# The Evolution of a μController Autonomous Compact System for Biomeasurements Logging via WSN

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*Abstract:* - This thorough investigation has been made on how to deliver cost-effective emergency services and yet, they still remain a challenge of pivotal importance for the healthcare industry. This project displays the practicability of flexible exploitation, of equipment to notify others when patient-user needs an emergency interference. In regard to factors that mediate inefficiency, premature discernment of emergent heart problems can allow medical interventions to reduce the impact and severity of heart-related incidents to users. This equipment combines technologies of digital cellular communication with data transmission via a Wireless Sensor Network. It unifies software and hardware engineering for heart monitoring with respect to human body and environmental temperature at a low cost and ease to use at home. Herein, we describe an ascendable emergency medical response system that unites the efficient data collection of a pulse and two temperature sensors (environmental and body) with internet data transmission plus distance monitoring data with the flexibility and interoperability of GSM / GPS / Wireless Sensor Network service architecture with no need of suppliers. Worth mentioning is that users significantly ameliorate their insecurity and such device has a tremendous impact on their everyday activities.

*Key-Words:* - Emergency Medical Response, Heart Rate and Temperature Signs, GSM, GPS, Wireless Sensor Network (WSN)

## 1 Introduction

The medical monitor system is an integrated system which combines computer technology, communication technology, information technology and medical technology. However, most constrained for clinical purpose, the equipment cannot be used for a real-time health monitor when we are in office or at home. Therefore, the acute symptoms of the heart system diseases cannot be possibly identified at the first time, resulting in a high risk [1]. Medical alarm devices are beginning to become more and more popular because they provide feeling of safety to the user in combination with the practicality they offer to proactively detect diseases or abnormalities to the human body function and react reactively take measurements. However they are mostly preferred by senior citizens since they lack the ability to immediately respond to unwanted situations. The specific devices are mostly miniaturized products. They usually have the shape of a watch if found on the wrist, or a pendant on the neck [2]. Conventional devices when in need combine the pushing of a button, usually found on a bracelet, with the notification of a service supplier, who, in turn, is going to inform the police or relative of interest. Hence, time is wasted and the cost is higher since the interfering supplier is essential and necessary. Delay and failure to activate a response and establish communication with the service supplier continues to remain a challenge for healthcare industry [3].

The innovation of the device of the project presented here is found at the installation of sensing equipment to proactively detect undesirable function. The difference between the conventional medical devices and the gear-technology presented at this paper is at the interferers and the data transmission. No service supplier is needed and the person getting activated at moments of need is the relative [4]. Hundreds of hours and funds are spent to actually achieve monitoring of a patient from the comfort of his home. In Ref [5] a continuous distant monitoring of sleep disorders with an innovative cost-effective integrated system for respiration is presented. The system is based on the creation of a wireless sensor network and low power circuits. Similarly, in Ref [6] the capability to measure and transmit patient's arterial blood-oxygen saturation (SpO2) level and heart rate (HR) is noted. The patient can achieve medical assistance of a chronic condition, or can be supervised during recovery from an acute event or surgical procedure. A huge variety of sensor can be used in several ways depending on their necessity to patients and their needs. Likewise, Ref [7] proposes eMAS (embedded Medical Advisory System) . It is well articulated with the MCMD (Mobile Cardiovascular Monitoring Device) and provides hierarchical medical advices for home users. It greatly promotes the acceptance of cardiovascular monitoring devices, based on hemodynamic analysis of sphygmogram, in home healthcare. Benefited from the advance of embedded systems it is feasible to implement the novel cardiovascular monitoring device in a self-contained mobile platform, which provides higher computing performance and more powerful communicating ability [7]. In this project, the motivation of study arises from the need to trace people who need assistance. This gear is a well designed wrist cuff for the elderly or people who need help and attention and combines the accuracy of sensing systems with the quick response of this technology. It consists of a medical aspect where reaching the phone or calling for help is not possible. So far, this user-friendly and low-cost gear is safe for children, adults and the elderly. It refers to people who need help such as a situation of heart diseases or Alzheimer and live alone. It is particularly meaningful to patients of cardiovascular and cerebrovascular disease, as myocardial infarction and cerebral hemorrhage are high risk diseases required immediate care if emergency arises. As to the above patients, continuous monitor of heartbeat or pulse is very necessary. Immediate alarm is extreme important to save lives [1].This study will also be assisted by up to date technology like GPS location of the patient. In addition, data taken from the microprocessor at the bracelet is transmitted through wireless network via WSN protocol, to the doctor in interest. Specifically, txt files are transformed either in Microsoft Office Excel graphs/ plots or Labview graphics depending on the user's software knowledge [4]. Sensing systems for body and environment temperature are used. Their effect on heart rate is demonstrated and monitored. Furthermore, numerous diseases have fever as one of the early symptoms. Sensors can distinguish the divergence at the normal heart rates and temperature signs and respond accordingly. An emergency medical response in combination with the sensor signs is presented. This is an attempt to make the step beyond of what is already implemented nowadays, in other words, this system adopts today's technology and develops it in order to make people's -who need assistance- everyday life easier and safer.

## 2 Construction and Methodology

### 2.1 Materials

This wireless medical emergency response system is composed by the following components that are installed into the bracelet: A GSM module, as in Fig. 1. GSM network plays an important role in wireless clients management and data transmission, and can be applied in the fields of wireless meter reading and monitor systems [8]. A GPS module, as in Fig. 2. GPS can precise locate out of doors [9]. The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites [10]. A total amount of three sensors: a heart rate sensor, as in Fig. 3, and two temperature sensors, one for measuring environmental temperature and the other for body parameters, as in Fig. 4a-4c, with the usage of WSN IEEE 802.15.4 standard for the physical and MAC layers [11].

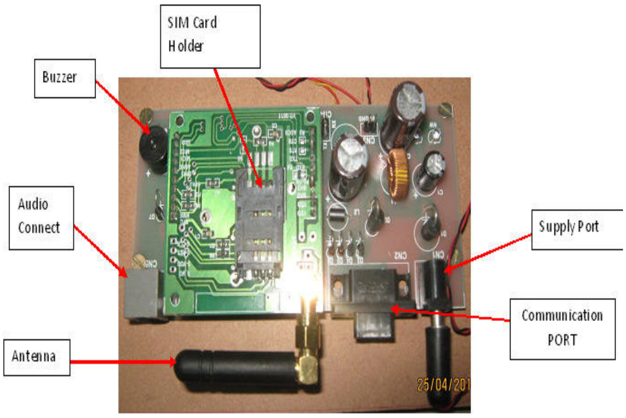


Fig.1: GSM Module


Fig. 2: GPS Module

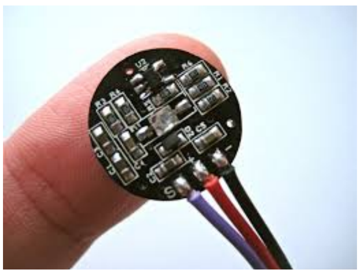

Fig. 3 Heart rate, pulse sensor


Fig. 4a: Environmental Temperature Sensor

Fig. 4b: Body Temperature Sensor for E-Health Platform (Biometric/Medical Applications)

Fig. 4c: Ultra-Thin Body Temperature Sensor

Different to conventional body thermometers, as in Fig 4b, in Fig. 4c a flexible thermometer that adheres to the skin has been developed at the University of Illinois. The sensor, which is only as thick as half the width of a human hair, is incredibly sensitive and can measure temperatures with accuracy up to thousandths of a degree. Moreover, the eZ430RF2500 module has been used. This is a small wireless radio development kit (Texas Instruments) based on the MSP430F2274 microcontroller and CC2500 wireless transceiver. It provides all the necessary hardware and software tools to evaluate the MSP430F2274 microcontroller as in Ref [5] as seen in Fig. 5.

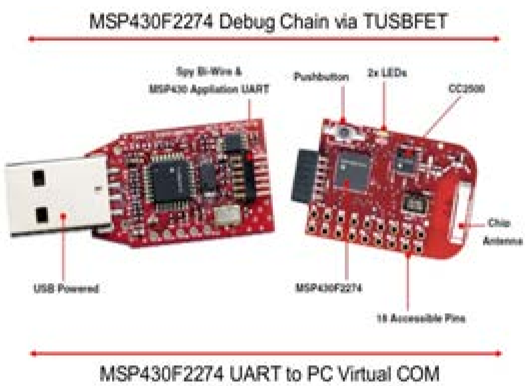


Fig. 5: The eZ430RF2500 module

The Arduino Lilypad using the low-power version of the ATmega168 microcontroller has turned out to be an interesting choice for the specific project; since it is a very small (a circle approximately 50mm (2") in diameter. The board itself is 0.8mm (1/32") thick (approximately 3mm (1/8") where electronics are attached) microcontroller board designed for wearables and e-textiles, as seen in Fig. 6.

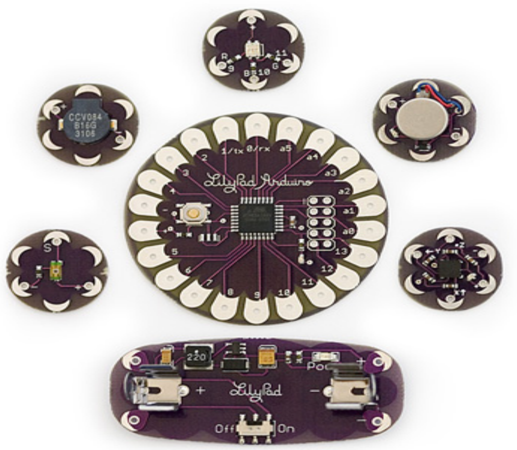

Fig. 6: Lilypad Arduino

In contrast, the eZ430RF2500 module is an efficient solar energy harvesting module, allows battery-less operation, and works in low ambient light. In addition, it is highly integrated; an ultra-low-power MSP430 MCU with 16-MHz performance and it has two green and red LEDs for visual feedback to the patient.

## 2.2 Sensors

The gear is a combination of three different sensors: a heart rate sensor, an environmental temperature sensor and a body thermometer. Temperature directly affects the heart rate condition of the patient; therefore it had to be considered strictly. The Pulse Sensor is a well-designed plug-and-play heart-rate sensor which is placed in the inside part of the wrist and allows viewing the heartbeat waveform and checking the heart rate, as seen in Fig. 7.

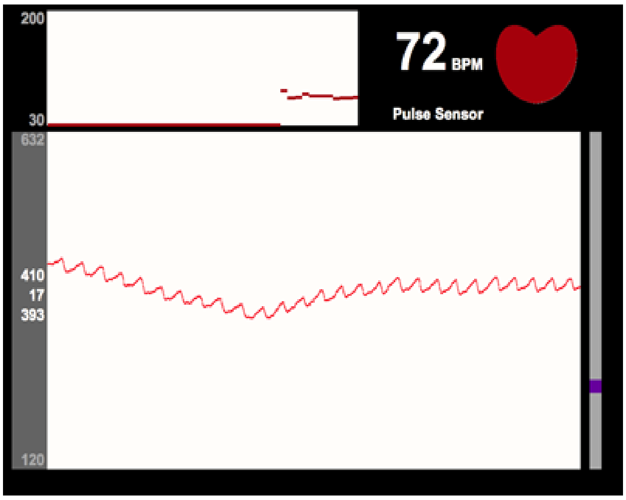


Fig. 7: Heart Rate Sensor Simulation

Ref [12] introduces a novel wearable sensor in intelligent clothing for human body temperature measurement called FBG. The method noted is the law of energy conservation of the human body, which is considered in determining heat transfer between the body and its clothing. This receiver can store information, and then indicate it on the mobile phone, family personal computer or wrist monitors, in order to monitor the important life characteristics of certain person, issuing a warning signal in time. For more accuracy, high-precision negative temperature coefficient (NTC) thermistors, precision amplifiers, can be used and actually perform thorough calibration, reaching a temperature accuracy of up to 0.02◦C in the temperature range 16-42 ◦C. The system is designed to be unobtrusively worn by patients in their home environments and includes real-time feedback to a doctor's monitoring unit, so that the medical staff can continuously monitor the correctness of the collected results and guarantee the health of the patient, as in [13]. In Fig. 8-9 some test results of the body thermometer TMP 006 evaluation module are shown. The end application is external body temperature measurement, so extremely low noise is critical.

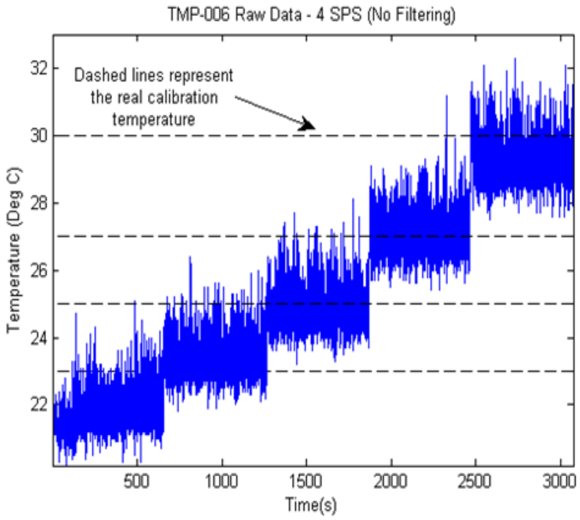


Fig. 8: The response curve of the TMP 006 when going through cycle 23-25-27-30-33 degrees C

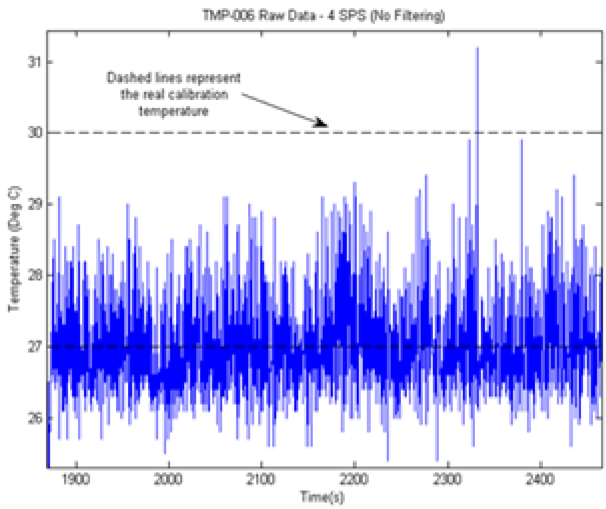


Fig.9: zoomed in on noise at 30 degrees C step

### 2.3 Battery Performance

This is fairly obvious for anybody worn device (BWD). As the presented gear is focused mainly on human in need, the constant recharging of the battery is a serious challenge. However, maximizing battery life requires system designers to develop an understanding of the capabilities and limitations of the batteries that power such systems, and to incorporate battery considerations into the system design process [14]. Rechargeable battery technology is mature and of high energy density, but it requires a dedicated circuit support, at mean time it costs high, while times of charge and discharge are limit; super capacitors have a virtually unlimited charge and discharge capacity and a higher power capacity. But due to a larger leakage current, it cannot be used for long-term storage of energy [15]. There are several types of battery, such as Nickel Cadmium, Nickel Metal-Hydride, Lithium Ion, Reusable Alkaline, and Lithium Polymer. In this project, we prefer Lithium Polymer to the other types, because this emerging technology enables ultra thin batteries (less than 1 mm thickness). Additionally, they are expected to improve over current lithium ion technology in terms of energy density and safety. Longer lifetimes have made them the most popular battery choice for notebooks, PDAs, and cellular phones. However, these batteries are currently expensive to manufacture, and face challenges in internal thermal management [16]. Nevertheless, alternative sources of energy are under review and the results are encouraging. [17] Presents ultra capacitor technology working on improved activated carbons or devices where one electrode functions as a battery and the other as an ultra capacitor. A sheet of silica is covered with a nanometer-thick layer of an iron catalyst. The sheet is placed in a vacuum, heated to 650 ºC, and exposed to a thin hydrocarbon gas, perhaps ethanol or acetylene. The heat causes the iron to form tiny droplets, which steal carbon molecules from the gas. The carbon molecules then begin to self-assemble into tubes, which grow upward from each of the droplets. An advantage of nanotubes over activated carbon is that their structure makes them less chemically reactive, so they can operate at a higher voltage. And certain types of nanotubes, depending on their geometry, can be excellent conductors—which means they can supply more power than ultra capacitors outfitted with activated carbon [17].

### 2.4 Wireless Sensor Network (WSN)

Wireless sensor networking research has been mainly focused on internal wireless sensor network issues such as MAC and routing protocols, energy saving, HW design and to some extent on the architecture of gateways that connect a wireless sensor network with the rest of the world [18]. Network topology is the first step for designing and setting up a sensor network, it lays the foundation for other protocol implementation. A desirable topology will improve the efficiency of routing and MAC protocol, besides it provides the basis for data fusion, time synchronization and object location [19]. Simulation results indicate that the average number of hops will decrease if some of the edges are added into the network to form network shortcut. The overall average path length will shorten accordingly. Shortcuts can be added to the network, and the average path length will decrease rapidly. This is quite useful to saving energy for network communication [19]. Each sensor network is a sensor information provider that offers specific sensor information defined by the type of available sensors and their spatial and temporal conditions to the interested users [18]. In the specific case, the sensors that are of interest measure temperature and heart pulses. However, the nodes are the three relatives, the sensors and the doctor. Ref [20] suggests an inter-connective attestation protocol for sensor node suitable for wireless sensor network. This protocol is able to earlier detect a node that was damaged through neighbour node under a sensor network environment without a reliable sensor node. This protocol is for safe authentication for a sensor node. A sensor network has a limited computing and communication resource. In order to overcome this barrier, collaboration with surrounding nodes is required. In other words, information sharing between hierarchies is required rather than a hierarchical approach. A sensor network generally consists of a large number of sensor nodes for exact sensing and extendibility of sensing areas [20].

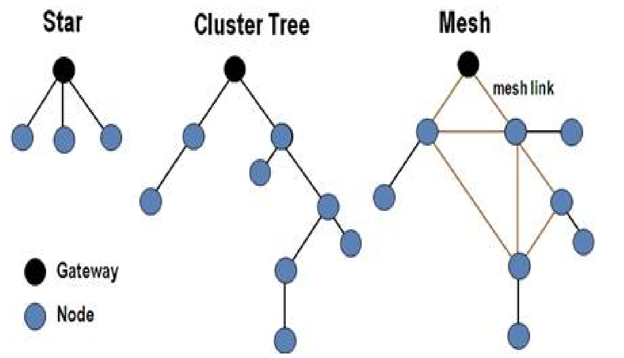


Fig. 10: Types of Networks

Mesh type of network, as in Fig. 10, therefore WSN, is the most preferable since it provides path shortcuts. Shortcuts lead to a less energy consuming system.

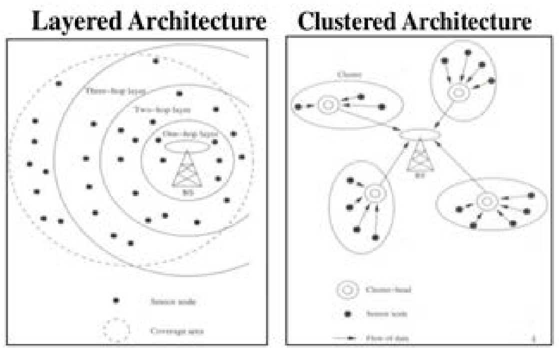


Fig.11: The two types of WSN Architecture

In the applications of wireless sensor network, energy supply is a key factor restricting the performance and lifetime of wireless sensor network [21]. There are two aspects to improve the using value of the network, which are energy supply and energy consumption. Currently more energy consumption issues for wireless sensor network node were studied, mainly to solve the problem of low-power optimized circuit design, communication protocols and operating modes. But as to change the situation of poor energy fundamentally, it is necessary to consider the research of continuity of energy. Energy harvesting technology is to obtain and convert environmental energy such as light, heat, wind and mechanical (pressure or vibration) energy into electrical energy [15]. The rapid development of wireless sensor networks in environmental monitoring, structural health monitoring and many other fields has broad application prospects, but energy self-sufficiency is the main bottleneck of these applications. With the application environment of WSN node be fully considered, a variety of energy harvesting technology are combined to provide a steady energy supply for nodes. In this way, normal operation of nodes can be ensured and the network lifetime can be extended subsequently [15].

## 2.5 Data Rate

Data Rate is the speed with which data can be transmitted from one device to another. Data rates are often measured in megabits (million bits) or megabytes (million bytes) per second. These are usually abbreviated as Mbps and MBps, respectively. Increases in data rate have to be paid for, either in increased power (which in radiated terms may not be possible) or decreased range or decreased interference rejection, as well as in terms of bandwidth and/or signal to noise network requirements [22]. The use of mm wave bands has attractions in terms of small antenna size, and where the development of technology allows the use of such spectrum with reasonable power level requirements. However, mitigation techniques must be designed into any successful radio system. Ultra Wide Band (UWB) technology has many advantages claimed for it, including high data rate, low interference potentiality [22]. The key advantages provided by the UWB technology, such as low power consumption of UWB transmitters, high data-rate capability, small form factor, and immunity against multipath interference [4], provide a significant edge over the existing narrowband technologies such as Medical Implant Communication Service (MICS) [23], Bluetooth [24], [25]. When the patient information comes in, the mobile communication device will begin to process the information properly. For better data rate we find Ref [26] where a new adaptive rate selection algorithm for high data rate wireless packet data networks is described. The algorithm employs a set of thresholds to which the measured pilot Ec/Nt is compared for the selection of the data rate to be requested. The algorithm maintains a set of "effective" throughput values for each data set option and at each decision point the data rate with highest throughput is selected to maintain a high throughput. An extensive investigation on capacity and data rates on networks is noted in [27].

## 3 System integration

When emergency occurs, the system will remind automatically the relatives of the patient, which, in turn is designed to take immediate action as soon as possible especially when the reminding includes emergent treatment instructions. More specifically, the user-patient informs, by pushing the only button on the bracelet, three relatives by text messages. The content of the message is a phrase (for example «HELP») and the coordinates of the patient's location (using GPS) are transformed into street addresses. Those are sent to the relative in response, who, in turn, is obliged to use/ carry a Smartphone or a PDA device and the data from sensor to the doctor's PC. Thanks to the wide coverage of GSM, the patient can be well under the protection as long as he/she is within the coverage [1]. There are many applications already designed for this transformation task. The main operation procedure includes many scenarios. If the button is pressed accidentally then a buzzer is set on. The mechanism gives the ability to the user to press it again, so that the buzzer is turned off, within 10 seconds. The microcontroller is receiving data continuously by a plug-and-play heart-rate sensor; sensor details and characteristics are provided in the following chapter. In case of abnormal heart rate (heart rate > 120 or heart <40), the module of the button is pushed simultaneously with the activation of the buzzer. If ten seconds have passed, without the repressing of the button, the procedure for the messages begins [4]. In contrast to Ref [28], where the Microcontroller (μC) is generating the frequency of red and infrared wavelength. The heart beat sensor on the Pulse Oximetry **(**PO) reflectance calculates the heart rate (HR) and transmits to the μC. The controller receives the details from the reflected waves and displays the HR in the Liquid Crystal Display (LCD). This data is also stored in the personal computer (PC). However, external temperature affects the heart rate of the patient and should be regarded as well. Internal temperature is noticed, too. Therefore, in case that the temperature is less than 5.5 ºC, and the heart rate is found to be less than 40 (( temp< 5.5) AND ( hr < 40)) then the operation will not take place since it is a considered to be a normal body activity [29]. On the other hand, if the external temperature exceeds the 40.3 Celsius degrees, and the heart beats are found more than 120 ((temp>40.3) AND ( hr> 120)) the activity will be assumed regular and no reaction will happen from the device [30]. The data is sent to the doctor of the patient. The receiving device may be a computer with independent IP address and public net access, or a computer which has wireless network adaptor with SIM chip embedded. The procedure is noted at Fig. 12 and Fig. 13. With a view to give immediate aid to the patient in danger, the acquisition is necessary for positioning information, compared with the uninterrupted acquisition, such information acquisition may be performed regularly, meanwhile, such information is not acquired and sent out by mobile communication device itself, instead, it is detected and acquired based on GSM system automatically. When emergency occurs, the central processing system sends inquiring requirement to the GSM network and latest positioning data to the alarm system for a higher efficiency [1].

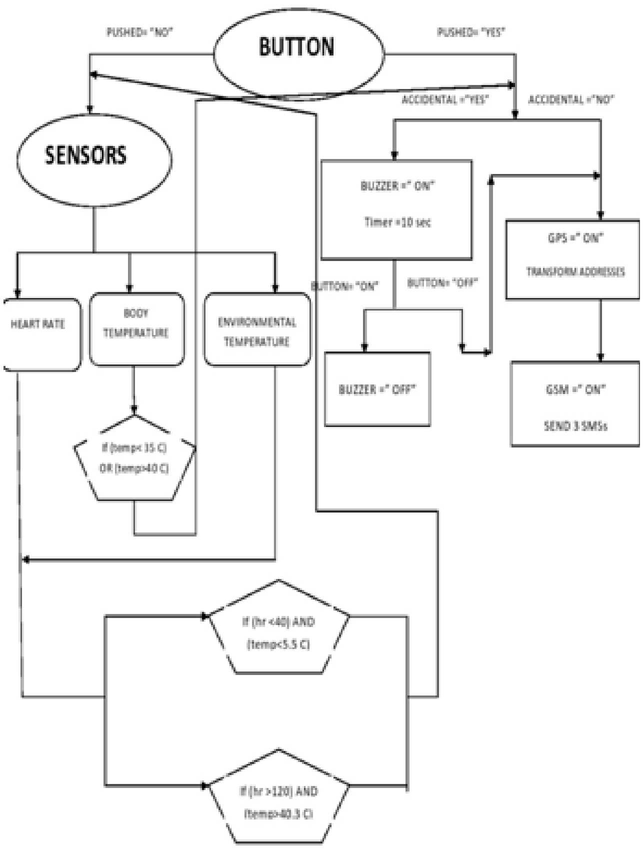


Fig.12: Presented gear's block diagram

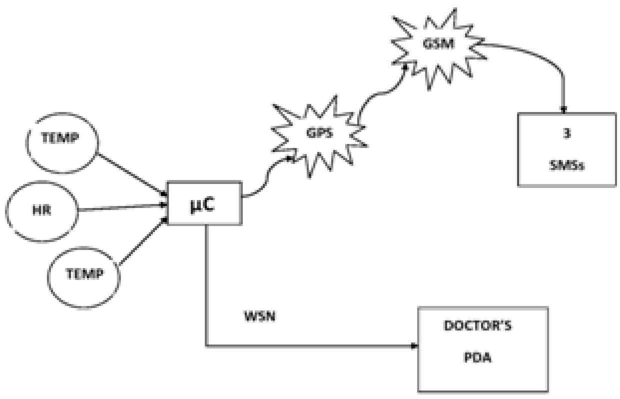


Fig.13: The procedure

# 4 Conclusion

The necessity for the patients to keep track on their progress, especially after a surgery, or feel safe while being at home away from other human interaction, in addition, to the concern of the relatives for their beloved ones is our motivation to study and create such a gear. The mechanism allows people to be found, if lost, especially people who have Alzheimer and live alone. On the other hand, people with heart diseases or panic crisis will benefit as well [31]. The presented project is a system which can either transmit real-time data taken from the sensors on the bracelet, or get active just in the moment of need. The programming regarding the two procedures depends on the condition of the patient and whether a 24 hour monitoring is requisite or not. Text messages are sent to relatives with a word (i.e. "HELP") along with GPS coordinates transformed into street addresses. Furthermore, in case that someone does not have the ability to push the button, a heart rate sensor activates the microprocessor and a buzzer, if heart rates are abnormal. If not, the beeper turns off when the button is pressed [4]. However, concerning that external temperature may cause divergence at the results taken from the heart sensor; an environmental temperature sensor had to be involved. The body thermometer is one step beyond, since it can activate the function of the bracelet regardless of other signs at the patient. Therefore, diseases related to high body temperature can be proactively detected and treated respectfully. It has to be mentioned, that a bracelet is all the user has put on. Likewise in Ref [32] where an alarm message is sent from central station to patient's family, or doctors via GPRS. On the one hand, it can reduce time for patient's relief, and on the other hand it can help doctors grasp more comprehensive condition of the patient and get support from a large hospital doctors. As a whole, this can improve the success rate of rescue greatly. Obviously, this process is unable to complete without establishing a linkage mechanism between medical institutions, patients' family and other social resources. The focus may be on the elderly, because they are the most in need, but adults or even children can use this gear. If a child is left alone on the streets or in danger the bracelet, or even get a cold it will activate the system via the body thermometer, and it can actually be of much help. This gear combined with Wireless Sensor Network architecture offer a unique system for EMS.

# 5 Future Work

The preliminary results of the attempt suggest that the gear described herein is sufficiently robust and scalable to meet the needs of our changing world. On the one hand, this project presents an efficient, flexible and low-cost device but on the other hand improvements such as an LCD monitor indicating warnings for pills that the patient should take instantly can be implemented. There is space for adding extra elements (for example body humidity sensors or even ECG) thanks to miniature technology improvements. RFID technology has some useful possible applications in areas such as secure patient identification for drug and treatment application, too [22]. In respect to the power efficiency, the Bluetooth technology helps to reduce the power consumption and thus, information acquisition and transmission can last a longer time [1]. In addition, the alarm system can also be designed to improve the resource commitment. Two or more patients may need first aid, and then the system should commit proper resource including the doctors, ambulance, if any, providing every patient with efficient treatment. The alarm system should be designed to take care of the patient and meanwhile, it should not be so sensitive that leads to inappropriate response. Therefore, artificial intelligence can be used to analyze the acquired information of the individual patient which helps to take proper treatment measures [1]. Furthermore, Wi-Fi can replace operation such as the wireless sensor network between the patient and the doctor. Wi-Fi direct, as described in Fig.14, Ref [33] has investigated it on real-time data transmission system. They have evaluated the throughput performance of Wi-Fi Direct system using a test bed and compare with the conventional Wi-Fi system. In case of Wi-Fi Direct, they could transfer high-quality video data more reliably. Therefore, Wi-Fi Direct was proven to be more adequate for the wireless medical equipments transmitting large real-time traffic.

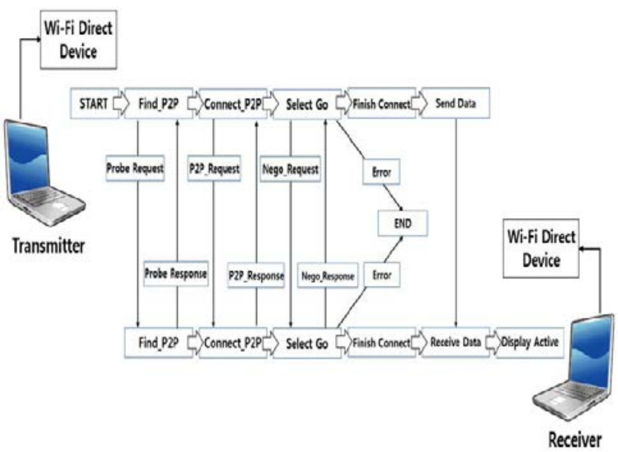


Fig.14: Real time data transmission system using Wi-Fi Direct.

They experimentally evaluated the throughput of two communication methods using Wi-Fi Direct and existing Wi-Fi involving access points (AP) relaying for medical equipments. As show in Fig. 11, two laptops had been used for measuring the throughput. For medical image data with M-JPEC video compression, minimum required data-rate is about 1 megabyte per second (MBps) as using Wi-Fi. On the other hand, Wi-Fi Direct can provide 2.72MBps on average while 1.98MBps and 2.12MBps were available with the probability 95% and 99%, respectively. As the experimental results, Wi-Fi Direct data transmission is more reliable than existing Wi- They experimentally evaluated the throughput of two communication methods using Wi-Fi Direct and existing Wi-Fi involving access points (AP) relaying for medical equipments. As show in Fig. 11, two laptops had been used for measuring the throughput. For medical image data with M-JPEC video compression, minimum required data-rate is about 1 megabyte per second (MBps) as using Wi-Fi. On the other hand, Wi-Fi Direct can provide 2.72MBps on average while 1.98MBps and 2.12MBps were available with the probability 95% and 99%, respectively. As the experimental results, Wi-Fi Direct data transmission is more reliable than existing Wi-Fi medical device communication [33]. Therefore, Wi-Fi Direct can be more reliable towards conventional methods of WSN where noise may affect the signals sent. Ref [34] combines UWB with an impulse radio system which transmits data by means of short pulses .Impulse Radio Ultra Wide Band (IR-UWB) has emerged as an attractive wireless technology for biomedical data monitoring in recent years. They report a complete wearable sensor node solution and incorporate unique physical layer properties of UWB into the operation of the sensor node. The UWB-WBAN sensor node uses IR-UWB for data transmission from sensor nodes to the coordinator node (up-link) and a narrowband link to receive control messages from the coordinator node to sensor nodes (down-link). This unique technique provides the means of achieving low-power consuming sensor nodes with high data-rate capability. A complete communication platform including sensor nodes, coordinator nodes, and interfacing computer software has successfully been implemented and evaluated for WBAN applications. The sensor nodes are fully integrated and present a wearable solution for WBAN applications, as seen in Fig. 15, [34].

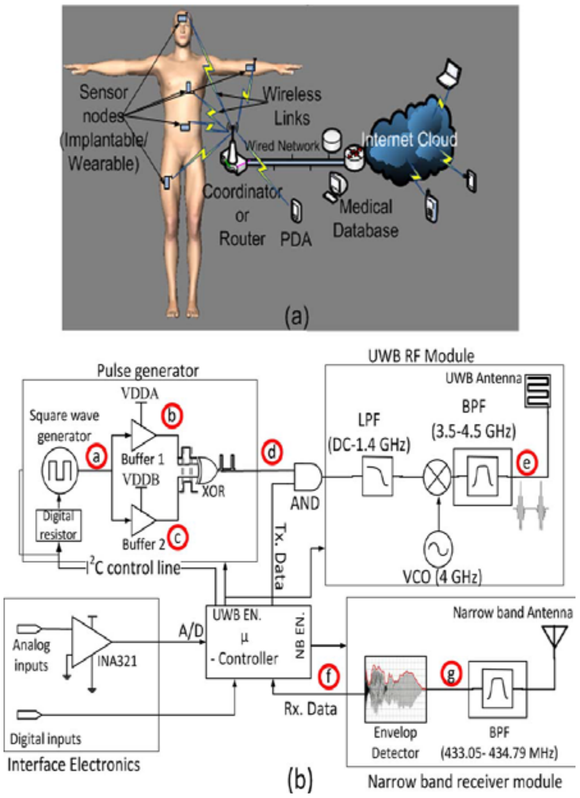


Fig. 15: (a) WBAN with multiple sensor nodes. (b) Block diagram of the dual band sensor node.

Similarly, the reported gear can use the UWB radio technology for its advantages.

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