Transfer Some of the Vital Signs of the Body by using Wireless Sensor Network

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Abstract - *Remote healthcare is a term sought by many to be a way to save millions of people's lives and to be an alternative to monitoring the patients' conditions in hospitals which may be far from some sudden cases or to save expenses for some families who are not able to afford the cost of transportation and accommodation in health centers, This technique allows data collection of the patient's condition in a calm home environment away from the pressures of health centers accommodation and under normal life conditions of relaxation or effort or exhaustion of work and the like. This technology also provides the opportunity for researchers and medical centers to monitor patients' cases without constant presence with the patient, which may be difficult for the doctor or researcher to the excessive cost or the necessity to be in places of infections dangerous to them ,the researcher intends to rely on the revolutionary advance in the networks of remote sensing and WBAN in particular in the design of a system that allows the transfer of some vital functions of the body simultaneously to be viewed by the specialist or recorded and monitored for a long time. This paper describes the working of a wireless heartbeat and temperature monitoring system based on a microcontroller PIC18F4550-I/P. Most monitoring systems that are in use in today's world works in offline mode but our system is designed such that a patient can be monitored remotely in real time and in offline mode. The proposed approach consists of sensors which measures heartbeat and body temperature and ECG of a patient which is controlled by the microcontroller. Both the readings are displayed in LCD monitor. Wireless system is used to transmit the measured data from the remote location. The heartbeat sensor counts the heartbeat for specific interval of time and estimates Beats per Minute while the temperature sensor measures the temperature while ECG sensor collect sample to draw full ECG then all the data are sent to the microcontroller for transmission to receiving end. Finally, the data are displayed at the receiving end. This system could be made available at a reasonable cost with great effect.*

Key Words: **Microcontroller, Heartbeat, Health Monitoring System, Temperature Sensors, Remote Monitoring, ECG, WSN, WBAN.**

1. INTRODUCTION

Wireless Sensor Networks (WSNs) have and will continue to play a vital role in our daily lives. A Wireless Sensor Network (WSN) refers to a distributed network, consisting of dispersed and autonomous sensing stations. Each sensing station—also known as a sensor node—consists of a microcomputer (computing component), transceiver (communication component), a power source (normally a battery), and some sensor(s) depending upon the application area. Some smart sensors are equipped with an actuator [1]—an electro-mechanical device used to control different components of the system. These nodes self-organize themselves upon deployment and form a network, which is typically comprised of several to thousands of such sensor nodes. Upon forming the network, sensor nodes sense, measure and gather information from the surrounding environment for some activity and report the sensed data to a special station called base station or sink in a multi-hop fashion.

WSNs can be deployed on a large or small scale (depending on the requirements and applications) to detect and collect the required information from the surrounding environment. They can be deployed either in a pre-planned manner or on random basis. WSNs have the ability to change people's lifestyle [2]. They can be used for different applications [3], such as environmental monitoring and seismic sensing [4], natural disaster relief [5], bio-medical health monitoring [6–9], and military target tracking, national defense and surveillance [10,11], habitat monitoring [11], classroom/home [12], structural monitoring [13], measuring traffic flows on roads, tracking the location of personnel in a building and health monitoring.

Wireless Body Sensor Networks (WBSNs) are a subset of wireless sensor networks, The Wireless Body Area Network (WBAN) represents a recent evolution of sensor technology for the development of a new generation of Human-Computer Interfaces (HCIs) that provide natural and context-aware access to personalized services. Sensor technology enables the development of small and intelligent medical sensors which can be worn on or implanted in the human body. These biosensors are capable of measuring significant physiological parameters like heart rate, blood pressure, body and skin temperature, oxygen saturation, respiration rate, electrocardiogram, etc. The obtained measurements are communicated either via a wireless or a wired link to a central node, like a Personal Digital Assistant (PDA) or a microcontroller board, which may then in turn display the information on a user interface or transmit the aggregated vital signs to a medical center. Using a wired connection for this purpose turns out to be too cumbersome and involves a high cost for deployment and maintenance. However, the use of a wireless interface results in an emerging new technology called WBAN [14]. A WBAN could be seen as a special purpose wireless sensor network with a number of additional system design requirements. A WBAN is most likely to incorporate a wearable and implantable node operating in two different frequencies. An implantable node operates at 400 MHz using the MICS band whereas the wearable node could operate in ISM/UWB or some other band [15].

The ageing population around the world has been rapidly growing as a result of increased longevity, mainly attributable to the substantial improvement in nourishment, medicine and public health. In the United Kingdom alone, the population over the age of 85 is predicted to nearly triple by 2035 [16]; in the United States, the population over the age of 65 is estimated to double by 2040 [17]; in the People's Republic of China, the population over the age of 60 is expected to double by 2040 [18]; and by the year 2050 Japan will have the eldest population in human history, with an average age of 52 years [19]. Simultaneously, public-funded healthcare systems in many developed countries are currently confronting an increase in the number of people diagnosed with chronic diseases such as obesity and diabetes. These chronic illnesses are not simply a result of ageing population but are due to inappropriate diet, sedentary lifestyle and insufficient physical activity [20,21]. As reported by the World Health Organization (WHO), diabetes is estimated to become the seventh leading cause of death by 2030 [22]. Due to its chronic nature, diabetes is an expensive illness not only for individual patients but also for healthcare systems as well. And thus, health care becomes is the top priority for all countries and takes the bulk of the big world's budgets. For example, health care expenditure in the United States is $ 2.9 trillion in 2009, with an increase to $ 4 trillion in 2015 (23)

The interest or expenses are not limited to the treatment of diseases, but the most important is to know the causes and the tracking of diseases and symptoms and try to improve the methods of rapid intervention in critical and sudden cases, for example, sudden heart cases, which studies have proven to cause high rates of mortality worldwide: statistics proved that they cause the largest proportion of deaths in America and Europe since 1900, where more than ten million people are affected by these conditions in Europe, more than 1 million people in America and 22 million people worldwide (24). These are expected to increase the ratio tripled to 2020 Where growth rates are expected to be 17% in North Korea and 39% in the United Kingdom (25) (26)

Therefore, the researcher intends to rely on the revolutionary advance in the networks of remote sensing and WBAN in particular in the design of a system that allows the transfer of some vital functions of the body simultaneously to be viewed by the specialist or recorded and monitored for a long time.

2. Issues and Challenges in WSN

•Energy

Sensors require power for various operations. Energy is consumed in data collection, data processing, and data communication; also, continuous listening to the medium for faithful operation demands a large amount of energy by node components (CPU, radio, etc.) even if they are idle. Batteries providing power need to be changed or recharged after they have been consumed. Sometimes it becomes difficult to recharge or change the batteries because of demographic conditions. The most crucial research challenge for the WSN is design, develop and implement energy efficient hardware and software protocols for WSNs. [27]

•Self-Management

Wireless sensor networks once deployed should be able to work without any human intervention. It should be able to manage the network configuration, adaptation, maintenance, and repair by itself [28].

•Hardware and Software Issues:

Sensor Networks consists of hundreds of thousands of nodes. It is preferred only if the node is cheap. Flash memory is advised to be used in sensor networks as it is inexpensive. [29]

•Security

Security is quite challenging issue as WSN is not only being deployed in battlefield applications but also for surveillance, building monitoring, burglar alarms and in critical systems such as airports and hospitals. [30]

•Data Collection and Transmission

Data gathering is the main objective of sensor nodes. The sensors periodically sense the data from the surrounding environment, process it and transmit it to the base station or sink. Data gathering involves data collection and transmitting data to the sink node. Sometimes the sample of data collected is redundant and there is no need of transmitting such samples to the sink node as it will only consume energy. So, care must be taken during data collection and transmission [31].

•Calibration

Calibration is the process of adjusting the raw sensor readings obtained from the sensors into corrected values by comparing it with some standard values. Manual calibration of sensors in a sensor network is a time consuming and difficult task due to failure of sensor nodes and random noise which makes manual calibration of sensors too expensive [32].

•Limited Memory and Storage Space

A sensor is a tiny device with only a small amount of memory and storage space for the code. In order to build an effective security mechanism, it is necessary to limit the code size of the security algorithm. For example, one common sensor type has a 16- bit, 8 MHz RISC CPU with only 10K RAM, 48K program memory, and 1024K flash storage. With such a limitation, the software built for the sensor must also be quite small. [33]

•Fault Tolerance

Sensor network should remain functional even if any node fails while the network is operational. Network should be able to adapt by changing its connectivity in case of any fault. In that case, well- efficient routing algorithm is applied to change the overall configuration of network [34].

3. Issues and Challenges in WBSNs

In the following sections, we discuss the issues and challenges of WBSNs.

•Network Topology

Network topology describes the logical way in which the different communicating devices communicate with each other. Efficient routing protocol development requires a proper network topology as it effects the overall performance of the communication system [35]. Proper network topology is very important for WBSNs because of the energy constraint, body postural movements, heterogeneous nature of the sensors and short transmission range. Some researchers use single hop communication, where each node communicates directly with the destination, while others use cluster based multi-hop routing

•Topological Partitioning

The network topology of WBSNs often faces the problem of disconnection or partitioning because of body postural movements and short-range transmissions. Different researchers have tried to solve the problem of disconnection and partitioning in different ways. For example, the authors of [20] use Line-of-Sight (LoS) and None-Line-of-Sight (NLoS) communication, while the authors of [36] use store-and-forward routing to solve this problem.

•Energy Efficiency

Energy efficiency covers both the local energy consumption of nodes and the overall network lifetime. For implanted bio-medical sensors, it is not possible to replace the power source, while for wearable bio-medical sensors replacing the batteries might lead to discomfort of patients. Therefore, both energy consumption and network lifetime are major challenges in wireless body sensor networks.

Communication among the sensor nodes consumes more energy as compared to sensing and processing [37]. Any proposed algorithm should be able to use different paths and/or nodes to send the data instead of depending on a single path and/or node preventing the consumption of total energy of that specific node(s). In [38], the authors define the network life as the time from which the network starts till the time when the first node of the network expires. The network life is very much important in WBSNs because of energy constraints and the impossibility of replacing the energy source for implanted sensors.

•Limited Resources

Along with limited energy source, WBSNs also have short Radio Frequency (RF) transmission range, poor computation capabilities, limited storage capacity, as well as low bandwidth—which may keep on changing due to noise and other interferences [35].

•Quality of Service (QoS)

In WBSNs different types of data require different quality of services as it deals with vital signs of the human body. The authors in [39] have classified the patient data into critical data (like EEG, ECG etc.), delay sensitive data (for example video streaming), reliability- sensitive data (like vital signals monitoring respiration monitor, and PH monitor) and ordinary data (for example temperature, heartbeat, etc.). The other data-centric applications of WSNs also cannot tolerate latency and/or any loss of packets. The proposed protocols need to be aware of the different types of quality of service required for different types of patients' vital sign- related data.

•Radiation Absorption and Overheating

The two sources of temperature rise of a node are antenna radiation absorption and power consumption of node circuitry, which will affect the heat sensitive organs of the human body and may damage some tissues [40]. we should carefully develop the protocols for WBSNs to keep human tissues safe from any overheating caused by radiation absorption and operation of the implanted bio-medical sensor nodes.

•Heterogeneous Environment

Different types of sensor nodes are required to sense and monitor the different health parameters of human beings, which may also differ in computation, storage capabilities and energy consumption [35]. Thus, the heterogeneous nature of WBSNs also imposes some more challenges.

•Path Loss

Path loss or path attenuation is a measure of the decline in power density of an electromagnetic wave as it propagates through the wireless medium. It is the ratio of the power of transmitted to received signals. The wireless communication between the implanted sensor nodes is through the human body, where the path loss exponent varies from four to seven [41]

•Security and Privacy

Like other applications of WSNs, security and privacy are among the basic requirements of WBSNs. It is impossible to apply the conventional techniques of security and privacy because of the low energy availability, limited resources and other constraints [42].

4. Architecture of Wireless Body Sensor Networks

The architecture of WBSNs can divided into following three different tiers [43], as shown in Figure 1:

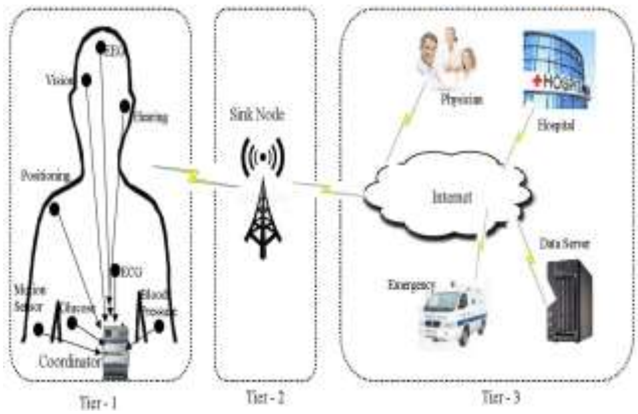

Figure 1. Architecture of Wireless Body Sensor Networks.

Tier 1—Intra-WBSN: In Intra-WBSN, the on-body and/or implanted bio-medical sensor nodes send the sensed data to the coordinator or base station.

Tier 2—Inter-WBSNs: In Inter-WBSN, coordinators or base stations send the received data to the sink(s) after required data processing and data aggregation.

Tier 3—Extra-WBSN: In this tier the sink(s) send the collected data to the remote medical center and/or any other destination via regular infrastructure such as internet.

5. Previous studies

in this section, the previous related works about wireless healthcare scenarios, are presented

Design both Vikramsingh & Akesh(44) wireless heartbeat and temperature monitoring system based on a microcontroller ATmega328 (Arduino Uno) The proposed approach consists of sensors which measures heartbeat and body temperature of a patient which is controlled by the microcontroller. Both the readings are displayed in LCD monitor. Wireless system is used to transmit the measured data from the remote location. The heartbeat sensor counts the heartbeat for specific interval of time and estimates Beats per Minute while the temperature sensor measures the temperature and both the data are sent to the microcontroller for transmission to receiving end.

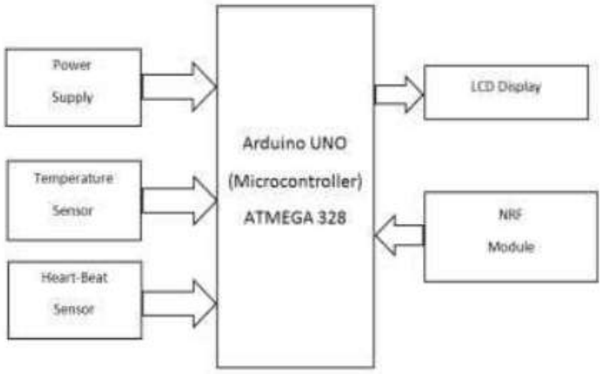

Figure 2. Block diagram of transmitter section

FUTURE & Issue of APPLICATION

•The device can be connected to PC by using serial output so that measured heartbeat and temperature can be sent to PC for further online or offline analysis.

•Warning for abnormalities of health condition can be displayed.

•Sound can be added to the device so that the device makes a sound each time a pulse is received and alarm is started for abnormal health condition.

•The output can be sent to mobile phones by using GSM module or Bluetooth module for further analysis.

•More parameters (like blood pressure) can be added to the device.

•In addition to the system can also provide more than one numbers so that more than one user can receive emergency message.

•According to availability of sensors or development in biomedical trend more parameter can be sense and monitor which will drastically improve the efficiency of the wireless monitoring system in biomedical field.

Design both C. K. Das & Alam(45) wireless heartbeat and temperature monitoring system based on a microcontroller which measures heartbeat and body temperature of a patient which is controlled by the microcontroller. Both the readings are displayed in LCD monitor.

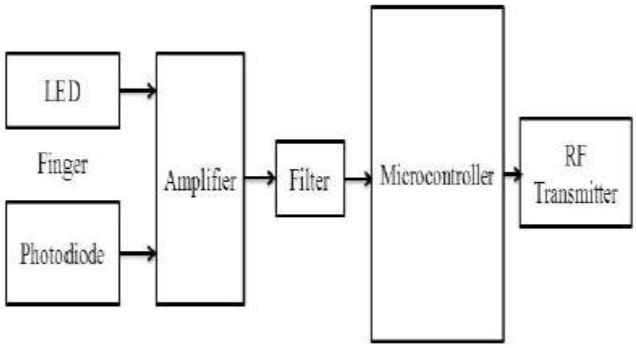

Figure 3. Block diagram showing heartbeat and temperature measuring and transmitting system

FUTURE & Issue of APPLICATION

•The RF module used in this project is able to handle one-way data transfer but is not able send the other way around.

•The RF module is not able to eliminate garbage data.

•The device has 100 meter transmitting range in open space according to specification but we found it to be 15m only which can be solved by using XBee-PRO 868 which can be used for long range RF connectivity.

Design both Bandana & Patro (46) technique of measuring the heart rate through a fingertip and Arduino It is based on the principal of photophelthysmography (PPG) which is non-invasive method of measuring the variation in blood volume in tissue using a light source and detector. While the heart is beating, it is actually pumping blood throughout the body, and that makes the blood volume inside the finger artery to change too. This fluctuation of blood can be detected through an optical sensing mechanism placed around the fingertip. The signal can be amplified and is sent to arduino with the help of serial port communication. With the help of processing software heart rate monitoring and counting is performed.

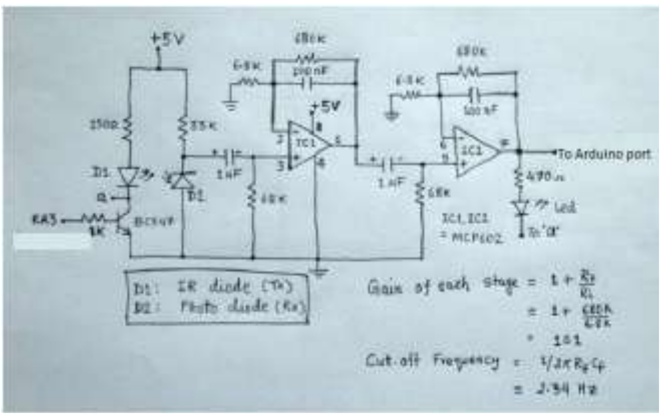

Figure 4. Circuit diagram of sensor

FUTURE & Issue of APPLICATION

•The application displays the near-real-time PPG waveform and heart rate but does not record anything. There is a lot of room for improvements.

•Don't Logging heart rate measurements and PPG samples along with the time-stamp information available from the PC

•Can be add Beeping sound alarm for heart rates below or above threshold

•Heart rate trend over time

Based on the problems and challenges that faced previous research in this field, the researcher tried to design a system to transfer some vital functions from the human body through WBAN networks to avoid some of these problems such as:

1- Developing a network of sensors that the patient wears to record some important biomarkers for recording and transmission to be reviewed by a specialist

2 - To develop the possibility of movement between the sensors by separating one or focusing on the other according to priorities determined by the specialist and allow the separation or operation of any stage by the specialist.

3 - Allow the use of multiple web browsers to display the patient data from any computer or mobile device by displaying the results on a central server

4 - Allow the view of results on the application of mobile phones to diversify the means of display and to ensure greater documentation of data

6. The presented System Architecture

Figure 5 illustrates the general structure of the system and, in an overall view; it is composed of the following:

1. A range of sensors around the patient, consisting of the body area network (BAN), but unable to connect to the wireless receivers. The researcher uses three sensors (temperature sensor - heart rate sensor HBR – ECG (electrocardiogram))

2 - The system, which is designed by the researcher to connect the sensors, then performing the configuration of signals: filtering and amplifying the signal received before entering the microcomputer to complete the process of collection, registration and preparation of the transmission via the Internet through the WI-FI from the Internet around the patient or through the patient's phone or any phone of those around him

3. Displaying the data on an LCD screen attached to the system as a means to display the data to any specialist near the patient

4 - Transmission of encrypted data over the Internet to data collection server.

5 - Saving the data in a public server to allow the display from any location in the world and the server used in the search is Thingspeak

6 - Displaying the collected data of the patient on any computer or laptop through the browser when connected to the server

7. Displaying the collected data of the patient on the application of the mobile phone via the server

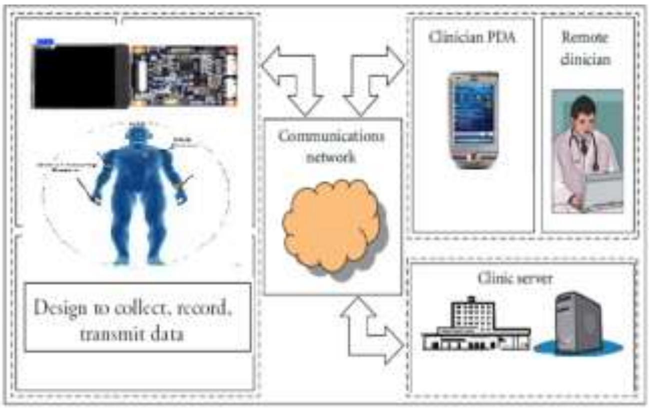

Figure 5. The general structure of the system

Figure 6 shows the system chart of the system in general and then we review each phase one by one:

6.1 System design (simple case)

In many cases, the doctor only measures the patient's temperature and pulse to make an initial diagnosis of the condition, so we will start by designing a system to measure the patient's pulse and temperature

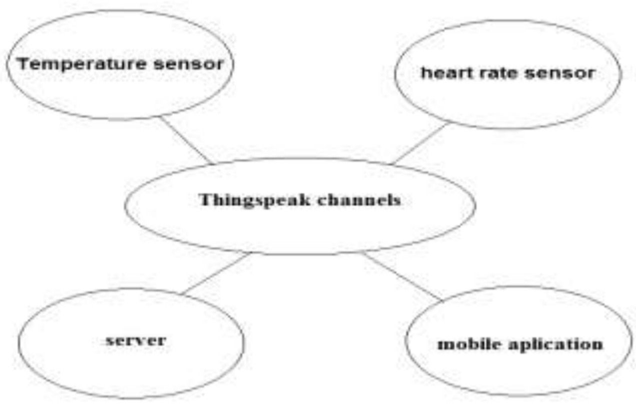

Figure 6. System design (simple case)

Figure 7 shows the system chart of the system in general and then we review each phase one by one:

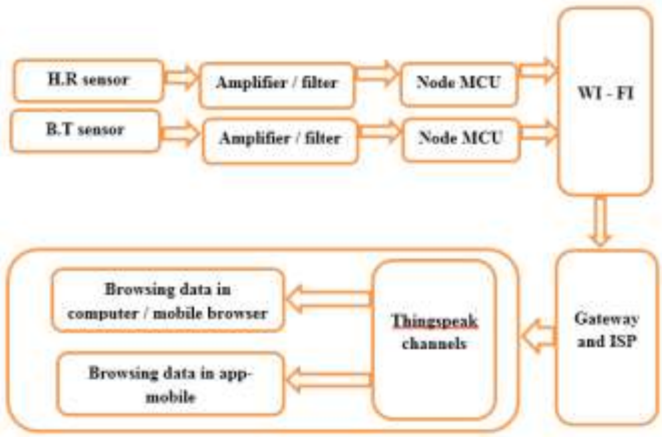

Figure 7. the system chart of the General system

6.1.1 Phase 1: Heart Rates

Heart rate is the number of heart beats per minute. This rate is an important indicator of the health of the human heart system and also reflects different physiological conditions such as workload, work stress, task concentration, drowsiness and active state of the independent nervous system. The heart rate at adults is 72 beats per minute and children is about 120 beats per minute, while older children have a heart rate of about 90 beats per minute. Heart rate increases gradually during exercise or hard work and slowly returns to normal value after exercise [47]

Design of the heart rates circuit

There are two ways to display the heart rate, electric method, and optical method, the electric method requires winding a huge belt of sensors around the chest, but the optical method does not need this belt and is a more convenient method than electric method.

Optical method technique makes use of the fact that the subcutaneous blood vessels (capillaries) in any spot of the skin (such as a finger or earlobe) have well flow of the blood, expanding and contracting with heart beat in time. The normal pair of phototransistors can sense this rhythmic change, despite being slight but detectable changes, so it is accurate, efficient and inexpensive

The circuit is built in three stages: the first external sensor and the second stage signal conditioning circuit and the third stage signal conditioning circuit [48]

First stage: the heart rate sensor

The search uses a n optical sensor as shown in Fig. 8. It is small in size, easy to install and compatible with many systems such as Arduino or microcontrollers

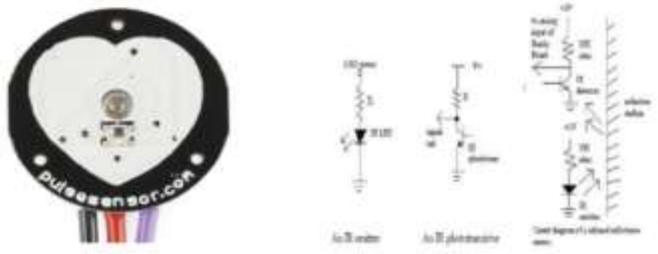

Figure 8. the heart pulse rate sensor

It is a LED that lights up, there is also a box slightly under the LED. This box is an ambient light sensor, just like those used in mobile phones, and computers, to adjust the screen brightness in different lighting conditions.

The LED lights up in the finger, earlobe, or other capillary tissue, and the sensor read the light that reverberates again as Figure 9

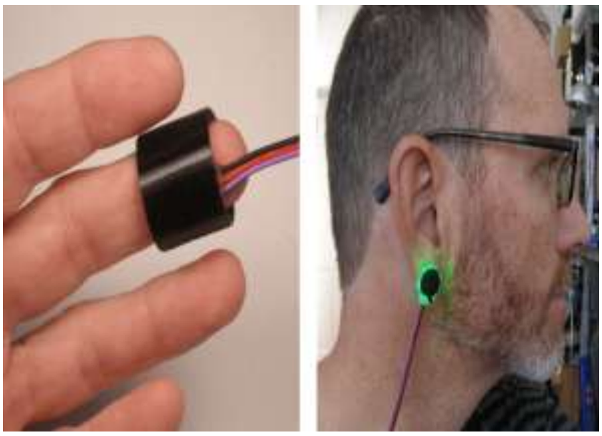

Figure 9. Examples of the installation of the heart pulse rate sensor

The second and third stage: the signal configuration

It is a circuit in which the process amplifier and a whole set of different filters are used.it is shown in figure 10

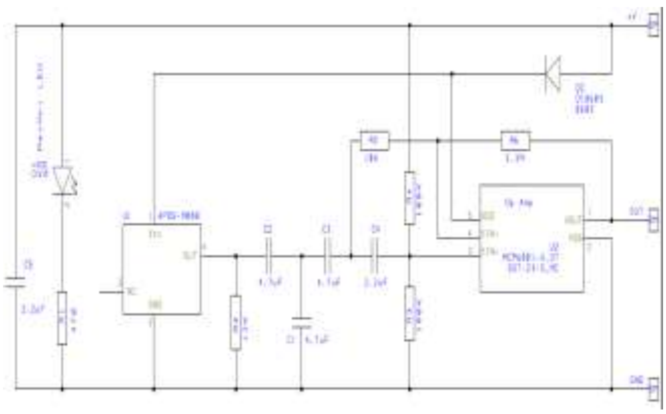

Figure 10. Sensor Signal Configuration Circuits

6.1.2 Phase 2: Body Temperature

The body's natural temperature varies from person to person and varies for the person throughout the day. The body temperature is lower in the morning and higher in the evening. The body's normal temperature is about 37 ⍰C. However, it can be as low as 36.1 ⍰C in the early morning or slightly higher to 37.2 ⍰C and is considered normal too. The natural temperature of the human body ranges from 36.1 ⍰to 37.8 ⍰C [49].

Temperature can be measured using different kinds of sensors. These sensors come in various forms such as thermocouples, thermistors, thermal resistors (RTD), integrated IC sensors

Design of the Body Temperature Circuit

This unit consists of a temperature sensor to measure the temperature of the patient that is directly connected to the microcontroller. The temperature sensor used in this project is non-linear heat-resistant

Figure 11 illustrates the circuit design

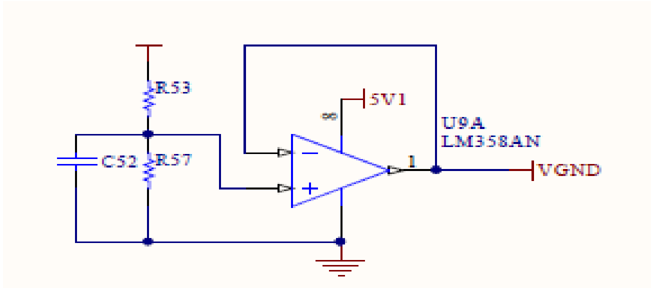

Figure 11. Temperature sensor Circuit design

6.2 System design (critical case)

Sometimes it is not enough for the doctor to measure the patient's pulse and temperature to diagnose his condition, but an electrocardiogram is required to give appropriate instructions in critical cases.

6.2.1 ECG

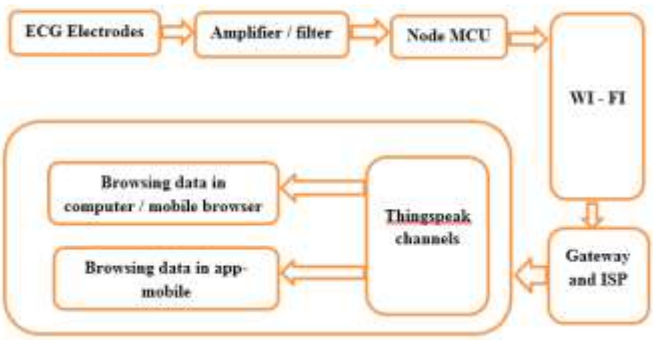

Figure 12. System design (critical case)

ECG (electrocardiogram) is a test used to determine the rhythmic activity of the heart. ECG indicates cardiac activity using electrical signals generated during the heart cycle; measured using external electrodes. ECG is used to detect abnormal heart rhythms, determine heart rates and causes chest pain. Cardiac ECG activity is recorded on graph sheets or screens by placing electrodes on the person's body and the records show a series of electrical waves occurring during each pulse of the heart. Recorded waves contain peaks and valleys, usually represented by letters P, Q, R, S, T, and U (as shown in Figure 13.

The U wave is unstable and can be invisible in 70% of people, but clinically, the U wave is as important as other waves [50].

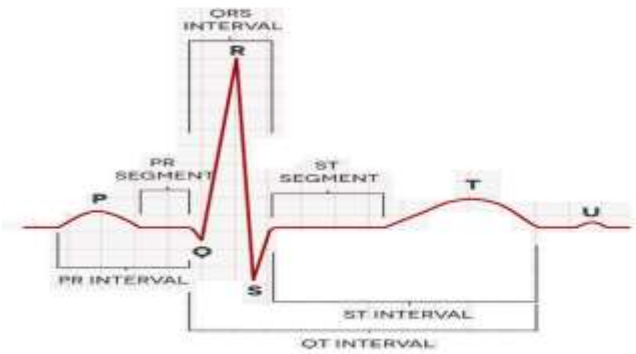

Figure 13. shows different samples of ECG ECG for different cases

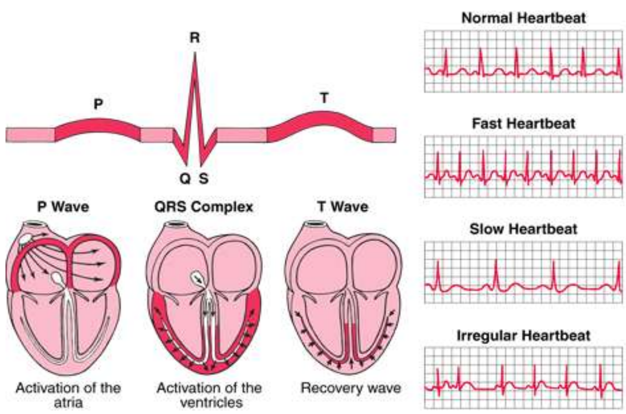

Figure 14. ECG signal samples

Proper electrode placement is necessary to obtain accurate ECG readings. Manufacturers of ECG provide safe use guidelines that include electrode guidelines for their products. Figure 5 illustrates the different positions for placing the 3 electrodes used by the researcher.

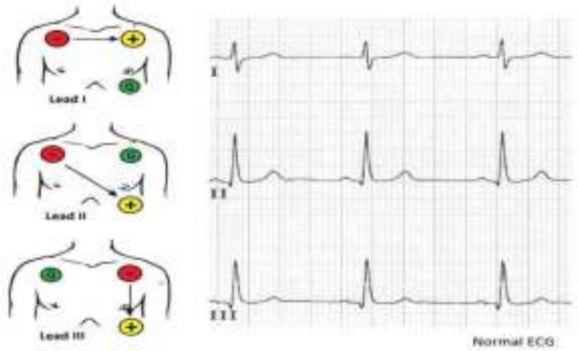

Figure 15. Different Leads for installing ECG electrodes

Lead I compares the flow of current between the right arm electrode (-) and the left arm electrode (+), Lead I offers a lateral view of the left ventricle and left atrium.

Lead II views the left and right ventricles from the apex. It is the most commonly monitored lead, producing the universally recognized normal sinus rhythm (NSR) tracing

Lead III provides an inferior view of the right and left ventricles. Lead III along with leads I, II and the unipolar leads VR, VL and VF can be helpful when determining cardiac axis.

ECG bandwidth contains an invaluable information about frequency; therefore, the frequency-domain is an important issue that is needed to determine the linear system preprocessing parameters. [0.5-3Hz] is the heart rate frequency for heart rate of 30-180 bpm. Many issues play a role in identifying the highest frequency like age, sex, and the overall state of health of the patient, about 125Hz is considered the typical value [51].

DESIGN OF THE ECG CIRCUIT

Figure 16 illustrates the stages of the design of the electrocardiograph. The following is an explanation of each stage (installation - characteristics)

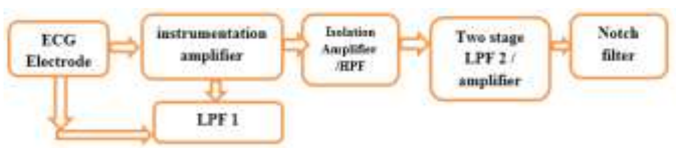

Figure 16. The ECG chart

stage one: instrumentation amplifier

The ECG electrode output is weak within (1mv-10mv), which requires an amplification of the signal before starting any process. Therefore, the researcher uses an instrumentation amplifier and to build the amplifier, the integrated circuit IC (AD620) has been used as it has many characteristics that suits the nature of the design such as: low noise, low cost and excellent performance whether DC or AC.

The characteristics of this integrated circuit can be summarized as follows

1- Low input bias

2. Gain range from 1 to 1000

3. Need for only one external resistor for setting this gain rang

4- Wide power supply range from ± 2.3V to ± 18V

5. Low power dissipated

Figure 17 shows the structural components of the AD620 chip where the gain rate is controlled by the RG resistor connected to the ends [52]

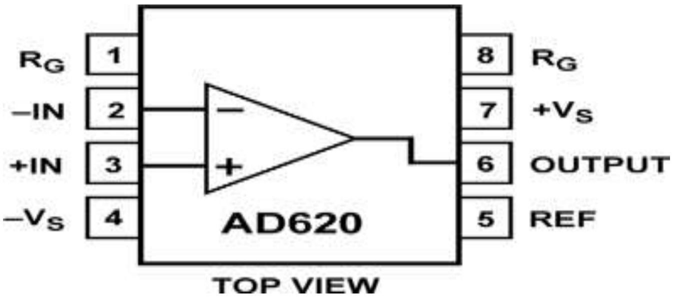

Figure 17. AD620

The chip has two analogue inputs 2, and the negative terminal of the electrode is connected to it, and the terminal 7 to which the positive side of the electrode is connected. Table 1 shows the three electrode terminals

Lead	Positive (+) electrode	Negative (-) electrode
I	Left arm	Right Arm
II	Left leg	Right Arm
III	Left leg	Left Arm

Table 1. Electrode connection for three bipolar limb leads

The gain of the amplifier can be adjusted by means of the following relationship and by controlling the resistance value of RG to get gain equal to 6

G = (R1 + R2)/ RG + 1

Figure 18 shows the connection of the instrumentation amplifier

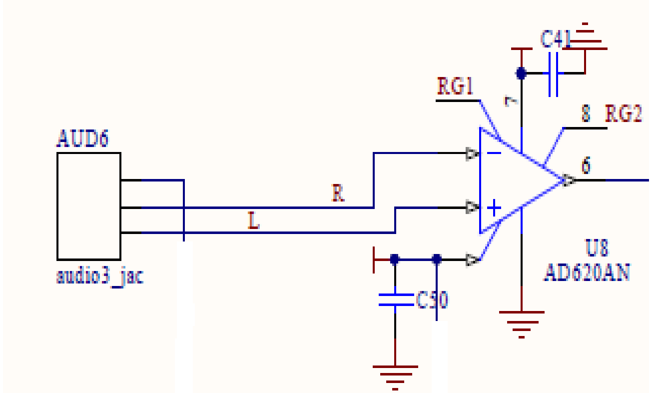

Figure 18. the instrumentation amplifier

Stage two: Low pass filter 1

Due to the weak output of the electrode, LPF should be connected to the third end to avoid any interference and only allow the ECG to enter the amplification phase through the filtering phase using the process amplifier LM358 as shown in Fig. 19 and its function can be summarized in the deletion of frequencies that are higher than the frequency of cardiac activity Which is often deleted at 180 Hz, and this circuit contains a chemical capacitor at the beginning , its function is the separation of continuous currents overlapping on the heart signal and the process amplifier in this filter should work properly in this field of the frequency, No amplifications are performed in this phase of the circuit and It must be mentioned that the cardiac signal frequencies are between 0.001 Hz and up to 180 Hz.

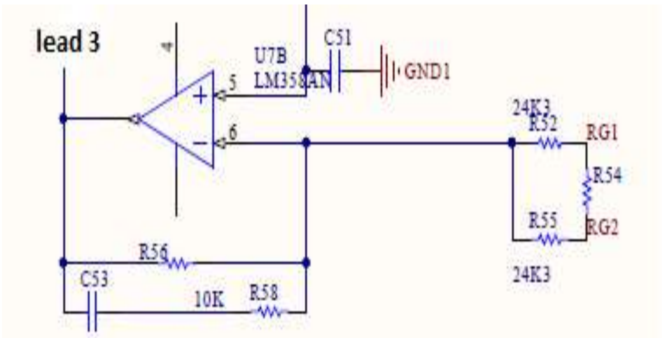

Figure 19. Filtering phase

Stage three: Isolation Amplifier

When the patient is connected to a power line, this requires isolating the patient's body from harmful current, and isolating the electronic circuitry that is connected to it from damage as well. Therefore, Isolation Amplifier is installed.

HCPL7800 is the IC that was chosen to do such a role, this IC is an optocoupler packaging technology (light pipe) and usually used for isolation purposes of a general analog signals that require high accuracy, linearity, and stability in similar noise conditions

Figure 20 shows the structure of the HCPL7800

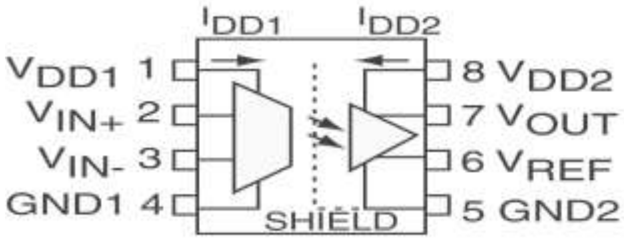

Figure 20. HCPL7800

Figure 21 shows the Isolation Amplifier where two voltage regulators were connected to the HCPL7800 IC through the terminals 1 and 8 in series to keep the voltage as close as possible to the desired value and maintaining the performance of DC insulation circuit simultaneously.

The output of the instrumentation circuit amplifier is now the input of this phase at the second end, the capacitor (C3 = 0.01µF) is connected in parallel to the input and the other end to the ground. The ends 3 and 4 are connected to the ground, while the fifth end is connected to the patient ground.

The end 6 is not connected, and we get the output of this circuit from the end 7

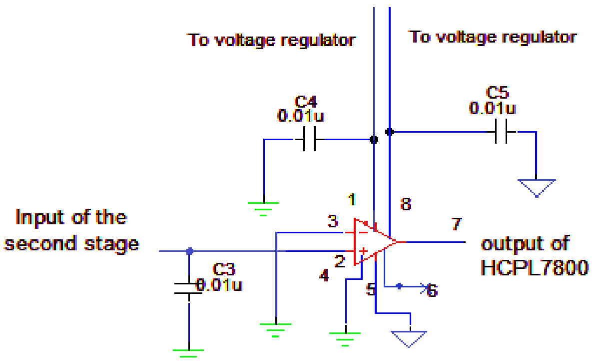

Figure 21. Instrumentation amplifier

Stage four: Combined Filters

This phase consists of three filters to improve the form of the signal and get the desired output of the design, which consists of three different filtering stages which are:

High pass filter and two stages of low pass filter, the amplifier LM358 was used in the implementation of all of them, and they were also used to increase the total gain of the design to reach the level of signal that corresponds to the input of the microcontrollers.

Figure 22 shows the executive of the combined filters

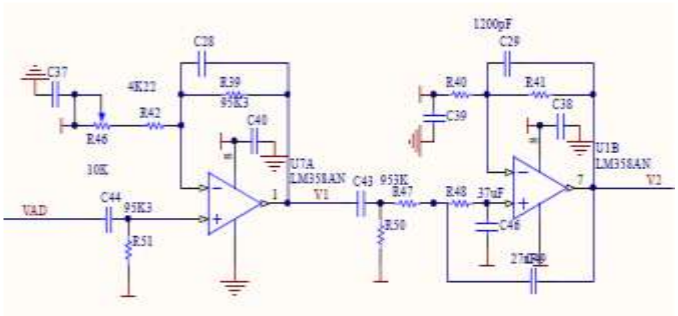

Figure 22. Executive Circuit for Combined Filters

As indicated before, clinical bandwidth for standard 12-Lead ECG is [0.05-100HZ], for diagnostic purposes, fc of 0.05Hz is required for good acceptable ECG quality while 0.5Hz is used for monitoring purposes, that's why, R4 and C6 of the HPF circuit were changed to be 3.3MΩ and 1µF respectively to get fc of:

fc=1/(2piR4C6) = 1/[2pi(3.3MΩ) (1µF)] ≈ 0.05Hz

The total gain of the design is calculated from the following relationship and is set to a gain equal to 206

GTotal = GainIA * GainHPF * GainLPF

Stage 5: Notch filter circuit

Notch filter is a kind of filters that passes all frequencies and reject a particular frequency, which is determined by the user [53].

The function of this circuit is to delete the frequency band 50 Hz, which is the result of interference in the electricity network of the city in which the device is located and may be to delete the frequency 60 Hz depending on the different systems of electricity in countries and so we finally got the required heart signal which is then displayed on the screen attached to the device or sent after processing in microcontrollers.

Figure 23 illustrates its executive Notch filter circuit

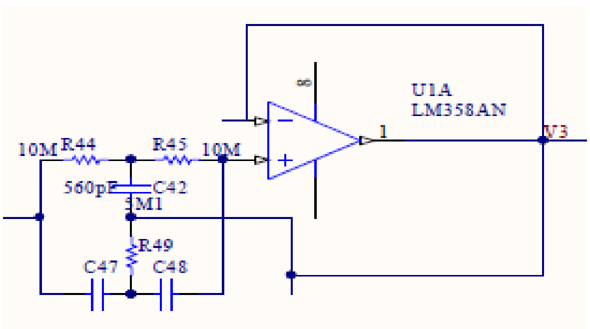

Figure 23. Executive Notch filter circuit

Figure 24 also shows the form of the signal before filtering and Figure 25 shows it after filtering

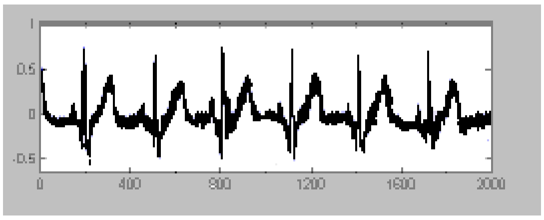

Figure 24. ECG pre-filter signal

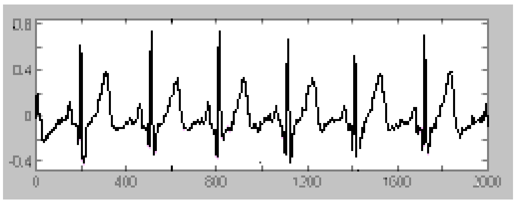

Figure 25. ECG signal after filtration

7. Phase 4: THINGSPEAK PLATFORM

It is an open source platform launched by ioBridge in 2010 to support (Internet of Things) IoT applications, which enables the collection, visualization, analysis and display of live data streams in the cloud [54] and also provides the ability to designing MATLAB code for online data analysis and processing

THINGSPEAK has many capabilities and advantages including the following: [55]

1. Easy configuration: configure devices to send data to Thingspeak using general IoT protocols.

2. Visualization: visualize collected sensor data in Realtime.

3. Aggregation: aggregate data on request from third party sources.

4. Analysis: run the automatic IoT analytics based on events or schedules.

5. Prototyping: build and prototype IoT systems without setting up servers or developing web software.

6. Automation: automatically manipulate the data and communicate using third party services such as Twitter or Twilio.

Thingspeak allows the possibility of adding channels to receive the data of each patient and storing them in different ways, whether digital or graphic drawings, with the possibility to add more than one field in one channel to measure more than one indication of the patient and allows the import of these data in the form of tables or displayed on any page designed for that such as the site of a hospital or e-mail to a doctor or medical center or view this data on a mobile application designed to receive data for patients, which was carried out by the researcher from receiving data from patients, recorded and then displayed it on the mobile application as he will show in the findings.

Sending data to Thingspeak

The design sends the patient's temperature continuously to Thingspeak, but after a delay period at the beginning for 4 minutes, the period required to obtain stable readings without recording initial readings that don't reflect the actual degree of the patient.

The design sends the patient's heartbeat to Thingspeak every minute with the possibility of displaying it in a digital system or a pulse chart.

The design sends a pulse of the ECG divided into 128 samples. Each sample is sent every 15 seconds so the process of sending a complete pulse to the patient requires a time of about 32 minutes.

The design enables the distribution of pulse display every 32 minutes or distribution of pulse transmission throughout the day or continuous pulse storage. it can send it when the receiver requests for data and can also cancel the measurement of one of the previous indications or concentrates on one indication for a period and then switch to another.

8. Results

The following are some of the readings from patients measured by design through the browser or mobile application

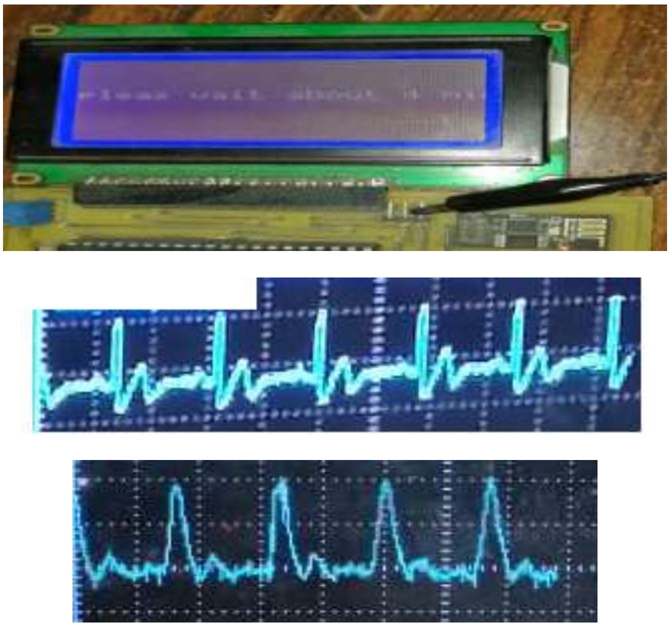

Figure 26.some of result

• As shown in this result, the circuit design which was introduced is successful and effective, but there is still a location which would be improved more and more to get best signal.

• The circuit was for single channel ECG but it can be easily modified and expanded for multi-channel.

• It is also very simple and low cost that can be easily collected and printed, offering the ability to manufacture it in Egypt.

• Digital filtration is very important, it improves the quality of the signal and it can be added and modified with the circuit design based on the obtained results.

CONCLUSIONS

The study aims to build a health care system based on remote sensing networks to transfer some vital functions from the human body to medical centers through the system and thingspeak cloud The system allows doctors and medical centers to monitor their patients remotely through a reliable system that enables them to take preventive health measures for patients and track the development of their condition and monitor the changes that appear to their vital functions during their daily work

Results and observations on the system showed that it was effective in monitoring cases of heart patients and sudden heart attacks and assist in the development of ambulance systems and recording the development of disease cases to be researched, especially in epidemics

The system also allows access to patient data through more than one means such as computer server and mobile application

It also enables specialists to create a database of many patients and monitor their condition at the same time

REFERENCES

1- Yick, J.; Mukherjee, B.; Ghosal, D. Wireless sensor network survey. *Comput. Netw.* 2008, *52*, 2292–2330.

2- P�ez, J.J.; Alvaro, J.S.; Bustamante, J. A Wireless Body Sensor Network Platform to Measure Vital Signs in Clinical Monitoring. In Proceedings of 2013 Pan American Health Care Exchanges (PAHCE), Medellin, Columbia, 29 April–4 May 2013; pp. 1–6.

3- Lee, Y.S.; Lee, H.J.; Alasaarela, E. Mutual Authentication in Wireless Body Sensor Networks (WBSN) Based on Physical Unclonable Function (PUF). In Proceedings of 9th International Wireless Communications and Mobile Computing Conference (IWCMC), Sardinia, Italy, 1–5 July 2013; pp. 1314–1318.

4- Wener-Allen, G.; Lorincz, K.; Ruiz, M.; Marcillo, O.; Johnson, J.; Lees, J.; Walsh, M. Deploying a wireless sensor network on an active volcano. *IEEE Int. Comput.* 2006, *2*, 18–25.

5- Castillo-Effer, M.; Quintela, D.H.; Moreno, W.; Jordan, R.; Westhoff, W. Wireless Sensor Networks for Flash-Flood Alerting. In Proceedings of the 5th IEEE International Caracas Conference on Devices, Circuits and Systems, Punta Cana, Dominican Republic, 3–5 November 2004; pp. 142–146.

6- Gao, T.; Greenspan, D.; Welsh, M.; Juang, R.; Alm, A. Vital Signs Monitoring and Patient Tracking Over a Wireless Network. In Proceedings of IEEE-EMBS 27th Annual International Conference of the Engineering in Medicine and Biology Society, Shanghai, China, 17–18 January 2006; pp. 102–105.

7- Lorincz, K.; Malan, D.J.; Fulford-Jones, T.R.; Nawoj, A.; Clavel, A.; Shnayder, V.; Mainland, G.; Welsh, M.; Moulton, S. Sensor networks for emergency response: Challenges and opportunities. *IEEE Pervasive Comput.* 2004, *3*, 16–23.

8- Umamaheswari, S.; Priya, R.M. An efficient healthcare monitoring system in vehicular Ad Hoc networks. *Int. J. Comput. Appl.* 2013, *78*, 45–49.

9- Aminian, M.; Naji, H.R. A hospital healthcare monitoring system using wireless sensor networks. *J. Health Med. Inform.* 2013, *121*, doi:10.4172/2157-7420.1000121.

10- Simon, G.; Mar�, M.; L�eczi, �.; Balogh, G.; Kusy, B.; N�as, A.; Pap, G.; Sallai, J.; Frampton, K. Senso r Network-Based Countersniper System. In

Proceedings of the 2nd International Conference on Embedded Networked Sensor Systems, Baltimore, MD, USA, 3–5 November 2004; pp. 1–12.

11- Cerpa, A.; Elson, J.; Estrin, D.; Girod, L.; Hamilton, M.; Zhao, J. Habitat monitoring: Application driver for wireless communications technology. In Proceedings of ACM SIGCOMM Computer Communication Review—Workshop on Data Communication in Latin America and the Caribbean, San Jose, CA, USA, April 2001.

12- Essa, I.A. Ubiquitous Sensing for Smart and Aware Environments. *IEEE Pers. Commun.* October 2000, *7*, 47-49.

13- Nadler, B.; Tanner, N.; Farrar, C.R. Structural Health Monitoring: Remote Sensing. Available online: http://www.lanl.gov/projects/damage_id/motes.htm (accessed on 18 March 2011).

14- Cypher, D.; Chevrollier, N.; Montavont, N.; Golmie, N. Prevailing over wires in healthcare environments: benefits and challenges. IEEE Commun. Mag. 2006, 44, 56-63.

15- Ullah, S.; Higgins, H.; Braem, B.; Latre, B.; Blondia, C.; Moerman, I.; Saleem, S.; Rahman, Z.; Kwak, K.S. A comprehensive survey of wireless body area networks: On PHY, MAC, and Network Layers Solutions. *J. Med. Syst.* 2010, in press.

16- Office of National Statistics. Statistical Bulletin National Population Projections, 2012-based Statistical Bulletin. Available online: http://www.ons.gov.uk/ons/dcp171778_334975.pdf (accessed on 1 May 2016).

17- U.C.B.P.I. Office. Unprecedented Global Aging Examined in New Census Bureau Report Commissioned by the National Institute on Aging; U.S. Census Bureau: Washington, DC, USA, 2009.

18- Wei, C.; Jinju, L. Future Population Trends in China: 2005–2050; Centre of Policy Studies/IMPACT Centre, Victoria University: Victoria, Australia, 2009

19- Department of Economic and Social Affairs Population Division. World Population Prospects: The 2012 Revision. Methodology of the United Nations Population Estimates and Projections; Rep. ESA/P/WP. 235; UN: New York, NY, USA, 2004.

20- Roberts, C.K.; Barnard, R.J. Effects of exercise and diet on chronic disease. J. Appl. Physiol. 2005, 98, 3–30. [CrossRef] [PubMed]

21- Who and FAO Expert Consultation. Diet, Nutrition and the Prevention of Chronic Diseases; World Health Organization Technical Report Series 916;World Health Organization: Geneva, Swiss, 2003.

22- Alwan, A. Global Status Report on Non-Communicable Diseases 2010; World Health Organization: Geneva,Switzerland; Available online: http://www.who.int/nmh/publications/ncd_report_full_en.pdf (accessed on 1 May 2016).

23- C. Borger, et al.:"Health spending projections through 2015: Changes on the horizon," In Health Affairs Web Exclusive W61, February 22, 2006.

24- J. G. Cleland, K. Swedberg, and F. Follath,"A survey of the quality of care among patients with heart failure in Europe. Part 1: Patient characteristics and diagnosis," The Euro Heart Failure Survey Programme, Euro Heart Jour-nal, pg 24, pp. 442-463, 2003.

25- Heart Failure Facts and Figures: OU Medical Centre.

26- Barroso, J. Benson, et al., "The DSYS25 sensor plat-form," In Proceedings of the ACM sensys, 2004.

27- M.H. Anisi, A.H. Abdullah, and S.A. Razak, "Energy-Efficient Data Collection in Wireless Sensor Networks",Wireless Sensor Networks, vol. 3, 2011, pp. 329-333.

28- K. Sohrabi, J. Gao, V. Ailawadhi and G.J. Pottie, "Protocols for self organization of a wireless sensor networks", IEEE Personal Communications, vol. 7, no. 5, 2000, pp. 16-27.

29- P. Zhang, M. Sadler, A. Lyon and M. Martonosi, "Hardware Design Experiences in ZebraNet", Proc. 2nd International Conf. Embedded Networked Sensor Systems (SenSys), Nov. 2004, pp. 227-238.

30- P. Mohanty, S. Panigrahi, N. Sarma, and S.S. Satapathy, "Security Issues In Wireless Sensor Network Data Gathering Protocols: A Survey", Journal of Theoretical and Applied Information Technology, vol. 13, no.1, 2005-2010, pp. 14-27.

31- J. Feng, S. Megerian and M. Potkonjak, "Model Based Calibration for Sensor Networks", Proc. of IEEE Sensors, vol. 2, Oct. 2003, pp. 737-742.

32- V. Bychkovskiy, S. Megerian, D. Estrin, and M. Potknojak, "A Collaborative Approach to In place Sensor Calibration", Proc. 2nd International Workshop Information Processing in Sensor Networks (IPSN'03), Apr. 2003, pp. 301-316.

33- J. Polastre, R. Szewczyk and D. Culler, "Telos: enabling ultra-low power wireless research", Proc. 4th International Symp. Information Processing in

Sensor Networks (IPSN'05),Apr. 2005, pp. 364 – 369.

34- M.K. Jain, "Wireless Sensor Networks: Security Issues and Challenges", International Journal of Computer and Information Technology, vol. 2, no. 1, 2011, pp. 62-67.

35- Ullah S., Higgins H., Braem B., Latre B., Blondia C., Moerman I., Saleem S., Rahman Z., Kwak K.S. A comprehensive survey of wireless body area networks. J. Med. Syst. 2012;36:1065–1094.

36- Quwaider M., Biswas S. On-Body Packet Routing Algorithms for Body Sensor Networks. Proceedings of 1st International Conference on Networks and Communications; Chennai, India. 27–29 December 2009; pp. 171–177.

37- Kandris D., Tsioumas P., Tzes A., Nikolakopoulos G., Vergados D.D. Power conservation through energy efficient routing in wireless sensor networks. Sensors. 2009;9:7320–7342.

38- Quwaider M., Biswas S. Probabilistic Routing in On-Body Sensor Networks with Postural Disconnections. Proceedings of the 7th ACM International Symposium on Mobility Management and Wireless Access; Tenerife, Canary Islands, Spain. 27–30 October 2009; pp. 149–158.

39- Djenouri D., Balasingham I. New QoS and Geographical Routing in Wireless Biomedical Sensor Networks. Proceedings of 6th International Conference on Broadband Communications, Networks, and Systems; Madrid, Spain. 14–16 September 2009; pp. 1–8.

40- Tang Q., Tummala N., Gupta S.K., Schwiebert L. TARA: Thermal-Aware Routing Algorithm for Implanted Sensor Networks. Proceedingsof 1st IEEE International Conference Distributed Computing in Sensor Systems; Marina del Rey, CA, USA. 30 June–1 July 2005; pp. 206–217.

41- Sayrafian-Pour K., Yang W.B., Hagedorn J., Terrill J., Yazdandoost K.Y. A Statistical Path Loss Model for Medical Implant Communication Channels. Proceedings of IEEE 20th International Symposium on Personal, Indoor and Mobile Radio Communications; Tokyo, Japan. 13–16 September 2009; pp. 2995–2999.

42- Lee Y.S., Lee H.J., Alasaarela E. Mutual Authentication in Wireless Body Sensor Networks (WBSN) Based on Physical Unclonable Function (PUF). Proceedingsof 9th International Wireless Communications and Mobile Computing Conference (IWCMC); Sardinia, Italy. 1–5 July 2013; pp. 1314–1318.

43- Movassaghi S., Abolhasan M., Lipman J. A review of routing protocols in wireless body area networks. J. Netw. 2013;8:559–575.

44- Vikramsingh R. Parihar, Akesh Y. Tonge, Heartbeat and Temperature Monitoring System for Remote Patients using Arduino, *Vol-4, Issue-5, May- 2017.*

45- C. K. Das, M. W. Alam, A WIRELESS HEARTBEAT AND TEMPERATURE MONITORING SYSTEM FOR REMOTE PATIENTS, 1-3 May 2014, Chittagong, Bangladesh

46- Bandana Mallick1 Ajit Kumar Patro2, HEART RATE MONITORING SYSTEM USING FINGER TIP THROUGH ARDUINO AND PROCESSING SOFTWARE, *Volume 5, Issue 1, January 2016*

47- Sachin Singh and Netaji Gandhi.N, "Pattern analysis of different ECG signal using Pan-Tompkin's algorithm", International Journal of Computer Science and Engineering (IJCSE), Vol. 02, No. 07, 2010.

48- Nagendra H, S. Mukherjee, and Vinod Kumar, "Application of Wavelet Techniques in ECG Signal Processing: An Overview", International Journal of Engineering Science and Technology (IJEST), Vol. 3, N0. 1, 2011.

49- Bronzino, J.D., the Biomedical Engineering Handbook. CRC Press, Inc., 1995.

50- S. Carmel and A. J. Macy, "Physiological signal processing laboratory for biomedical engineering education," in Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005. 27th Annual International Conference of the, 2006, pp. 859-862.

51- Provaznik, Ivo, Adaptive Systems in ECG Processing. Ph.D Dissertation, Technical University of Brno, Czechoslovakia, 1995.

52- C.-M. Chang, et al., "Voltage-mode notch, lowpass and bandpass filter using current-feedback amplifiers," Electronics Letters, vol. 30,1994, pp. 2022-2023.

53- Simmers, Louise. Diversified Health Occupations. 2nd Edition, Canada: Delmar, 1988:150-151.

54- M. Sruthi and B. R. Kavitha, "A Survey on IoT Platform", International Journal of Scientific Research and Modern Education (IJSRME), ISSN(online): 2455-5630, Vol. I, Issue I, 2016.

55- www.thingspeak.com

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