, J. Ryckaert, R. F. Yazicioglu, P. Fiorini, and V. Leonov, *Human++: Emerging technology for body area networks in Very Large Scale Integration*, 2006 IFIP International Conference on, Oct. 2006, pp. 175{180.

[6] *IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields*, 3 khz to 300 ghz, 1999.

[7] Kevin J. Frasera, Vincenzo F. Curtoa, Shirley Coylea, Ben Schazmannb, Robert Byrnea, Fernando Benito-Lopeza, Róisín M. Owensc, George G. Malliarasc & Dermot Diamonda, *Wearable electrochemical sensors for monitoring performance athletes*

[8] Yun-Thai Li, *Pulse Oximetry*

[9] Instruction Manual and Experiment Guide for the PASCO scientific
Model CI-6539A 012-06852A 11/98 EKG SENSOR

[10] A. Rehman, M. Mustafa, N. Javaid, U. Qasim, Z. A. Khan, *Analytical Survey of Wearable Sensors*, arXiv:1208.2376v1 [cs.SY] 11 Aug 2012

[11] A. Godfrey, R. Conway, D. Meagher, and G. ´OLaighin, *Direct measurement of human movement by accelerometry*, Medical engineering & physics, vol. 30, no. 10, pp. 1364–1386, 2008.

[12] J. Schepps and A. Rosen, *Microwave industry outlook-wireless communications in healthcare*, Microwave Theory and Techniques, IEEE Transactions on, vol. 50, no. 3, pp. 1044–1045, 2002.

[13] http://www.sciencedaily.com/releases/2013/03/130319124227.htm

[14] T. Zasowski, F. Althaus, M. Stager, A. Wittneben, and G. Troster, *UWB for noninvasive wireless body area networks: channel measurements and results*, in Ultra Wideband Systems and Technologies, 2003 IEEE Conference on, Nov. 2003, pp. 285{289.

[15] T. Penzel, B. Kemp, G. Klosch, A. Schlogl, J. Hasan, A. Varri, and I. Korhonen, *Acquisition of biomedical signals databases*, IEEE Engineering in Medicine and Biology Magazine, vol. 20, no. 3, pp. 25{32, May/Jun. 2001.

[16] B. Gyselinckx, J. Penders, and R. Vullers, *Potential and challenges of body area networks for cardiac monitoring*, pages s165-s168." Journal of Electrocardiolog, vol. 40, no. 6, pp. S165 {S168, November December 2006, iSCE 32nd Annual Conference.

[17] P. S. Hall and Y. Hao, *Antennas and Propagation for Body-Centric Wireless Communications, Artech House*, 2006.

[18] Huasong Cao, Victor Leung, Cupid Chow, Henry Chan, *Enabling Technologies for Wireless Body Area Networks: A Survey and Outlook*, IEEE Communications Magazine, December 2009

[19] H. Li, J. Tan, *An ultra-low-power medium access control protocol for body sensor network*, in 27th Annual International Conference of the Engineering in Medicine and Biology Society, 2005. IEEE-EMBS, Shanghai,, 2005, pp. 2451{2454.

[20] E. Reusens, W. Joseph, G. Vermeeren, L. Martens, B. Latrie, B. Braem, C. Blondia, and I. Moerman, *Path-loss models for wireless communication channel along arm and torso: Measurements and simulations*, in IEEE Antennas and Propagation Society International Symposium 2007, Honolulu, HI, USA, 9-15 June 2007, pp. 336{339.

[21] Victor Shnayder, Borrong Chen, Konrad Lorincz, Thaddeus R. F. FulfordJones, and Matt Welsh, Sensor *Networks for Medical Care*

[22] Wood, A., Virone, G., Doan, T., Cao, Q., Selavo, L., Wu, Y., Fang, L., He, Z., Lin, S., Stankovic, J. *ALARM-NET: Wireless Sensor Networks for Assisted-Living and Residential Monitoring*, Department of Computer Science, 2006.

[23] Ng, J.W.P., Lo, B.P.L., Wells, O., Sloman, M., Peters, N., Darzi, A., Toumazou, C., Yang, G.-Z. *Ubiquitous Monitoring Environment for Wearable and Implantable Sensors*, (UbiMon), 2004.

[24] Chakravorty, R., *A Programmable Service Architecture for Mobile Medical Care*, March 2006.

[25] Ko, J., Lim, J.H., Chen, Y., Musaloiu-E., R., Terzis, A., Masson, G.M., *MEDiSN: Medical Emergency Detection in Sensor Networks*, 2010.

[26] Ganti, R.K., Jayachandran, P., Abdelzaher, T.F., Stankovic, J.A., *SATIRE: Software Architecture for Smart AtTIRE*, June 2006.

[27] C.Y. Chong and S.P. Kumar, *Sensor networks: Evolution, opportunities, and challenges*, in *IEEE Proceedings*, pp. 1247–1254, Aug. 2003.

[28] A. Mainwaring, J. Polastre, R. Szewczyk, D. Culler, and J. Anderson, *Wireless sensor networks for habitat monitoring*, in First ACM Workshop on Wireless Sensor Networks and Applications, Atlanta, GA, Sept. 2002.

[29] T. Fulford-Jones, D. Malan, M. Welsh, and S. Moulton, *CodeBlue: An ad hoc sensor network infrastructure for emergency medical care*, in International Workshop on Wearable and Implantable Body Sensor Networks, London, UK, 2004.

[30] "*Self-healing Mines*" http://www.darpa.mil/ato/programs/SHM/.

[31] Garth V. Crosby, Tirthankar Ghosh, Renita Murimi, Craig A. Chin, *Wireless Body Area Networks for Healthcare: A Survey*, International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) Vol.3, No.3, June 2012 DOI : 10.5121/ijasuc.2012.3301

[32] T. R. F. Fulford-Jones, et al., *A Portable, Low-Power, Wireless Two-Lead EKG System*, in 26th Annual International Conference of the IEEE EMBS San Francisco, CA, USA, 2004, pp. 2141-2144.

[33] K. Kario, et al. *Ambulatory Blood Pressure Monitoring for Cardiovascular Medicine,* IEEE Engineering in Medicine and Biology Magazine. 81-88, (2003).

[34] A. G. Ruzzelli, R. Jurdak, G. M. O'Hare, and P. V. D. Stok, *Energy-e_cient multi-hop medical sensor networking*, in HealthNet '07: Proceedings of the 1st ACM SIGMOBILE international workshop on Systems and networking support for healthcare and assisted living environments. New York, NY, USA: ACM, 2007, pp. 37{42.

[35] M. Nabi, et al., *A Robust Protocol Stack for Multi-hop Wireless Body Area Networks with Transmit Power Adaptation*, in 5th Annual International ICST Conference on Body Area Networks, Corfu Island, Greece, 2010.

[36] V. Shankar, et al., *Energy-Efficient Protocols for Wireless Communication in Biosensor Networks*, in IEEE Personal, Indoor and Mobile Radio Communications Conference, San Diego, CA, 2001, pp. D-114- D-118.

[37] O. Omeni, et al., *Energy Efficient Medium Access Protocol for Wireless Medical Body Area Sensor Networks*, IEEE Transactions on Biomedical Circuits and Systems, vol. 2, December 2008.

[38] G. Fang and E. Dutkiewicz, *BodyMAC: Energy efficient TDMA-based MAC protocol for Wireless Body Area Networks,* in 9th International Symposium on Communications and Information Technology (ISCIT 2009), 2009, pp. 1455-1459.

[39] N. F. Timmons and W. G. Scanlon, *An Adaptive Energy Efficient MAC Protocol for the Medical Body Area Network*, in 1st International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace(Wireless VITAE2009) Aalborg, Denmark, 2009, pp. 587-593.

[40] B. Otal and L. Alonso, *Highly Reliable Energy-Saving MAC for Wireless Body Sensor Networks in Healthcare Systems*, IEEE Journal on Selected Areas in Communications, vol. 24, pp. 553- 565, May 2009.

[41] T. Zasowski, G. Meyer, F. Althaus, and A. Wittneben, *Propagation effects in UWB body area networks*, in UltraWideband, 2005. ICU 2005. 2005 IEEE International Conference on, Sep. 2005, pp. 16{21.

[42] A. Ylisaukko-oja, E. Vildjiounaite, and J. Mantyjarvi, *Five-point acceleration sensing wireless body area network design and practical experiences,* iswc, vol. 00, pp. 184{185, 2004.

[43] T. Penzel, B. Kemp, G. Klosch, A. Schlogl, J. Hasan, A. Varri, and I. Korhonen, *Acquisition of biomedical signals databases*, IEEE Engineering in Medicine and Biology Magazine, vol. 20, no. 3, pp. 25{32, May/Jun. 2001.

[44] S. K. S. Gupta, S. Lalwani, Y. Prakash, E. Elsharawy, and L. Schwiebert, *Towards a propagation model for wireless biomedical applications*, in Communications, 2003. ICC '03. IEEE International Conference on, vol. 3, May 2003, pp. 1993{1997.

[44] L. Roelens, S. Van den Bulcke, W. Joseph, G. Vermeeren, and L. Martens, *Path loss model for wireless narrowband communication above at phantom*, Electronics Letters, vol. 42, no. 1, pp. 10{11, Jan. 2006.

[45] A. Fort, J. Ryckaert, C. Desset, P. De Doncker, P. Wambacq, and L. Van Biesen, *Ultra-wideband channel model for communication around the human body*, IEEE Journal on Selected Areas in Communications, vol. 24, pp. 927{933, Apr. 2006.

[46] B. Braem, B. Latr_e, I. Moerman, C. Blondia, E. Reusens, W. Joseph, L. Martens, and P. Demeester, *The need for cooperation and relaying in short-range high path loss*

sensor networks, in First International Conference on Sensor Technologies and Applications (SENSORCOMM 2007), Valencia, Spain, 14-20 October 2007, pp. 566{571.

[47] A. Fort, C. Desset, J. Ryckaert, P. De Doncker, L. Van Biesen, and P. Wambacq, *Characterization of the ultra wideband body area propagation channel*, in Ultra-Wideband, 2005. ICU 2005. 2005 IEEE International Conference on, Sep. 2005.

[48] T. Zimmerman, *Personal area networks: Nearfield intrabody communication*, IBM Systems Journal, vol. 35, no. 3,pp. 609{617, 1996.

[49] I. Demirkol, C. Ersoy, and F. Alagoz, *MAC protocols for wireless sensor networks: a survey*, IEEE Communications Magazine, vol. 44, no. 4, pp. 115{121, Apr. 2006.

[50] L. Zhong, D. El-Daye, B. Kaufman, N. Tobaoda, T. Mohamed, and M. Liebschner, *Osteoconduct: Wireless bodyarea communication based on bone conduction*, in Proc. Int. Conf. Body Area Networks (BodyNets), June 2007.

[51] T. Falck, H. Baldus, J. Espina, and K. Klabunde, *Plug 'n play simplicity for wireless medical body sensors*, Mob.Netw. Appl., vol. 12, no. 2-3, pp. 143{153, 2007.

[52] M. Guennoun, M. Zandi, and K. El-Khatib, *On the use of biometrics to secure wireless biosensor networks*, in Information and Communication Technologies: From Theory to Applications, 2008. ICTTA 2008. 3rd International Conference on, Damascus, Apr. 2008, pp. 1{5.

[53] G. Zhou, J. Lu, C.-Y. Wan, M. Yarvis, and J. Stankovic, *Bodyqos: Adaptive and radio-agnostic qos for body sensor networks*, April 2008, pp. 565{573.