# KAUNAS UNIVERSITY OF TECHNOLOGY

## FACULTY OF ELECTRICAL AND ELECTRONICS ENGINEERING

**Dwivedi Pawan Kumar**

# INVESTIGATION OF THE CHARACTERISTICS OF WIRELESS BODY AREA NETWORKS

Master's Degree Final Project

**Supervisor**
Prof. dr. Liudas Mažeika

**KAUNAS, 2017**

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### DEPARTMENT OF TELECOMMUNICATIONS

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Master’s Degree Final Project

**Smart Telecommunications Technology (code 612H64001)**

**Supervisor**
(signature) Prof. dr. Liudas Mažeika
(date)
**Supervisor**
(signature) Assoc.prof. dr. Lina Narbutaitė
(date)

**Reviewer**
(signature)
(date)
**Project made by**
(signature) Dwivedi Pawan Kumar
(date)

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**KAUNAS UNIVERSITY OF TECHNOLOGY**
Faculty of Electrical and Electronics Engineering
(Faculty)
Dwivedi Pawan Kumar
(Student's name, surname)
*Smart Telecommunications Technology (code 621H64001)*
(Title and code of study programme)

" Investigation of the characteristics of wireless body area networks "

# DECLARATION OF ACADEMIC INTEGRITY

26 May 2017
Kaunas

I confirm that the final project of mine, **Dwivedi Pawan Kumar**, on the subject "Investigation of the characteristics of wireless body area networks" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarized from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by law) have been paid to anyone for any contribution to this thesis.

I fully and completely understand that any discovery of any manifestations/case/facts of dishonesty inevitably results in me incurring a penalty according to the procedure(s) effective at Kaunas University of Technology.

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## SUMMARY

Nowadays, remote patient health monitoring using wireless technology plays very important role in our society. Wireless technology helps monitoring of physiological parameters like body temperature, heart rate, respiration, blood pressure and ECG. Wireless sensor nodes can be either wearable or implanted into a human body. Nodes communicate with each other using certain short-range wireless technology: Bluetooth, ZigBee etc. Therefore, the first focus of the work presented in this thesis are the experimental evaluation of the signal propagation between sensor and sink in accordance with sensor position on human body and transmission environment. According these data define the best working performance zones for our system. The other aspect, that is very important for wireless body area network(WBAN) networks sensor lifetime. Lifetime extension is a critical issue for WBAN with limited battery life. Therefore, is presented the development of the model for simulation of performance of the sensor network under various conditions is presented in this thesis. The definition of wireless sensor nodes energy model for balancing energy is too. Simulation results show how maximum slaves can be connected to one master at the same time for transmission of information. The wide diffusion of healthcare monitoring systems allows continuous patients to be remotely monitored continuously and diagnosed by doctors. Because the most of patent using smartphone they need the application for monitoring health sensors. In this thesis, I present the solution to monitor patient health from a remote area. It was developed by an android based mobile application and PC through which the user (doctor/patient) can see the necessary patient’s records information in a chart. These platforms can be customized for individual users and an application-specific set of sensors then seamlessly integrated into a WBAN.

# Content

# Introduction

The rapid advances of Information and Communication Technology (ICT) has empowered the development of several application fields. Wireless Body Area Networks (WBAN) is an examples of ICT system applications used in medical areas. One important aspect of wearable health monitoring devices and WBAN is their wireless connectivity. Several technologies can be considered to provide connectivity: Wi-Fi, Bluetooth for local connectivity, cellular interface (2-5G) for mobile access.

Recent health monitoring system usually consists of the set of multiple sensors which measures different parameters of the patients, such as pulse, blood pressure and ECG etc. The measurements are performed according to advanced defined or adaptive to the patient status time intervals. All acquired data are collected by coordinator device, which later transmits collected data to external sensor network. There are several important problems affecting transmission of the information and performance of this sensor network in general. The first one is that the patient in most cases is moving and this affects the strength of the sensor signals. This leads to the need for application of relay approach that what on other hand leads to the increase of the energy consumption of the sensors and therefore reduction in the life time of the sensor network. This problem can be solved by dynamic clustering and configuring of the sensors based on some optimization algorithms.

Therefore, the ***aim of this thesis*** is to investigate different approaches in the network technologies with corresponding sets of parameters and sensor position on human body and transmission environment. The objective should be achieved by performing analysis of the parameters and characteristics of existing sensor with respect to data transmission, development of the model for simulation of performance of the sensor network under various conditions, investigation of sensor signals using models and experimental measurements. The investigation will lead to determination of efficient configurations and sets parameters of the network.

In order to reach this aim, these ***tasks*** should be solved:

- analysis of the parameters and characteristics of sensor and health applications with respect to data transmission;
- the experimental evaluation of the signal propagation between sensor and sink according to sensor position on human body and transmission environment. According to these data define the best working performance zones for the system;
- development of the model for simulation of performance of the sensor network under various conditions. The definition of wireless sensor nodes energy model for balancing energy;

- the proposal and implementation of an application level algorithm to solve the prototype of WBAN patient health monitoring application for smartphone and PC.

Different methods are used during the research:

- scientific literature review;
- experiment;
- simulation study;
- result analysis with conclusion.

The thesis is organized as follows:

- chapter 1: gives an overview of the related work that has been done in the area and results of the background search, represents the introduction part of the current research, contains the motivation and task description;
- chapter 2: provides an overview of WBANs regarding the communication architectures, and technologies that were used. The description of two main technologies: Bluetooth and ZigBee, WBAN applications, sensors;
- chapter 3: presents the results obtained from the experimental component of this work, using the experimental evaluation scenarios. A series of graphs and Tables are used to demonstrate the results from these experiments, which are commented and discussed;
- chapter 4 presents the proposed architecture of the WBAN model, work flow chart of the proposed system. Using sensor energy resource management model was calculated maximum number of sensor for one master and life time of sensor using 3 cases of the signals transmission between a master and a slave. A series of graphs and Tables are used to demonstrate the results.
- chapter 5 present the solution to monitor patient health from a remote area. Having developed android based mobile application and PC through which the user (doctor/patient) can see the require information in a chart.
- chapter 6 presents the overall conclusion of the work.
- chapter 7 list the references.

# 1 Analysis of recent Developments in WBAN

In scientific and industrial communities, wireless body area networks (WBANs) have been acknowledged as a rising interest by the hopeful prospects across a variety of applications, including remote medical services, sport monitoring, personal entertainments, etc. WBANs are featured as low-power, low data rate, and person-centric wireless communications. They are made of compact computing units working near the human body. WBANs are characteristically suitable for medical monitoring and other biotelemetry applications. There are firm requirements on the power consumption and long-term transmission stability which have raised various trials to WBANs on e.g. the antenna design and the channel characterization. The WBAN system's designs include different frequencies, like the ISM bands at 400 MHz, 900 MHz, and 2.4 GHz [1] – [3], and the ultra-wide band (UWB) [4]. Also, the use of existing short-range communication standards, like Bluetooth and ZigBee/IEEE 802.15.4 at 2.4 GHz, provide a low-cost WBAN solution, has also attracted many studies [5]. The radio waves propagating on the body surface also called on- body propagation, is an essential transmission mechanism in WBANs, either in the collecting and relaying of signals from the body-worn sensors to body-worn data sinks, or in peer-to-peer communications between the sensors. On-body propagation is dominated by the local body scattering, which not only forms a high path loss in a short distance on the body surface, unlike large-scale propagation [3], [4], but also forms a time-variation (fading) of the on-body channels due to the body movements [2], [3]. The time-variation is an unavoidable property of on-body channels because our bodies always move in realistic applications. The difficulty to understand the local body scattering is that the interaction among the transmitter (Tx), receiver (Rx), and the body occurs in a few wavelengths, which will complicate the scattering process and creates different impacts to the on-body channels depending on the channel distribution, the polarization, and the body posture, also the modified antenna Gain when placed near the skin. Therefore, the channel characteristics, e.g. on the fading variance and the Doppler dispersion, reflect the effects of body scattering consistently. Even though complex simulations like finite-difference time domain (FDTD) give an exact and high-solution field description of static on-body propagation as in [6], outspreading such simulations into dynamic cases is so costly and so most of the studies remain on statistical approaches or simplified analytical models. The dynamic on-body channels have been addressed by the IEEE 802.15.6 standardization group [7]. However, the final channel model for on-body applications in [8], is mainly focused on static scenarios. Other studies like [9], [10], were limited by their test-beds and the understanding of the on-body propagation mechanisms, which exclude some critical aspects of the dynamic on-body channels, like the Doppler spectrum and the space-time fading correlation. The WBAN channel modelling activities under the framework of the Special Interest Group E (SIG-E) of the COST 2100 action [11] have been focusing on different aspects of the dynamic on-body channels. The researches cover those featured in IEEE 802.15.6, and fulfil the needs for the design of obliging protocols. Hence, this paper presents a summary of the results on dynamic on-body channel characterization and modelling.

Throughout the world, every day, 160 thousand people turn 60. This is equivalent to 58 million sixtieth birthdays in a year and the number is increasing day by day. In 2012, 810million people, or 11.5 percent, of the global population were older than 59 years. This percentage is expected to grow to 2 billion (and therefore 22 percent of the population) in 2050. Presently the only country with more than 30 percent elderly people (>60 years) is Japan. By 2050, 64 additional countries will reach this percentage [12]. This is due to increase in life span. Due to aging of the world population it will be difficult for the aging population to go to a doctors practice setup for any treatments, due to their physical limitations. A solution is to provide them with an on distance heathcare. Hence, there is a need for new heathcare structures and bigger, better and faster facilities. In today’s world, several health care products are being developed to make life easier for patients and doctors. An example of this is capsule endoscopy which can replace normal endoscopy whereby the intestinal tract is reviewed to search for disorders. Normal endoscopy causes discomfort for the patients, and the whole tract cannot be viewed [13]. By means of latest technologies such as IC Technology, small cameras, and LED techniques, endoscopy pills can be made small enough to be swallowed [13]. Due to this the analysis of diseases in the human tract is made easier. The whole human tract can be analysed by capsule endoscopy, which has advantages such as lower risks and lower hospitalization and resection rates for the patients [14]. The capsule endoscopy is also of great importance for the detection of obscure bleeding, among other diseases, which cannot be observed in the bowel movement and occurs in the small intestine (SI) [15]. Devices such as the endoscopy capsule which transmit data can be considered as part of a body area network (BAN). BAN is a network concept to set up connections around a human who carries communication devices. This network consists of a devices or sensors which interconnect with each other. Three forms of BANs can be distinguished from each other: off body, on-body, and in-body communications [16], [17]. Figure 1 shows a pictorial representation of the different possible communication constellations and the communication areas of BANs. An off-body communication is the communication between a sensor and a device near the body. On-body communication is the communication between devices which are located on the body. The communication usually takes place wirelessly around the body, via the environment (which is the most prominent communication channel) or via creeping waves on the body surface. In-body communication is the communication from a sensor or device which is located within the body to another device in the body or on the surface of the body.

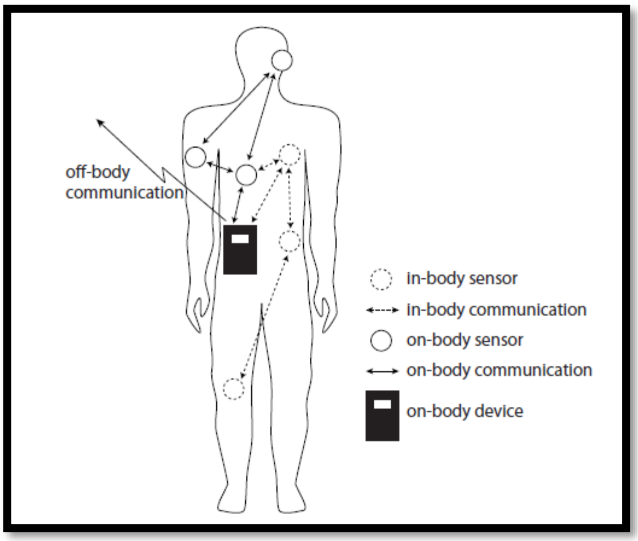


**Figure 1.1. Different possible communication areas of BANs [17]**

A proper interpretation of the measured values is dependent on the localization of sensors. Knowing the location of the capsule and the detected values leads to much better treatment of diseases. Various parts of the human body, such as the complete SI of the tract, could not be reached before using traditional endoscopy. Spinning and backwards movements of the capsule and the filling and emptying cycle of the human tract make it difficult to determine the position of the pill from the taken images [18] – [20]. Therefore, there is a need for an alternative localization method. An example of an existing and commonly used localization system for positioning in free space is the Global Positioning System (GPS). Other systems which are available use radars to determine the ranges of objects to the system. These techniques are well developed and are reliable. Due to the multipath environment, a localization technique for locating persons or devices in a room is challenging. Due to the varying environment and multiple reflections, it is difficult to extract the transmitted signal from the received signals. The human body which acts as a challenging propagation medium due to which the body sensor localization becomes more challenging. The human body is a complex being which has different types of tissue each having their own propagation characteristics. Knowledge of localization techniques and signal propagation in media needs to be coopted to develop an in-body localization method. Hence, this thesis studies radio frequency (RF) propagation inside the human body to gain more insight into the in-body signal propagation. This physical insight is required to estimate the channel properties which are required for later localization steps. The behaviour of RF propagation for different frequency dependent tissue layers for multiple frequencies is analysed.

A layered model is developed by means of which the travel times and attenuations of the propagating signals are studied. In contrast to other research, no simulations or measurements with a" complete" communication system is performed. The results of those simulations or measurements do not give information on the travel time and attenuation which are caused only by the material characteristics. Therefore, there is a demand for an analysis of the in-body to on-body propagation medium to make a step towards affordable and reliable in body applications. The keen interest and demand for the search for low-power, low-data-rate and body-centric wireless communications has led to an advent of a new kind of promising network, called the wireless body area networks (WBANs). A lot of academic and industrial efforts have been taken in this research field. WBANs consist of a set of wearable bio-sensor nodes, which collect or relay physiological and contextual signals profiling the human body activities. Typical applications include real-time monitoring of heart activity, blood pressure, breathing rate, or skin temperature; continuous diagnostics; and remote medical treatment of a patient [21]. It is important to limit the radiated power, the consumption as well as the interference with other sensors and coexistent networks due to the proximity of sensors to one another and to the human body demands. Hence, there is an urgent need for a detailed knowledge of on-body multi-link propagation to properly design relevant systems at the physical and access network layers. Related work: From early measurements, it seems obvious that body movements play an important role in WBAN fading characteristics and should therefore be accounted to develop accurate and reliable channel models. Only few papers characterize the time-variant properties of the channel, most likely owing to technical difficulties for performing measurements, despite the huge number of publications related to body communications. In 2007, the IEEE 802.15 Task Group 6 (TG6) was formed to address specific communication standards for WBANs: the associated on-body channel model [22] known as CM3. In [23], a channel sounder was used for measuring 10 channels configured in a star topology. The lognormal distribution seemed to match best in static scenarios while the Nakagami-m and Weibull distributions showed good potential in moderate to severe fading conditions. This work was extended in [24], [25]. The scenario-dependent behaviour of WBAN propagation was pointed out by authors in [26], and they argued that a single comprehensive channel model would not be suitable to describe the features of each transmission scenario. In addition to IEEE 802.15 TG6, a mixed-parameter distribution [27] and a Nakagami-m distribution [28] were suggested by Cotton et al. for modelling on-body fading statistics. Autoregressive transfer functions are presented as a preliminary analysis of time series in [29]. These measurements can also extract other statistical parameters, including level crossing rate (LCR) and average fade duration (AFD) [30], [31] More recently, the effects of arm waving using a dynamic phantom to mimic human walking and running motions are also depicted. [32] However, the study is focused on off-body single links in the horizontal plane. By contrast, [33] is focused on measuring multi-link cross-correlations in a wireless BAN using ZigBee sensor nodes at 2.4 GHz. While little light is shed on the other channel parameters, the correlation properties are discussed as a function of the on-body sensor locations and the various motion patterns. Correlation levels are in general very low. In [34], multi-link correlations are statistically characterized based on full wave simulations of a voxel model, but no experimental validation is proposed. Finally, the activities of the Special Interest Group E (SIGE) of the COST 2100 action [35] were focusing on different aspects of the dynamic on-body channels. The contributing authors presented a statistical model of about 20 time-variant channels for different scenarios [36]. By applying a sliding time window, a correlated lognormally-distributed large-scale fading was separated from the small-scale fading component. The latter was shown to be Rayleigh distributed depending on the motion mode. Moreover, an analytical model based on a three-cylinder representation was introduced in [37], while Doppler and correlation issues are experimentally characterized in [38]. In both cases, multi-link correlations were found to vary significantly as a function of the motion pattern and the involved nodes.

A lot of literature is available related to WBANs. Mostly extensive attempts have been made to advocate solutions for the issues of the WBANs. Before introducing the IEEE 802.15.6 standard, many researchers have been attracted by the concerns of the structure of WBANs and protocols and mechanisms of the physical layer and MAC sublayer of WBANs. A comprehensive survey on WBANs is provided by the author in [39]. Presently quite a lot of research groups have been focusing on design and implementation of a WBAN. Various wireless technologies have been employed by the researchers in their projects in the field of wireless short-range connectivity, such as the IEEE 802 family of WPANs, WLANs, Bluetooth and ZigBee. Due to major downsides of other WPAN and WLAN solutions the IEEE 802.15.4 [40]/ZigBee system has been the most preferred approach in the prevailing projects before the IEEE 802.15.6 standard is introduced. There are a limited number of projects that employ Bluetooth for implementing the WBAN [41; 42; 43]. A prototype developed by Jovanov and Otto et al. - WBAN based on a multi-tier architecture to handle the communications within the WBAN and between WBANs using off-the shelf wireless sensors such as the Tmote Sky from Sentilla [44]. In [45] a few applications were presented exploiting natural human detection interface based on their own WBAN solution, called WiMoCA. The sensors were characterized by tri-axial integrated MEMS accelerometers that help to detect postures and gestures of the human body. The WiMoCA has been designed to detect both static postures and dynamic postures in everyday life actions. The Bluetooth technology has severe pitfalls which make it inappropriate for WBANs from WBAN perspective. Bluetooth does not support the automatic network formation and the network formation is slow. Transmission on the frequency band is disrupted by the inquiry phase for another Bluetooth devices discovery. The power consumption of Bluetooth is not efficient enough for WBANs [39]. A comprehensive discussion about Bluetooth, performance modelling and analysis of Bluetooth networks has been provided in [46]. Most of the presently prevailing projects of WBANs employ IEEE 802.15.4 standard as the wireless communication technology. IEEE 802.15.4 is more power efficient and has a simpler protocol stack compared to Bluetooth. The authors in [47] provide an extensive performance modelling and interconnections of IEEE 802.15.4. Researchers in Harvard University in CodeBlue and Mercury projects have developed WBANs which employ IEEE 802.15.4. The CodeBlue is a distributed WBAN including a pulse oximeter, two-lead ECG, and a specialized motion-analysis sensor board for sensing and transmitting vital signs and geolocation data using the Tmote Sky platform [48; 49; 50]. Movement and physiological conditions monitoring for motion analysis of patients being treated for neuromotor disorders, such as Parkinson’s Disease, epilepsy, and stroke, Mercury which is wearable, wireless sensor platform for monitoring is used [51]. Ayushman is a ZigBee-based real-time sensor network based on a health monitoring infrastructure in which MicaZ and TelosB motes are employed for implementation [52]. The advanced system includes a wireless ECG, a pulse oximeter, gait monitoring and environment monitoring using off-the-shelf components. The Human++ research project by IMEC-NL marks the realization of miniaturized, intelligent and autonomous wireless sensor nodes for WBANs [53]. This project focuses on developing an IEEE 802.15.4-based wireless network which includes a series of miniature sensor/ actuator nodes. The main aim of such a monitoring system is to obtain, process, store, and picture several physiological parameters, including EEG/ECG/EMG biopotential signals, in an unobtrusive and ambulatory way. The system is created in such a way that it is highly power efficient so that the system can work for 3 months using two AA batteries in series operating in the 2.4 GHz ISM band. This project makes good use of thermal energy scavenging using Thermoelectric Generators (TEG) to increase the system’s lifespan. In the European MobiHealth project a generic WBAN for healthcare and a generic m-health service platform was developed, trialed and evaluated [54]. The WBANs are managed by the MobiHealth Service Platform by installing Bluetooth and ZigBee for ambulant patient monitoring and universal healthcare service. It handles external communications between the BANs and a remote healthcare server using 2.5/3G public wireless networks (GPRS and UMTS). The project targets different applications such as large-scale disaster and emergency system and facility of remote monitoring services to support work and recreation in extreme environments. The MobiHealth BAN continuously monitor vital signs of a patient who is equipped with medical sensors, such as blood pressure, heart rate, activity and ECG. In [55] AlarmNet, which is an assisted-living and residential monitoring network for universal, adaptive healthcare was presented. In this project, an extensible and diverse network middleware was planned which considering the environmental, system, and resident context. MicaZ and Telos Sky motes are employed in the implementation in which the WBAN measures heart rate, pulse oximetry, ECG, and body movement. The authors in [56] proposed a ZigBee-based WBAN platform for developing physical sensor node in relay-time health monitoring. In this project, ZiGW (ZigBee/Internet Gateway) was used for connecting WBAN and Internet. An ECG monitoring system was implemented using the planned method so that the real-time ECG signals can be remotely monitored by physicians and stored in an online ECG database. Other studies in the literature also employ IEEE 802.15.4 for design and implementation of a WBAN [57; 58; 59; 60]. They all conclude that though IEEE 802.15.4 was the most suitable available wireless technology for WBANs the results of the IEEE 802.15.4-based network is rather poor. In [61] there is a comparison between performance of Bluetooth and IEEE 802.15.4 when they are employed for a WBAN. The results show that neither has significant advantage over the other. Before the introduction of the IEEE 802.15.6, standard IEEE 802.15.4 was considered the most suitable physical layer and MAC sublayer protocol for WBANs due to the following reasons; the MAC is designed for low power and short-range communications and short message transmissions. The standard provides combination of TDMA on CSMA/CA for MAC and peer to peer-based communications. However, it does not provide priorities for CSMA MAC mechanism. However, as indicated in the IEEE 802.15.6 standard, none of WPANs including IEEE 802.15.4-based networks meet the medical (proximity to human tissue) and relevant communication regulations for some applications. Also, the combination of reliability, QoS, low power, data rate and non-interference required to broadly address the breadth of body area network applications are not supported. IEEE 802.15.4 supports the data rate of up to 250kb/s which is not sufficient for WBANs. In [62; 63] the IEEE WPAN technologies for medical implant communications have been explored. It goes to show the lack of suitability of WPAN for implementing WBANs because WBAN devices are physically located on the surface or inside of a person’s body which is a loss of environment for the electromagnetic waves. Few studies in the literature are available that have introduced specific MAC protocols for WBANs in addition to the projects which use the WPAN technologies. In [64] a slave master architecture was designed for the communication in the WBAN. This protocol was extended in [65] in which the time is divided into frames. One node based on the Earliest Deadline First Algorithm (EDFA) can access each frame. A MAC protocol is proposed in [66] for a star-networked WBAN employing TDMA to reduce collision and idle listening. H-MAC protocol [67] is a TDMA-based approach for a star-topology WBAN in which the nodes are synchronized by the human heartbeat rhythm. Though these protocols are specifically designed for WBANs they do not support QoS, low power and data rate required for WBANs. In [68] a protocol has been designed for WBANs. The proposed protocol delivers the prospect for switching from an inactive period to an active phase without providing a suitable Quality of Service such frames priorities. In [69] the MAC protocols submitted to IEEE 802.15.6 Task Group by public or private organizations are introduced and analysed to check if they satisfy the requirements of WBANs. In the study fifteen diverse points are considered for comparing the protocols, such as Quality of Service, reliability, topology, scalability, power efficiency, and performance evaluation.

Authors in [73] have presented path loss models for medical implant and communication channels They investigated statistical path loss model in Medical Implant Communication Service (MICS) channels. A work involving the path loss for On-body communications is provided by authors in [76]. In [77], sensor devices and server based architecture for UHC monitoring system is proposed. is given in This architecture gives the introduction of wireless sensor devices and server part. Communication between sensor and server is done via Base Station Transceiver (BST), which is connected to a server PC. Components based system architecture of UHC monitoring is designed in [78], to provide services for the elderly people. This architecture uses a prototype system that monitors location and health status using Bluetooth as WBAN and smart phone with accelerometer as Intelligent Central Node (ICN). This architecture provides accessibility to family members or medical authorities to identify real time position and health status of patients via internet. ZigBee consumes less power than Bluetooth hence it is used for small data rate applications. WBAN architectures using wearable devices are proposed in [79]. One of them is wearable smart shirt, which is based on UHC and activity monitoring. It includes smart shirt with multi-hop sensor network and server PC. All communication between smart shirt and server PC is done via BST. A device with two Process Control Block (PCB) mounted on each other is used in this architecture to reduce the size of integrated wearable sensor node along with Universal Serial Bus (USB) programming board as a separate module. It is needed only when nodes are connected to server PC. Utilization of the energy efficiently is one of the major concerns in the sensor network. For utilizing the energy efficiently an energy efficient algorithm was proposed by Mirak et. al. specially for the problem of target coverage in [80]. For efficient energy utilization, sensors should be arrayed in improved manner. In [81], different sensor placement techniques are applied for analysing the efficiency of sensor network and proposed an algorithm for solving the problem of complete coverage with minimum cost. The performance of network is massively affected by energy. Even anchor placement scenarios and position methodologies are also discussed in [82] for achieving the efficient energy utilization.

The field of HealthCare and telemedicine has been very advanced recently. There is introduction of Wireless Body Sensors, which provide efficient uses of resources. These sensors used in WBAN are lightweight, small, provide ultra-low power and are used for intelligent monitoring. Human vitals, physical activities and actions are continuously monitored. There is increasing demand of UHC systems, due to it less power consumes ability and longer battery lifetime. The demand is completely fulfilled by the system. High data rate communication is achieved by making body sensors compatible with underlying technologies. In this paper, a comprehensive and analytical survey is provided about the standards and devices for WBAN [70-73], [76-79] [83]. Also, there is simulation of In-Body path loss models proposed in [74] using MATLAB. In simulations, four path loss models have been considered; deep tissue implant to implant, near surface implant to implant, deep implant to implant, and near surface implant to implant. Further, simulations on different parameters affecting (i.e., attenuation, phase distortion, RMS delay etc.) communication in On-Body networks has been provided [75].

# 2 WBAN network, applications and sensors

## 2.1 WBAN network structure

A standard WBAN architecture includes a small network (personal) around the body, a gateway (sink) bridging to another network types that can be another node with some routing and data aggregate features, a wide network that can be an Internet or intranet network, and applications with GUI for medical or other healthcare personnel. Figure 2.1 shows this typical WBAN architecture.

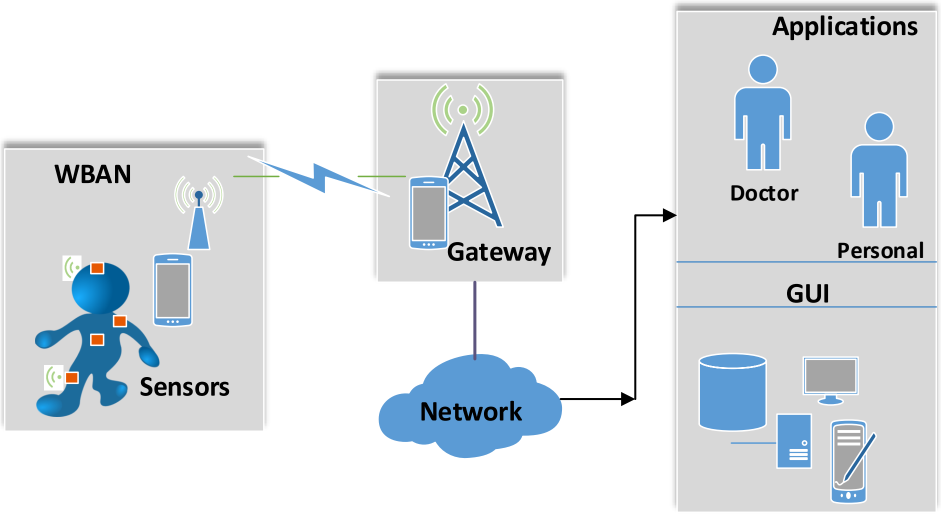


**Figure 2.1 WBAN network structure**

The proposed WBAN for ambulatory health monitoring is contained within a multi-tier telemedicine system. The telemedicine system spans a network comprised of individual health monitoring systems that connect through the Internet to a medical server tier that resides at the top of this hierarchy. The system is not merely a distributed data logger, which would provide great advantage over current systems, but provides distributed data processing and analysis functions. Each tier in the network is intelligent and provides some form of analysis; in some cases, it may be possible for on-the-spot real-time diagnosis of conditions. The top tier, cantered on a medical server, is optimized to service hundreds or thousands of individual users, and encompasses a complex network of interconnected services, medical personnel, and healthcare professionals. Each user wears several sensor nodes that are strategically placed on the body. The nodes are designed to unobtrusively sample vital signs and transfer the relevant data to a personal server through a wireless personal network implemented using ZigBee (802.15.4) or Bluetooth (802.15.1). The personal server, implemented on a home personal computer, handheld computer, smart phone, or residential gateway, controls the WBAN, performs sensor fusion, and preliminary analysis of physiological data. It provides graphical or audio interface to the user, and transfers captured health information to the medical server through the Internet or mobile telephone networks (e.g., GPRS, 3G). The medical server provides a variety of differing functions to WBAN users, medical personnel, and informal caregivers. The medical server stores electronic patient records in a database, provides a high availability daemon for authenticating registered WBAN users and accepting session uploads, summarizes physiological data and automatically analyses the data to verify it is inside or outside acceptable health metrics (heart rate, blood pressure, activity) and identifies known patterns of health risks. It is the responsibility of the medical server to interface the electronic patient records and insert new session data, generate alerts to the physician and emergency health care professionals when abnormal conditions are detected, and provide physician and informal caregiver portals via the Internet for retrieving health summary reports remotely. Integration of the collected data into research databases along with quantitative analysis of conditions and patterns could prove invaluable to researchers trying to link symptoms and diagnoses with historical changes in health status, physiological data, or other parameters (e.g., gender, age, weight).

The personal server, at the second tier, is responsible for interfacing with the medical server via the Internet, interfacing the WBAN sensors and fusing sensor data, and providing an intuitive graphical and/or audio interface to the end user. The personal server application can run on a variety of platforms with a variety of wide area network (WAN) access possibilities for Internet access. The personal server holds patient authentication information and is configured with IP address or domain name of the medical server so that it can access services over the Internet.

For every personal server, a network of intelligent sensor nodes captures various physiological signals of medical interest. Each node is capable of sensing, sampling, processing, and communicating physiological signals. For example, an ECG sensor can be used for monitoring heart activity, an EMG sensor for monitoring muscle activity, an EEG sensor for monitoring brain electrical activity, a blood pressure sensor for monitoring blood pressure, a tilt sensor for monitoring trunk position, a breathing sensor for monitoring respiration, while the motion sensors can be used to discriminate the user’s status and estimate her or his level of activity. Each sensor node receives initialization commands and responds to queries from the personal server. The network nodes continuously collect and process raw information, store them locally, and send processed event notifications to the personal server. The type and nature of a healthcare application will determine the frequency of relevant events (sampling, processing, storing, and communicating).

WBAN may involve different technologies at different levels.

***Zigbee***

ZigBee communication is specially built for control and sensor networks on IEEE 802.15.4 standard for wireless personal area networks (WPANs), and it is the product from ZigBee alliance. This communication standard defines physical and Media Access Control (MAC) layers to handle many devices at low-data rates. These ZigBee’s WPANs operates at 2.4 GHz, 950 MHz, 915 MHz, 868 MHz, 780 MHz, 500 MHz, and 3.1–10.6 GHz frequency bands. The capacity is 250 Kbps at 2.4 GHz, 40 Kbps at 915 MHz, and 20 Kbps at 868 MHz Some devices have an indoor communication range of 50 m, outdoor range of more than 500 m.

The date rate of 250 kbps is best suited for periodic as well as intermediate two-way transmission of data between sensors and controllers.

ZigBee is low-cost and low-powered mesh network widely deployed for controlling and monitoring applications where it covers 10-100 meters within the range. This communication system is less expensive and simpler than the other proprietary short-range wireless sensor networks as Bluetooth and Wi-Fi. ZigBee supports different network configurations for master to master or master to slave communications. And, it can be operated in different modes as a result the battery power is conserved. ZigBee networks are extendable with the use of routers and allow many nodes to interconnect with each other for building a wider area network.

ZigBee system structure consists of three different types of devices such as ZigBee coordinator, Router and End device. Every ZigBee network must consist of at least one coordinator which acts as a root and bridge of the network. The coordinator is responsible for handling and storing the information while performing receiving and transmitting data operations. ZigBee routers act as intermediary devices that permit data to pass to and for through them to other devices. End devices have limited functionality to communicate with the parent nodes such that the battery power is saved as shown in Figure 4. The number of routers, coordinators and end devices depends on the type of network such as star, tree and mesh networks. ZigBee protocol architecture consists of a stack of various layers where IEEE 802.15.4 is defined by physical and MAC layers while this protocol is completed by accumulating ZigBee’s own network and application layers.

### *Bluetooth*

Bluetooth is a wireless technology used to transfer data between different electronic devices. The distance of data transmission is small in comparison to other modes of wireless communication. This technology eradicates the use of cords, cables, adapters and permits the electronic devices to communicate wirelessly among each other. Bluetooth technology permits hands free headset for incoming voice calls, ability of printing and fax, and automatic synchronization of PDA. Bluetooth is a wireless technology standard for connecting fixed or mobile devices using short radio link. It aims at providing wireless communication along with small size, minimal power consumption and low price. The technology was designed to be simple, and the target was to have it become standard in wireless connectivity. Bluetooth technology was designed as a short-range wireless communication standard, intended to maintain high levels of security. The main attractive characteristic of Bluetooth is to allow a wide range of Bluetooth enabled devices to connect and communicate with each other, almost everywhere in the world. Bluetooth devices operate in the 2.4 GHz ISM band (Industrial, Scientific and Medical band), utilizing frequency hopping among 79 1 MHz channels at a nominal rate of 1600 hops/sec to reduce interference. The standard specifies three classes of devices with different transmission powers and corresponding coverages ranging from 1 to100 m. The maximum data rate is 3 Mbps.

***WiFi***

Wireless Fidelity– popularly known as WiFi, developed on IEEE 802.11 standards. It is widely used technology advancement in wireless communication for over decay now. As the name indicates, WiFi provides wireless access to applications and data across using radio waves. It sets up numerous ways to build up a connection between the transmitter and the receiver. The transmitter is normally a wireless router / Hotspot and receiver is normal WiFi enabled device such as Laptop, Mobile, Tablet etc. WiFi technology provides its users with the liberty of connecting to the Internet from any place such as their home, office or a public place without the hassles of plugging in the wires, by now you should be quite aware of that at least. WiFi station will scan the available channels to discover active networks where beacons are being transmitted. It then selects a network, be it in ad hoc mode or infrastructure. In the latter case, it authenticates itself with the access point and then associates with it.

The comparison of these technologies is presented in Table 2.1

Table 2.1 Comparison of ZigBee, Bluetooth and WiFi technologies

| Metric/Platform | ZIGBEE | Bluetooth Low energy (BLE) | Wi-Fi |
|---|---|---|---|
| Range | 10-100 m | >60m (10m for Classic BT) | Depends on specification |
| Power | Low | Very Low (High for classic BT and medium for others) | High (variable for Wi-Fi Direct) |
| Entries | 254 (>64000 per network) | 2 Billion (Classic: 7) | Depends on number of IP addresses |
| Latency | Low | 3 ms (compared to 100ms in classic BT) | Variable |
| **Metric/Platform** | **ZIGBEE** | **Bluetooth Low energy (BLE)** | **Wi-Fi** |
| Self-healing | Yes | - | Yes |
| Topologies | Mesh, Star and Cluster-tree | Star | Star and Point-to-Point |
| Data transmission rate | Up to 250Kbps | 1Mbps (BT v4.0: 25Mbps) | 11Mbps & 54Mbps (250 Mbps: Wi-Fi Direct) |
| Bandwidth | 2.4GHz, 915 MHz & 868 MHz | 2.4 GHz only (BT + HS: 6-9 GHz) | 2.4, 3.6 & 5 GHz |
| Transmission technique | DSSS | Adaptive FHSS (Classic BT: FHSS) | DSSS, CCK & OFDM |

## 2.2 WBAN applications and their requirements

Due to the diverse components that can be connected and integrated, body area networks will be able to provide various functions in healthcare, emergency, work, research, lifestyle, sports, or military. Current telemedicine systems either use devoted wireless channels to transfer data to the isolated stations, or power demanding protocols such as Bluetooth that are open to interference by other devices occupied in the same frequency band. These characteristics limit long health monitoring. A WBAN can be integrated into a telemedicine system that supports modest ambulatory health monitoring for long period of time.

### *Medical Applications*

BANs can provide interfaces for diagnostics, for remote monitoring of human physiological data, for administration of drugs in hospitals and as an aid to rehabilitation. In the future, it will be possible to monitor patients continuously and give the necessary medication whether they are at home, in a hospital or elsewhere. Patients will no longer need to be connected to large machines to be monitored. Medical application is very important for old people healthcare.

### *Lifestyle and Sports*

BANs enable new services and functions for wireless body centric networks including wearable entertainment system (e.g., music entertainment), navigation support in the car or while walking, museum or city guide, heart rate and performance monitoring in sports, infant monitoring, wireless cash card (e.g., display of recent transactions and checking of balance, etc.)

### *Military Applications*

The opportunities for using BANs in the military are numerous. Some of the military applications for BANs include monitoring health, location, temperature and hydration levels. A battle dress uniform integrated with a BAN may become a wearable electronic network that connects devices such as life support sensors, cameras, RF and personal PDAs, health monitoring GPS, and transports data to and from the soldier’s wearable computer. The network could perform functions such as chemical detection, identification to prevent casualties from friendly fire and monitoring of a soldier’s physiological condition. Calling for support, his radio sends and receives signals with an antenna blended into his uniform. As a result, BANs provide new opportunities for battlefield lethality and survivability.

Some parameters of application are shown in Tables 2.2 and 2.3

Table 2.2 In-body and on-body sensor networks applications

| Application Type | Sensor Node | Date Rate | Duty Cycle (per device) % per time | Power Consumption | QoS (Sensitive to Latency) | Privacy |
|---|---|---|---|---|---|---|
| In-body Applications | Glucose Sensor | Few Kbps | <1% | Extremely Low | Yes | High |
| | Pacemaker | Few Kbps | <1% | Low | Yes | High |
| | Endoscope Capsule | > 2Mbps | <50% | Low | Yes | medium |
| On-body Medical Applications | ECG | 3 Kbps | <10% | Low | Yes | High |
| | SpO2 | 32 bps | <1% | Low | Yes | High |
| | Blood Pressure | <10 bps | <1% | High | Yes | High |

Table 2.3 Examples of medical WBAN applications

| Application | Data Rate | Bandwidth | Accuracy |
|---|---|---|---|
| ECG (12 leads) | 228 kbps | 100-1000 Hz | 12 bits |
| ECG (12 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 sensors | 35 kbps | 0-500 Hz | 12 bits |
| Cochlear implant | 100 kbps | - | - |
| Artificial retina | 50-700 kbps | - | - |
| Audio | 1 Mbps | - | - |
| Voice | 50-100 kbps | - | - |

## 2.3 Body medical sensors

Wireless medical sensor nodes are integrated into a WBAN. Each sensor node can sense, sample, and process one or more physiological signals. A sensor node performs three mains tasks: signal detection, signal digitization/coding/controlling for communication that involves multiple access and finally transmitting the data through a transceiver wirelessly. The signals that are received from human body are not strong and are accompanied by noise. An electrocardiogram sensor (ECG) can be used for monitoring heart activity, an electromyogram sensor (EMG) for monitoring muscle activity, an electroencephalogram sensor (EEG) for monitoring brain electrical activity, a blood pressure sensor for monitoring blood pressure (Figure 2.2). Monitoring blood pressure at home is important for many people, especially if you have high blood pressure.

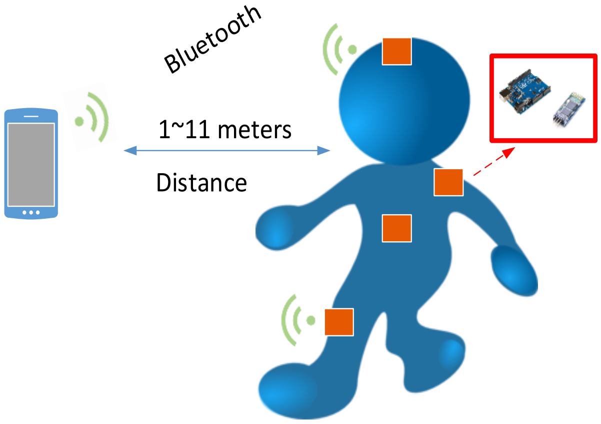
**Figure 2.2 WBAN network body sensors**

The electrical activity of heart is represented in the form of a graph which is known as ECG and is used for the diagnosis of any heart disease and to see how well effectively the cardiac medicines are working. Electrodes are placed on the human body at places like chest, arms etc. The potential difference between the electrodes gives the ECG signal. ECG signal data is transmitted at a rate of 2,000 Hz, providing an extremely high-resolution ECG waveform at the receiver’s output. Raw data from the pair is bandlimited from 0.05 Hz to 150 Hz, to provide a very high-quality recording. The matched pair incorporates internal, non-distorting, highpass and lowpass filters to provide for high quality amplification of the complete ECG waveform and associated complexes. Skin Temperature module pair consists of a matched transmitter and receiver to record one or two channels of temperature data. The module pair is typically used to measure skin surface temperature or variations in inspired/expired breath—for monitoring respiration. The pair is specifically designed to measure temperature in the range of 13 to 51 °C. Temperature signal data is transmitted at a rate of 2000 Hz, providing extremely high-resolution temperature variation waveforms at the receiver module’s output. Glucose level in blood is measured by extracting blood from a person’s finger by pricking it and transferring it on some strip which is made up of glucose sensitive chemicals. EEG sensor is used for measuring the electrical activity that occurs inside the brain. This is done by placing electrodes at various positions on the scalp humans. The electrodes sense the information about the electrical activities of the brain and pass it on to an amplifier which then produces tracing patterns. If electrical activities in some regions of the brain are synchronous this means that these regions have functional relationship. Blood pressure sensor is used for measuring systolic and diastolic blood pressure and makes use of oscillometric technique [39,43].

# 3 Investigation of signal strength level between sensor and sink

## 3.1 The experiment setup of Bluetooth signal strength level measurement

This section describes the various experiments that were conducted to evaluate the Bluetooth sensor system performance. The aim of these experiments is to measure sensor Bluetooth signal strength in the sink using different cases, because it influences of wireless sensor battery lifetime, which is the one of the main parameters of good WBAN performance. The experimental scheme for received signal level measure is presented in Figure 3.1.



| Parameter | Value |
|---|---|
| Sensor positions | Head, shoulder, Chest, knees,back |
| Distance | From 1 to 11 meters |
| Human rotation | 180 and 0 |
| Wall | Air, glass,wood,wall |
| Technology | Bluetooth |
| Measure | 10 measures in all events positions |
| Measure parameter | Received signal level |

**Figure 3.1(a) Experimental scheme for received signal level measure**

Material Required: Bluetooth (HC 05), Arduino UNO, Battery, Android mobile and Calculator.

Experiment Setup:

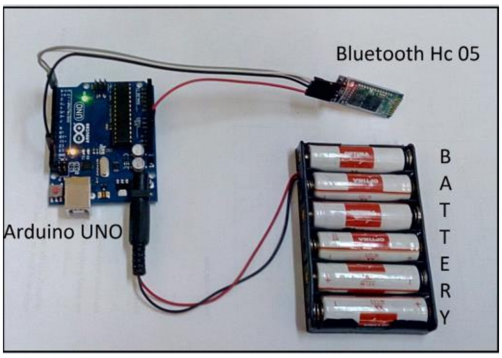


**Figure 3.2 Basic experimental material setup**

I connect Bluetooth (HC 05) with Arduino UNO and battery is connected to the Arduino UNO. This Bluetooth setup is placed on the patient and then I pair Bluetooth device with android mobile by entering default password 0000, Then download the application from the android mobile to analyse the Bluetooth signal level of the patient. Application name is Bluetooth signal and I measure the signal level in different environment like Air medium, Glass medium, wood door medium and wall medium. There are many locations on your body where you could wear sensor node. The different position of the patient like Head, Shoulder, Chest, Knee and Back was analysed. I continuously increase the distance of the Bluetooth which is place on the patient and take the reading 10 times at different Distances. Distance range is varying from 1 meter to 11 meters. I take average of 10 values at all distance ranges. Bluetooth signal application is good application for measuring the signal level of Bluetooth and for more accuracy I take 10 values and calculate the average of 10 values. For each of these cases, I measured the RSS emitted by ASUS mobile phone application. The experiment sensor on body is shown in Figure 3.3.

**Figure 3.3 Sensor on body**

The tests performed in this chapter demonstrate the effects of distance, environment, the user's body, for signal strength. I plot the graph between Signal level (in dBm) and Distance (in meter). I observe that as I increase the distance of the Bluetooth which is place on the patient the signal level decreases.

## 3.2 The result of experimental investigation

Figure 3.4-3.7 shows the results of this experiment. According our results with polynomial regression I can fit models of order n > 1 to the data and try to model nonlinear relationships.

The abbreviations and symbols which are using in the graph are in Table 3.1:

Table 3.1 The abbreviations and symbols

| | | |
|---|---|---|
| A – Air medium | G – Glass medium | D – Door medium |
| W – Wall medium | H – Head | S – Shoulder |
| C – Chest | K – Knee | B – Back |

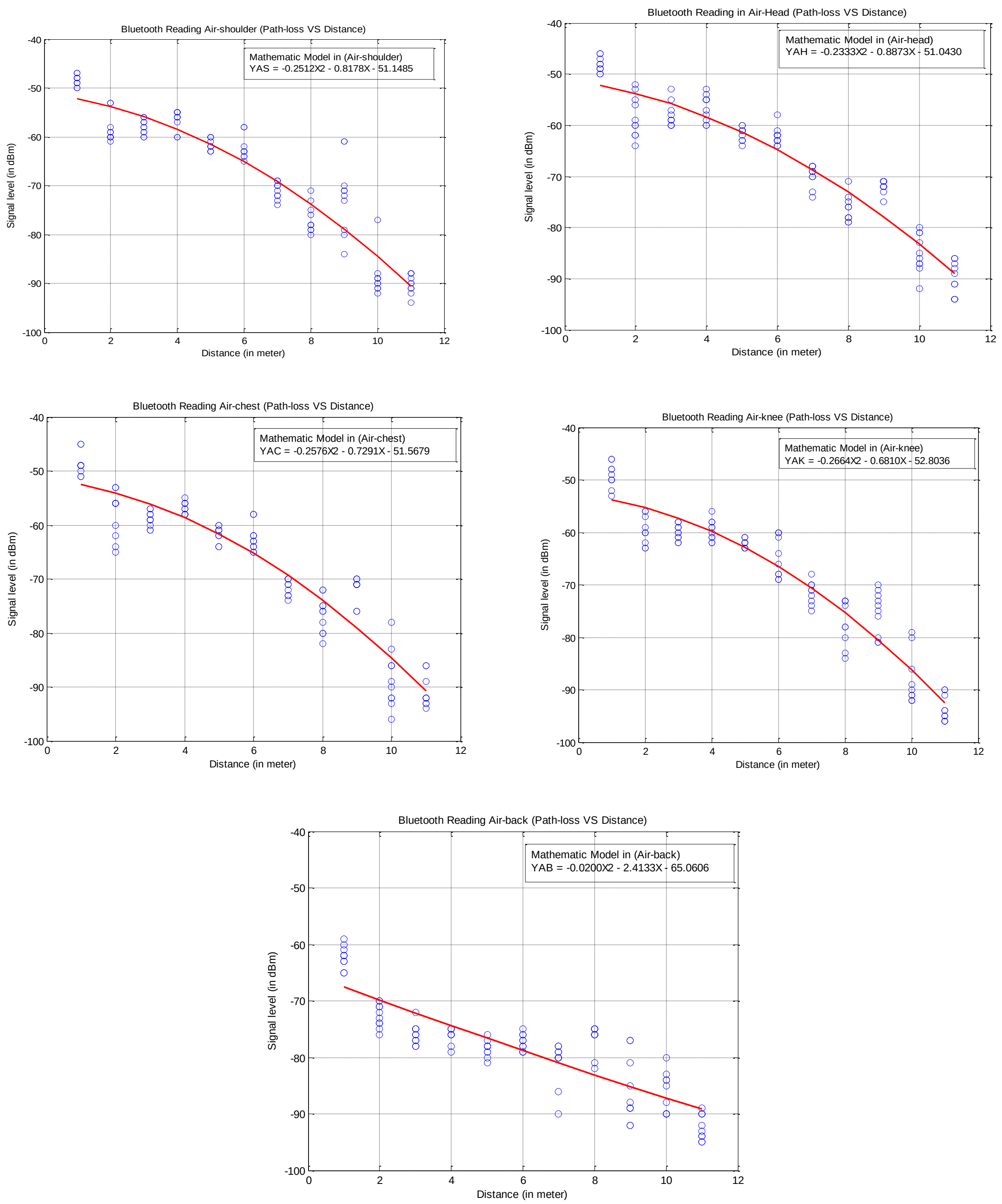


**Figure 3.4 Signal strength level versus distance on different sensor positions on human body and environment-air**

I observe (Figure 3.4) that when I place Bluetooth on head the maximum value of signal level is -48dBm and minimum value of signal level is -90dBm. In all cases, the signal level is decrease as I increase the distance but at 4 meters distance the signal level is little bit increase because of reflection of the signal from the wall of the room. The graph of the shoulder, chest and knee is almost same but the graph of the back is very different from all position. The maximum value of signal level at back is -62dBm and minimum value of signal level at back is -92dBm. And the behaviour of the graph is almost linear as shown in Figure. All graphs are decrease with distance in the shape of curve except Air medium on back.

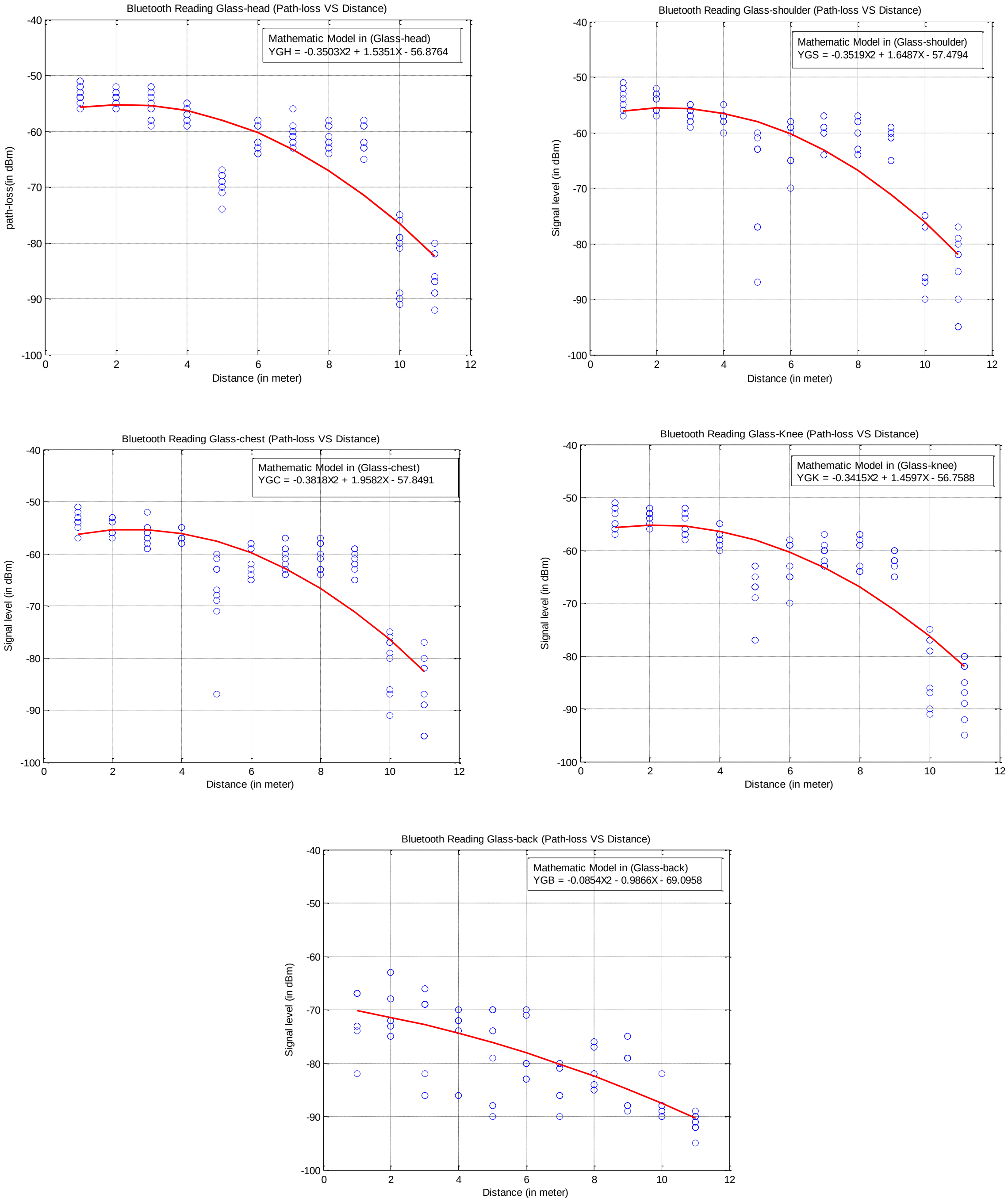


**Figure 3.5 Signal strength level versus distance on different sensor positions on human body and environment-glass**

I observe that when I place Bluetooth on head the maximum value of signal level is -53dBm and minimum value of signal level is -86dBm. In glass medium, I observe that there is no increase in signal strength on 4 meters. Shoulder, chest and knee are almost same but the graph of the back is very different from all position. The maximum value of signal level at back is -70dBm and minimum value of signal level at back is -91dBm.

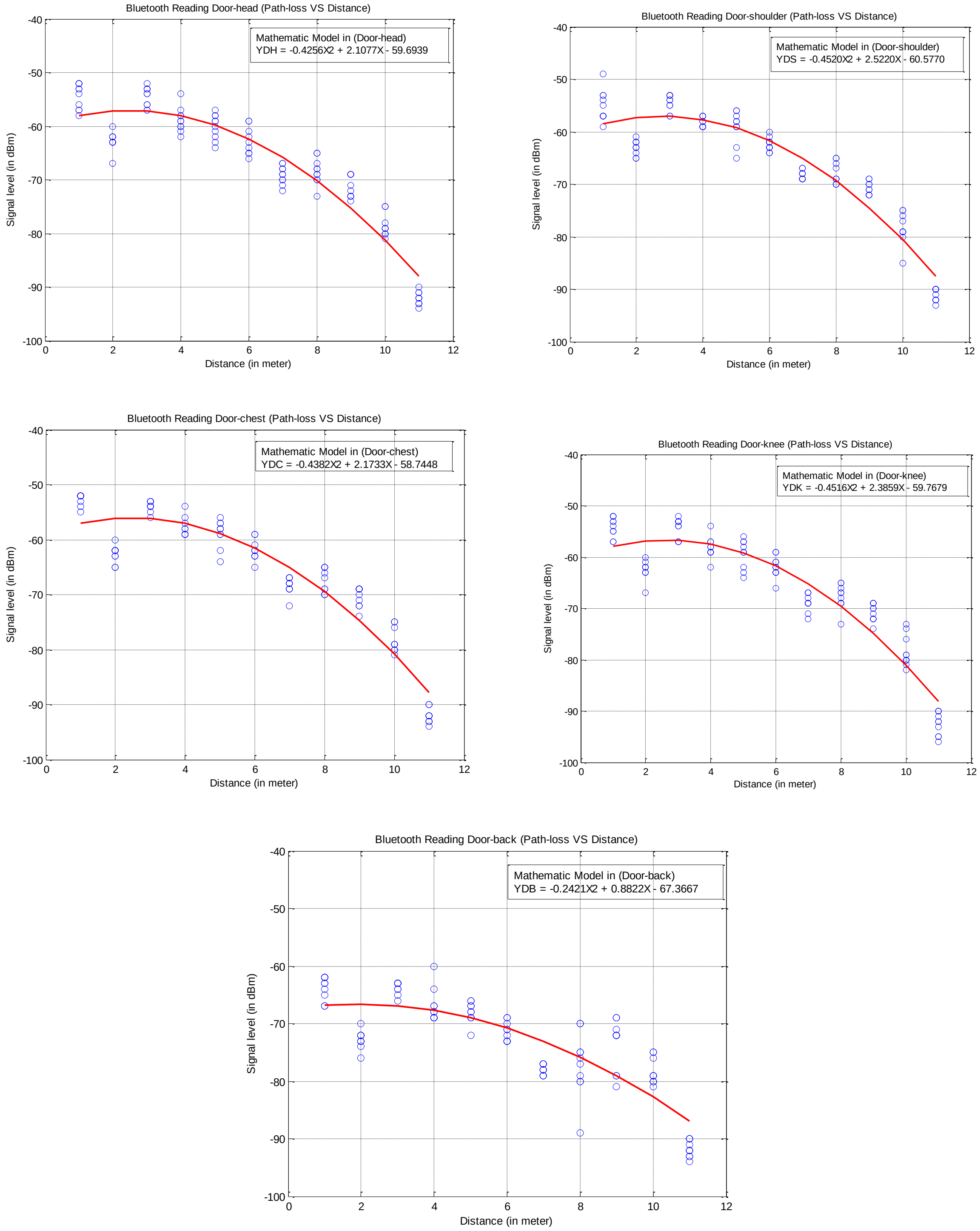


**Figure 3.6 Signal strength level versus distance on different sensor positions on human body and environment-door**

I observe that the maximum value of signal level is -54dBm and minimum value of signal level is -92dBm. In all cases, the signal level is decrease as I increase the distance but at 2 meters distance the signal level is decrease more as compared to other mediums because of wood medium. The graph of the shoulder, chest and knee is almost same but the graph of the back is very different from all position. The maximum value of signal level at back is -64dBm and minimum value of signal level at back is -92dBm.

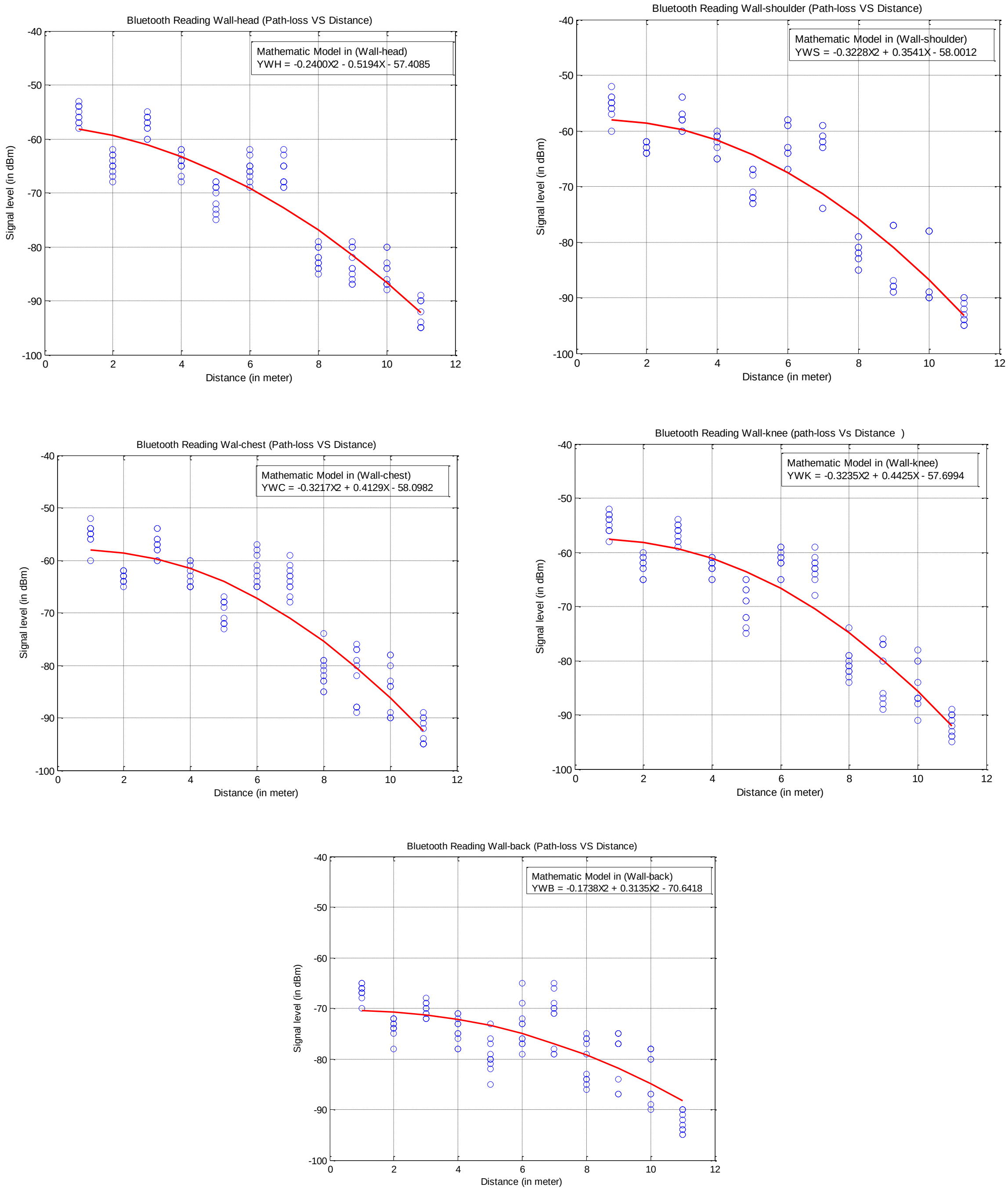


**Figure 3.7 Signal strength level versus distance on different sensor positions on human body and environment-wall**

The maximum value of signal level is -55dBm and minimum value of signal level is -92dBm. In all cases, the signal level is decrease as I increase the distance but at 2 meters and 5 meters distance the signal level is increases as compared to other mediums because of reflection of the signal from the wall of the room. The graph of the shoulder, chest and knee is almost same but the graph of the back is very different from all position. The maximum value of signal level at back is -66dBm and minimum value of signal level at back is -92dBm.

The fitting polynomial model's coefficients of experimental results are given in Table 3.2

$S = ad^2 + bd + c$

Now, compare all the mediums (Air, glass, door and wall) and result are in Table 3.3 Combining all measure results I plot the graph of relationship between signal level and distance and Figure 3.8 illustrate the distribution signal strength of all measures.

Table 3.2 Fitting polynomial model's coefficients

| **Mathematical Model in Air(A)** | **a** | **b** | **C** |
|---|---|---|---|
| s Air(A) | | | |
| Head (H) | -0.2333 | - 0.8873 | - 51.0430 |
| Shoulder(S) | -0.2512 | - 0.8178 | -51.1485 |
| Chest(S) | -0.2576 | - 0.7291 | - 51.5679 |
| Knee(K) | -0.2664 | - 0.6810 | - 52.8036 |
| Back(B) | -0.0200 | - 2.4133 | - 65.0606 |
| Glass(G) | | | |
| Head (H) | -0.3503 | + 1.5351 | - 56.8764 |
| Shoulder(S) | -0.3519 | + 1.6487 | -57.4794 |
| Chest(S) | -0.3818 | + 1.9582 | - 57.8491 |
| Knee(K) | -0.3415 | + 1.4597 | - 56.7588 |
| Back(B) | -0.0854 | - 0.9866 | - 69.0958 |
| Door(D) | | | |
| Head (H) | -0.4256 | + 2.1077 | - 59.6939 |
| Shoulder(S) | -0.4520 | + 2.5220 | - 60.5770 |
| Chest(S) | -0.4516 | + 2.3859 | - 59.7679 |
| Knee(K) | -0.4382 | + 2.1733 | - 58.7448 |
| Back(B) | -0.2421 | + 0.8822 | - 67.3667 |
| Wall(W) | | | |
| Head (H) | -0.2400 | - 0.5194 | - 57.4085 |
| Shoulder(S) | -0.3228 | + 0.3541 | - 58.0012 |
| Chest(S) | -0.3217 | + 0.4129 | -58.0982 |
| Knee(K) | -0.3235 | + 0.4425 | - 57.6994 |
| Back(B) | -0.1738 | + 0.3135 | - 70.6418 |

Table 3.3 Comparison all experiments result

| **Medium/ Parameter** | **Air** | **Glass** | **Door** | **Wall** |
|---|---|---|---|---|
| Good Zone at (head, shoulder, chest and knee) | 1 meter to 4 meter | 1 meter to 4 meter | Till 1 meter and 3 meter to 5 meter only | At 1 meter and 3 meter |
| Good zone (back) | Till 1 meter | Less than 1 meter | Less than 1 meter | Less than 1 meter |
| Accepted Zone at (head, shoulder, chest and knee) | Till 9 meter | Till 9 meter | Till 10 meter | Till 7 meter |
| Accepted Zone at (back) | Till 6 meter | Till 6 meter | Till 10 meter | Till 7 meter |
| Bad Zone (head, shoulder, chest and knee) | After 9 meter | After 9 meter | After 10 meter | After 7 meter |
| Bad Zone (back) | After 6 meter | After 6 meter | After 10 meter | After 7 meter |
| Signal level increases due to Reflection | At 4 meter | 6 meter to 9 meter | At 8 meter | - |
| Signal level decrease | - | - | At 2 meter | At 2 and 5 meter |
| Maximum Signal level | -48dBm | -53dBm | -54dBm | -55dBm |
| Minimum Signal level | -94dBm | -91dBm | -92dBm | -93dBm |
| Good position area for Bluetooth | Shoulder | Head | Chest | Knee |
| Bad position area for Bluetooth | Back | Back | Back | Back |
| Comments | Good signal strength on Head, Chest, Shoulder and knee but on back there is the resistance of the signal because of human body. And minimum signal level is also high as compare to other medium. Best position area is shoulder. I get good signal strength on 4 meters because of reflection of the signal. | Because of glass medium the range of signal level is almost same and reduction of signal is less as compare to other medium. The distribution of signal level is constant in room. Good zone for back is less than 1 meter. Maximum signal level is -53dBm. Head is good position area for Bluetooth. Bad signal strength for back. The range of signal strength due to reflection is more as compare to other medium (Range: 6 to 9 meter) | In this medium signal strength is not good as compare to air and glass medium.<br>Signal level is decrease at 2 meters. Good position area is chest. Minimum signal level is -92dBm. Accepted zone for all position is more than 10 meters. In this medium Good Zone at (head, shoulder, chest and knee) is 1 meter and 3 meters to 5 meters only. | In this case wall has good resistance for signal strength so in this medium Good Zone at (head, shoulder, chest and knee) is at 1 meter and 3 meters. Accepted zone is till 7 meters. Knee is the best position area and bad position area is back because of human body resistant.<br>Maximum signal level is -55dBm which is less as compare to other zones. |

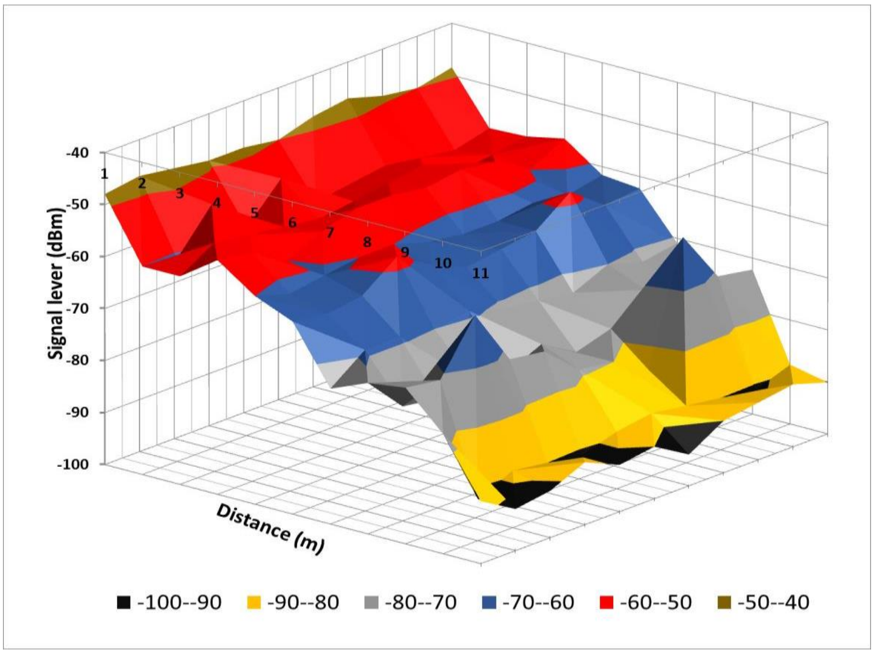


Figure 3.8 Signal strength level versus distance

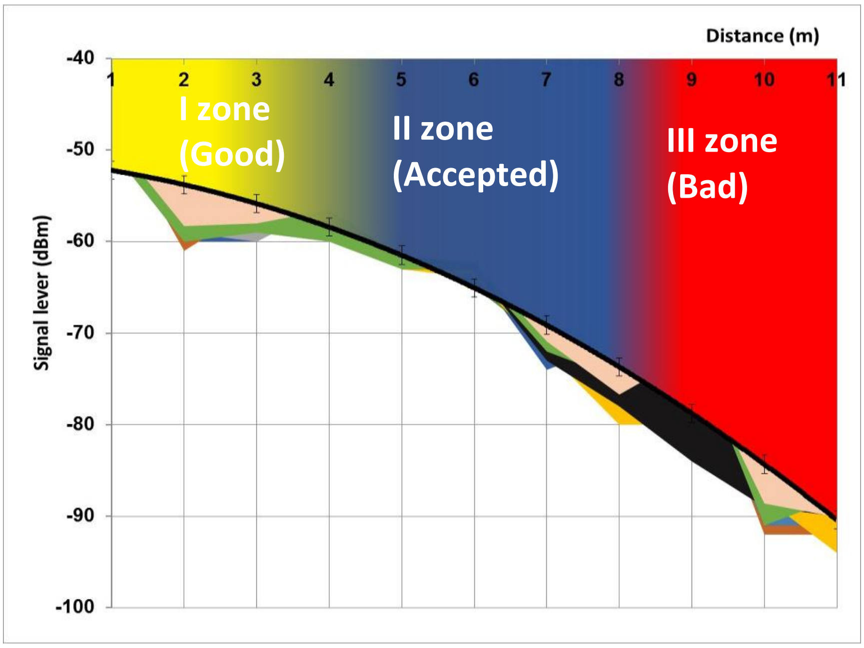


Figure 3.9 Working zones for Bluetooth technology according to signal strength level and distance

It was observed that had been see 3 zones, where minimum dispersal of signal. Therefore, using mathematical interpolation analysing fitting polynomic models together with experimental results I defined 3 working zones for Bluetooth technology: good, accepted and bad. This result is presented in Figure 3.9. In Figure 3.8 I plotted graph between signal level in dBm and distance in meter. I have 6 ranges of signal strength like: -100dBm to -90dBm, -90dBm to -80dBm, -

80dBm to -70dBm, -70dBm to -60dBm, -60dBm to -50dBm and -50dBm to -40dBm. Figure 3.8 represents these ranges in different colour and I can see the range of Bluetooth signal strength. As I increase the distance of the Bluetooth device the strength of the device become low. The Figure 3.9 I plotted graph between signal level in dBm and distance in meter. I can see that there are three zones present in this graph. 1 good zone, 2 accepted zones and 3 bad zones. I divide the signal level strength in three zones good zone is good for communication and there will be no problem when I transfer the data. Accepted zone is also good for communication but in bad zone communication will be not good and minimum signal strength in this zone.

## 3.3 Channel model for body signal level loss evaluation

An important step in the development of a wireless body area network is the characterization of the electromagnetic wave propagation from devices that are close to or inside the human body. The complexity of the human tissues structure and body shape makes it difficult to drive a simple path loss model for BAN. As the antennas for BAN applications are placed on or inside the body, the BAN channel model needs to consider the influence of the body on the radio propagation.

For this document, I define 3 types of nodes as follows [8]:

1. Implant node: A node that is placed inside the human body. This could be immediately below the skin to further deeper inside the body tissue.
2. Body Surface node: A node that is placed on the surface of the human skin or at most Two centimetres away.
3. External node: A node that is not in contact with human skin (between a few centimetres and up to 5 meters away from the body)

For body surface communication, the distance between the transmitting and receiving nodes shall consider the distance around the body if transmitter and receiver are not placed in the same side rather than straight line through the body. This allows creeping wave diffraction to be also considered. For external node communication, the distance between transmitter and receiver shall be from the body vicinity or inside body to 3 meters away. In some cases, the maximum range for medical device shall be 5 meters. The propagation characteristics of the wireless signal is becoming increasingly complex due the influence of human body. In the standard document, a list of scenarios can be identified in which IEEE 802.15.6 devices will be operating. The scenarios are grouped into classes that can be represented by the same Channel Models (CM) shown in Figure 3.10.

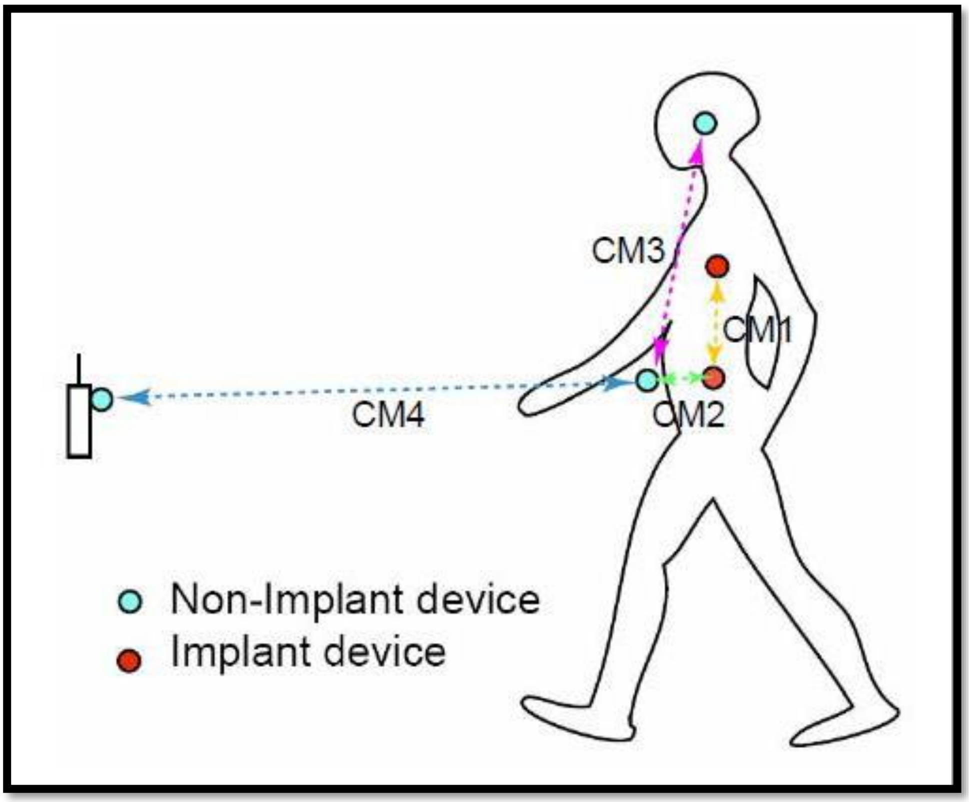


**Figure 3.10 Communication links for Body Area Networking [30]**

The frequency dependence of body tissues shall be considered. The path loss model in dB between the transmitting and the receiving antennas as a function of the distance d based on the Friis formula in free space is described (3.1).

$$P(d) = PL_O + 10n\log_{10}\left(\frac{d}{do}\right), \tag{3.1}$$

where $PL_0$ is the path loss, distance $d_0$, n is the path-loss exponent.

Here in this Figure (3.11-3.13) I can see that the graph is plot between distance (in mm) of the node from the sensor and the pathloss (in dB). Here in this graph I are taking 1200mm distance because the maximum average height of the person is 7 feet. If the node is on the middle of the body and sensor is at any part of the body then the maximum distance is 4 feet. That is why I are taking 1200mm distance which is equal to 4 feet. Here in Figure 3.14 I can see that the path loss is less after 280mm distance for 400 MHz and maximum path loss is there in 900MHz. In Figure3.15 I can see that the graph is plot between distance (in mm) of the node from the sensor and the path loss (in dB) for higher frequency 2.4GHz is having less path loss as compare to 3.1-10.6 GHz. After calculated the signal path loss for different sensor position on/in body (Figure 3.16-3.17)

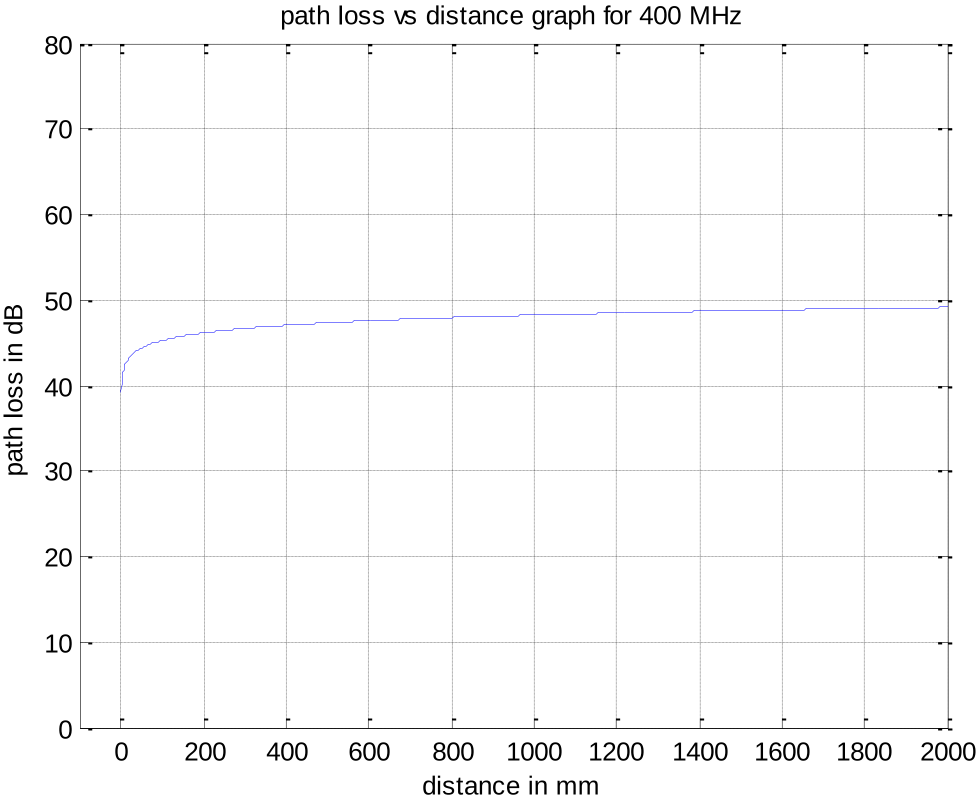


Figure 3.11 Signal path loss vs distance for 400 MHz

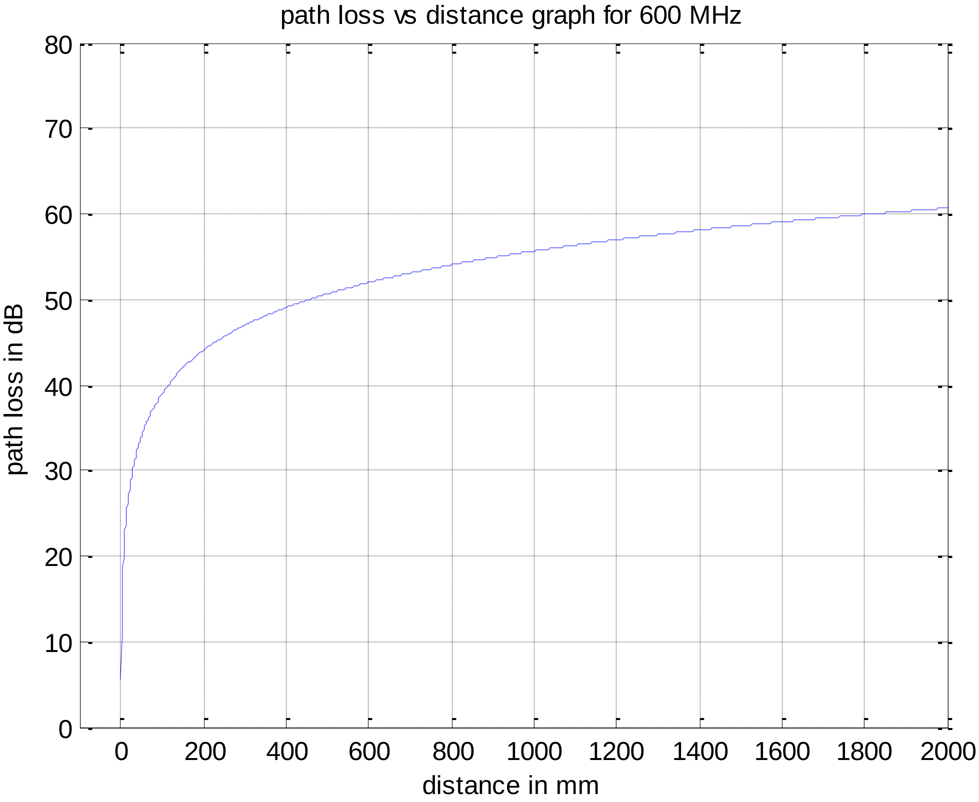


Figure 3.12 Signal path loss vs distance for 600 MHz

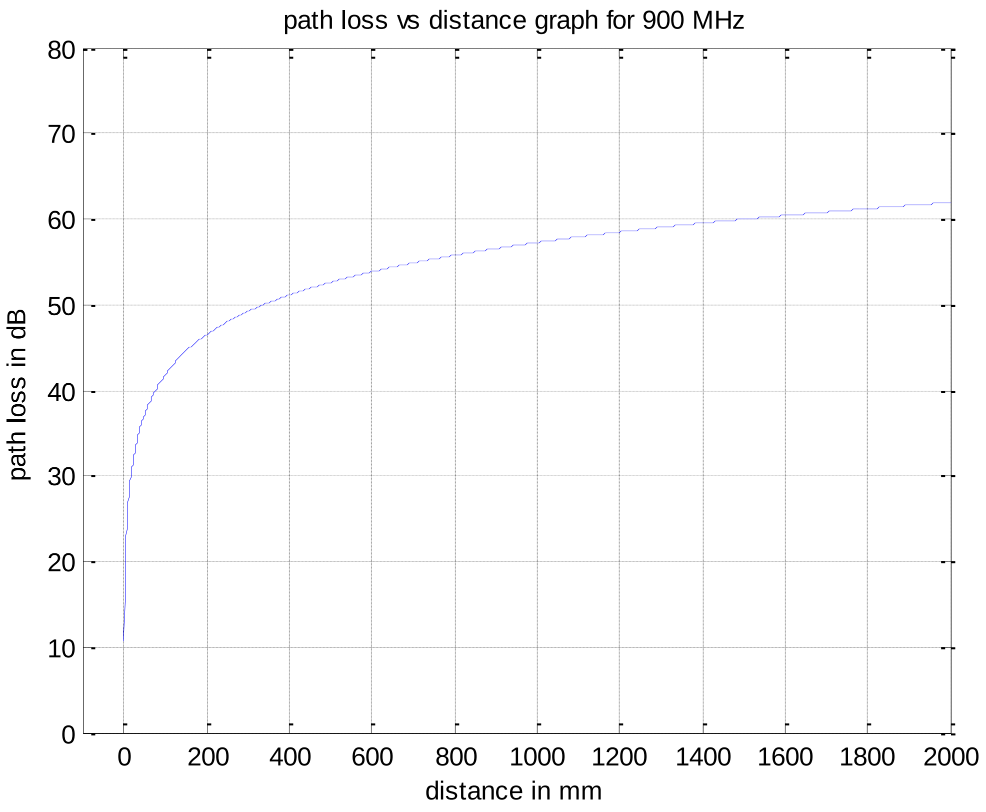


Figure 3.13 Signal path loss vs distance for 900 MHz

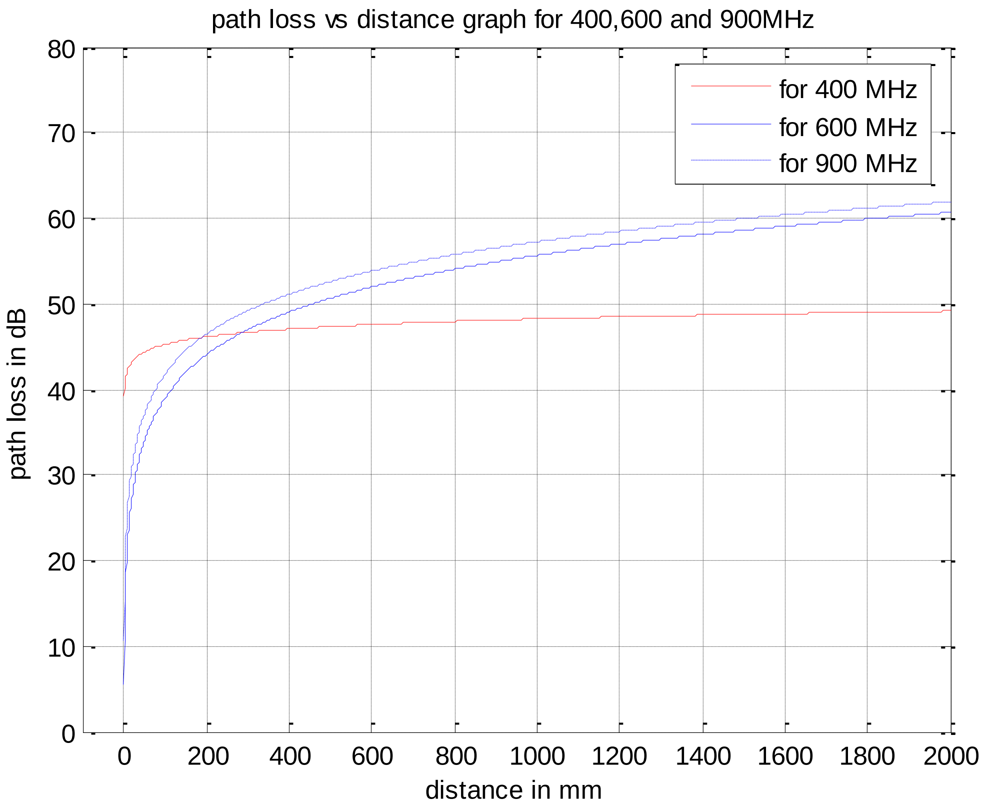


Figure 3.14 Signal path loss vs distance for 400,600and 900 MHz frequencies

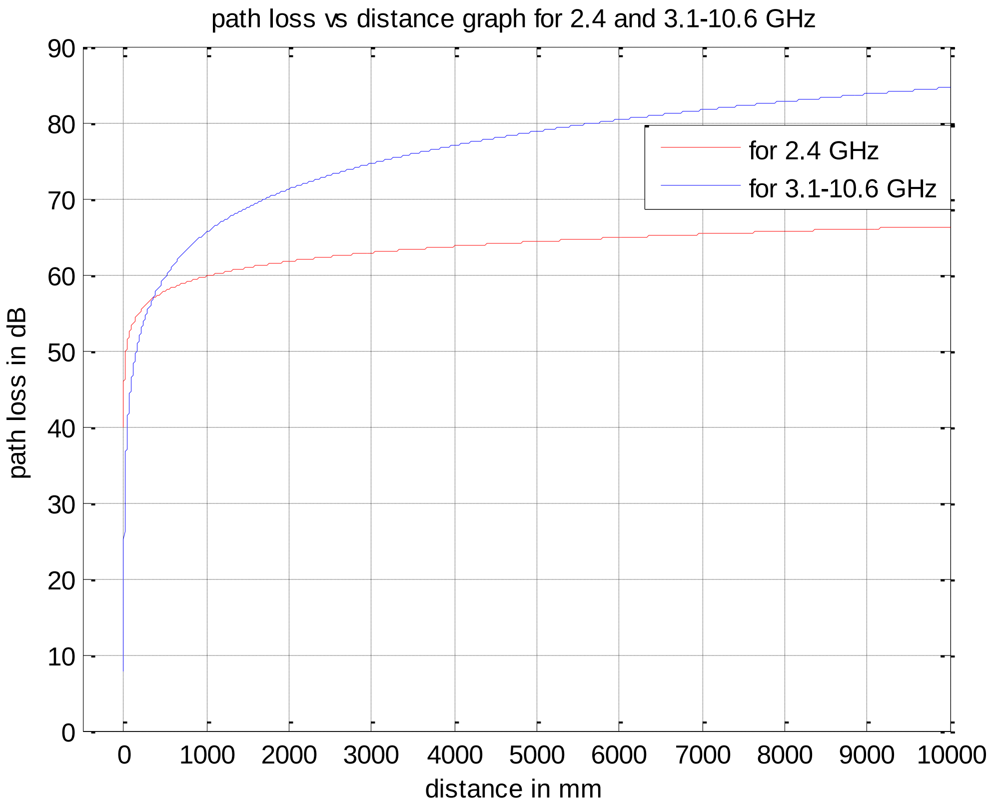


Figure 3.15 Signal path loss vs distance for higher frequency

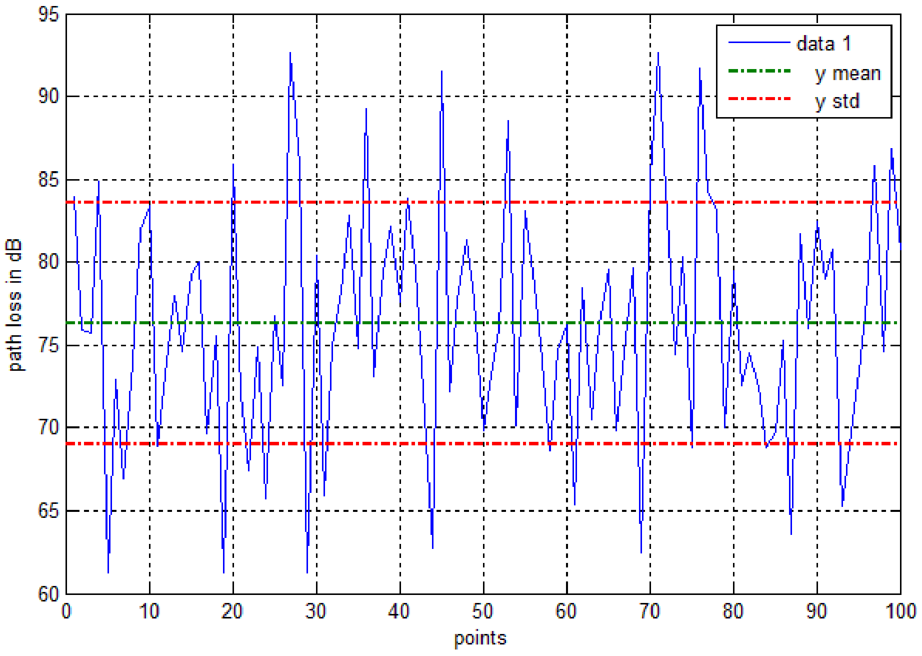


Figure 3.16 Signal path loss deep implant to on-body

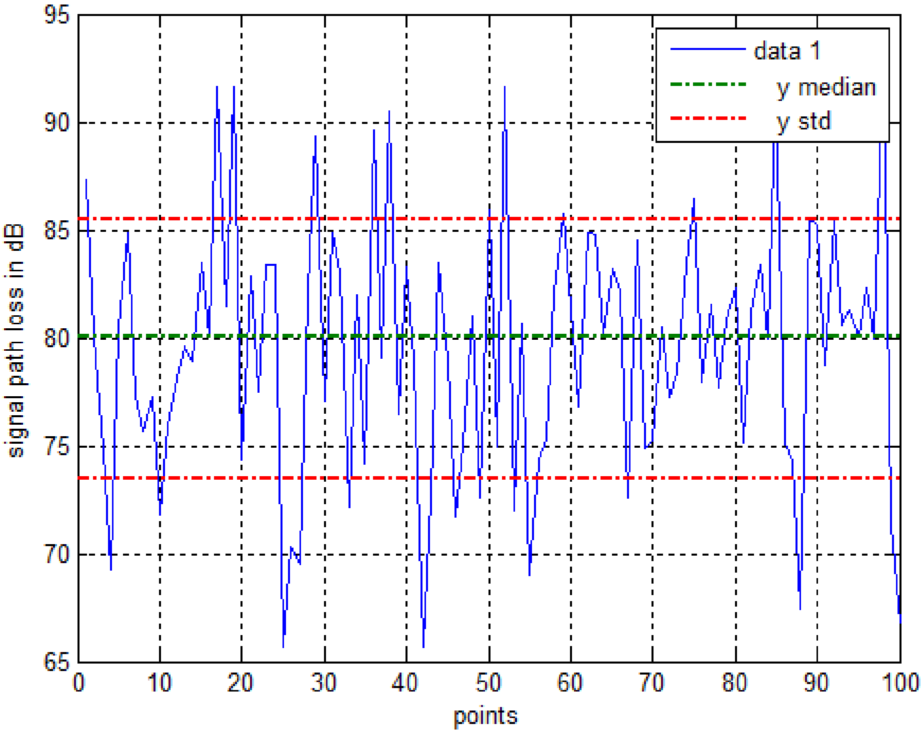


Figure 3.17 Signal path loss near-surface implant to on-body

# 4 Sensor energy resource management model

## 4.1 Proposed WBAN network system model

The proposed WBAN network framework is shown in Figure 4.1

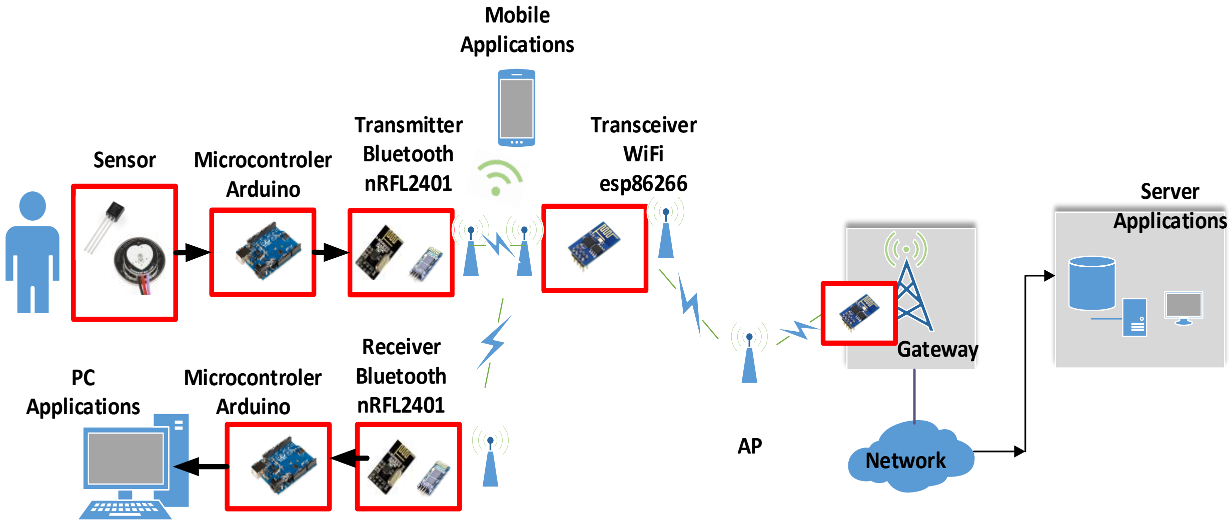


**Figure 4.1 Proposed WBAN system**

The proposed architecture of the model is a composite of hardware part and the software part. The receiver that is base station should be able to display the information received from the sensor nodes. Three wireless modules (esp8266, nRF24L01+ and Bluetooth HC-05) nodes were designed and tested to monitor patient's data. An ATmega328 microcontroller is used to design both the sensor nodes and at the base station. These microcontrollers are programmed in C with Arduino platform. The communication between base station and PC is established by a USB connection or Bluetooth with smartphone. Both devices are used as a display device. Sensors acquire the data and send it to microcontroller. These sensor (temperature and pulse rate sensor) send the analogy data to micro-controller. To make the data understandable to microcontroller it needs to be converted into digital form. It is done with the help of an ADC convertor which is integrated in the microcontroller. A microcontroller is used to interface sensors and wireless transceiver. PC is used as a display device for visualization data using created application by Visual studio 2017, and mobile smartphone - using created prototype of application using Mockpuls and Android studio.

The work flow chart of the proposed system is presented in Figure 4.2

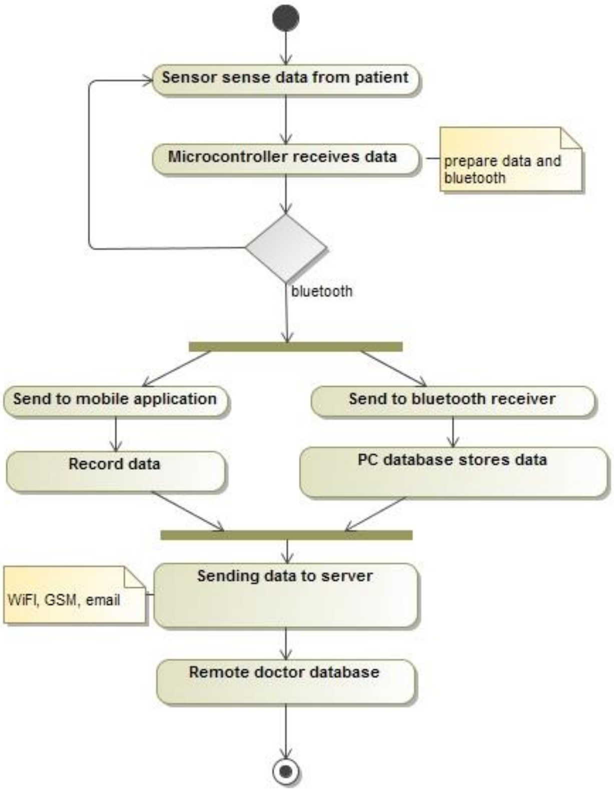


**Figure 4.2 Work flow chart of the proposed system**

When the patient takes a sensor result, then he will transfer this result to the smart phone using Bluetooth technology. The user, using mobile application on cell phone will store this result into the internal database and if he wants to send to the web service or send txt file to email or SMS. The patient's doctor will get a notification to look at the test result and give the feedback to the patient.

## 4.2 WBAN Bluetooth sensor energy consumption model

WBANs contain small-size sensor nodes with limited processing power and battery capacity. Nodes sense data from a field under observation and transmit them to a sink via one or multiple hops in this network. Figure. 4.3 illustrate the data exchange sequence diagram between the master and a slave for a connection event.

Communication during a connection event is started by the master, which sends a packet to the slave. After a connection between a master and a slave is established, time is divided into non-overlapping periods called connection events. Communication during a connection event is started by the master, which sends a packet to the slave.

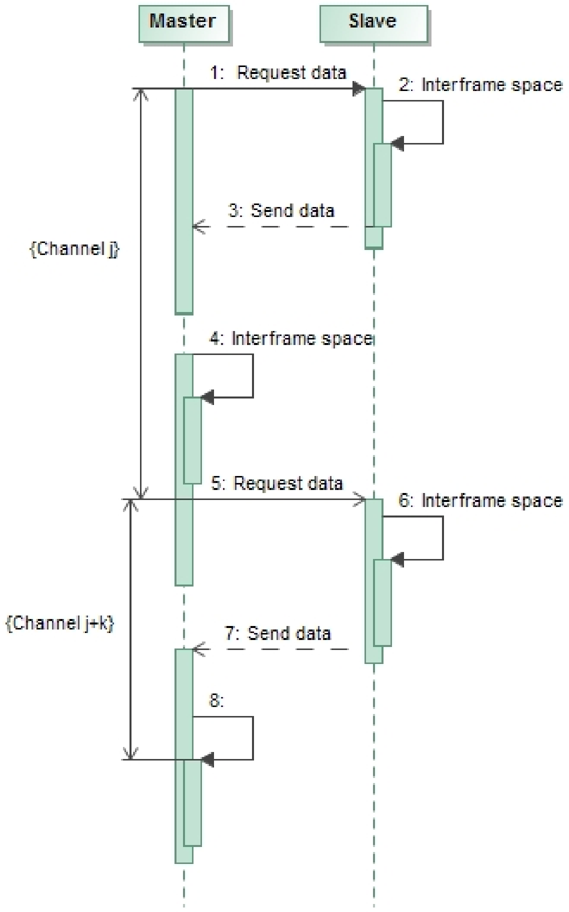


**Figure 4.3 Data exchange sequence diagram between the master and slave**

The master and the slave alternate the transmission of packets on the data channel until one of the devices does not have more data to transmit or until the connection event is over. During a connection event, all packets are transmitted using the same channel frequency.

The transmission time for the master can be calculated using equation (4.1) [ 60]

$$T_m = T_{pre} + T_{aa} + T_{lh} + T_{CRC}, \qquad (4.1)$$

and for slave (4.2)

$$T_s = T_{pre} + T_{aa} + T_{lh} + T_{CRC} + T_{pay} + T_{ATTh} + T_{op} + T_{L2CAP}, \qquad (4.2)$$

The total time for the exchange of packets between the master and the slave as given by (4.3)

$$T_{m-s} = T_m + T_s + 2 * T_{GT} \ , \qquad (4.3)$$

where $T_{GT}$ is the guard time interval, it value is 150μs

The interval between active connection events, which may also be called effective connection interval ($T_{eci}$), depends on two parameters: the connection interval ($T_{ci}$) and the slave latency ($N_{sl}$), and can be calculated using equation (4.4) where detail description of parameters is presented in the Table 4.1

Table 4.1 Detailed transmission times

| **Acronym** | **Field** | **Bytes** | **Transmission Time (in µs)** |
|---|---|---|---|
| $T_{pre}$ | Preamble | 1 | 8 µs |
| $T_{aa}$ | Access address | 4 | 32 µs |
| $T_{lh}$ | Link Layer header | 2 | 16 µs |
| $T_{L2CAPh}$ | L2CAP header | 4 | 32 µs |
| $T_{op}$ | ATT opcode | 1 | 8 µs |
| $T_{ATTh}$ | Attribute(ATT) handle | 2 | 16 µs |
| $T_{pay}$ | Application payload | 0-20 | 0-160 µs |
| $T_{CRC}$ | CRC | 3 | 24 µs |

$$T_{eci} = \frac{N_{not}\, L_{data}}{N_s\ Q_s\, f_s} = T_{Ci} + (1 + N_{Sl}), \tag{4.4}$$

where $N_{not}$ is the number of notifications per connection event, $L_{data}$ is the payload length, $N_s$ is the number of sensors, $Q_s$ is the sampling resolution, $f_s$ is the sampling frequency

When I know the called effective connection interval then can be calculated the number of supported slaves $N_{max}$. (4.5)

$$N_{max} = \frac{T_{eci}}{N_{not} \cdot T_{ms}}. \tag{4.5}$$

After that, the throughput of connection is expressed, instead, by equation (4.6)

$$S_{conn} = \frac{N_{not}\, L_{data}}{T_{eci}}\,. \tag{4.6}$$

During a connection event, the transceiver on the slave device switches among several states, which includes pre-processing, reception, transmission and post processing states. The average current ($I_{av\text{-}on}$) “on” state can be calculated using equation (4.7) [ 46]

$$I_{av-on} = \frac{\sum_{i=1}^{Ns}(T_{si} \cdot I_{si})}{T_{on}}, \tag{4.7}$$

where $T_{on}$ is the awake time, $T_{si}$ is the time of the each state , $I_{si}$ is the corresponding current consumption, $Ns$ is the number of states.

The common average current (4.8)

$$I_{avg} = \frac{I_{on}\, T_{on} + I_{sleep}(T_{eci} - T_{on})}{T_{eci}}, \tag{4.8}$$

where $I_{sleep}$ is sleep mode current consumption.

In order to estimate the battery lifetime ($TL_{bat}$), can be used equation (4.9)

$$TL_{bat} = \frac{C_{bat}}{I_{avg}}, \tag{4.9}$$

where $C_{bat}$ is the battery capacity.

For our sensor energy resource management model was used 3 cases of the signals transmission between a master and a slave. The dynamics of sensors states during data transmission is shown in Figure 4.4. The time and measurement current of each sates are presented in the Table 4.2-4.4. [46]. The evaluation maximum number slaves and sensor lifetime was done for 3 types of medical application: ECG, blood pressure and EEG. For our sensor energy resource management model was used 3 cases of the signals transmission between a master and a slave (parameters Table 4.2-4.4). The parameter of application was used from Table 2.2-2.3. The simulation was done using 2 case of notifications per connection (1 and 2 ACK). The calculated results of interval between activate connection and maximum number of slaves are presented in Figures 4.4-4.7. Because the medical applications have very different parameters (bit rate, sampling frequency and data rate) analysing Figure 4.4 seen very big dispersion between of interval between activate connection for different application. Having these values it is possible to find maximum number of slaves. The target value the interval between activate connection recording reccomendation is minimum 7.5ms. Therefore, in the other Figures are shown only the part (range) where I can have defined maximum numbers of slaves according target value.

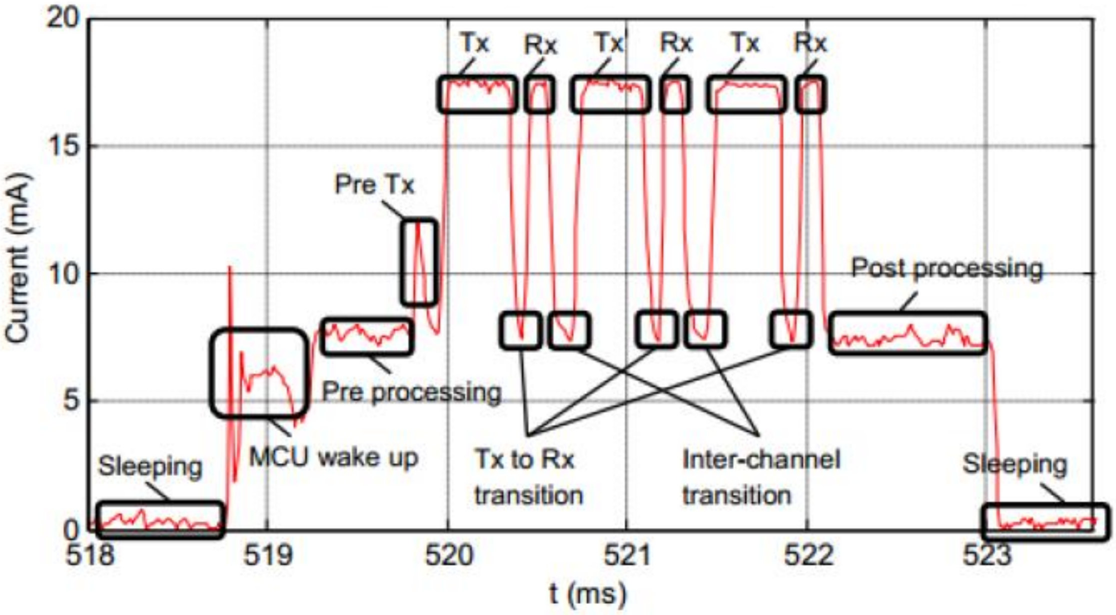


**Figure 4.3 The dynamics of sensors states [24]**

Table 4.2 Time and measurement current for first case

| State | Description | Time (µs) | Current (mA) |
|---|---|---|---|
| 1 | Wake-up | 400 | 6.0 |
| 2 | Pre-processing | 340 | 7.4 |
| 3 | Pre-Rx | 80 | 11.0 |
| 4 | Rx | 80 | 22.1 |
| 5 | Rx to Tx | 150 | 7.4 |
| 6 | Tx | 296 | 17.5 |
| 7 | Post-processing | 1280 | 7.4 |
| 8 | Pre-sleep | 160 | 4.1 |

Table 4.3 Time and measurement current for second case

| State | Description | Time (µs) | Current (mA) |
|---|---|---|---|
| 1 | Wake-up | 100 | 7.4 |
| 2 | Rx idel | 500 | 24.3 |
| 3 | Rx to Tx | 100 | 13.3 |
| 4 | Tx | 2500 | 33.5 |
| 5 | Pre-sleep | 100 | 15.0 |

Table 4.4 Time and measurement current for third case

| State | Description | Time (µs) | Current (mA) |
|---|---|---|---|
| 1 | Wake-up | 100 | 7.4 |
| 2 | Rx idel | 1200 | 26.8 |
| 3 | Rx active | 700 | 24.8 |
| 4 | Rx idel and post-processing | 1500 | 26.9 |
| 5 | Pre-sleep | 500 | 7.6 |

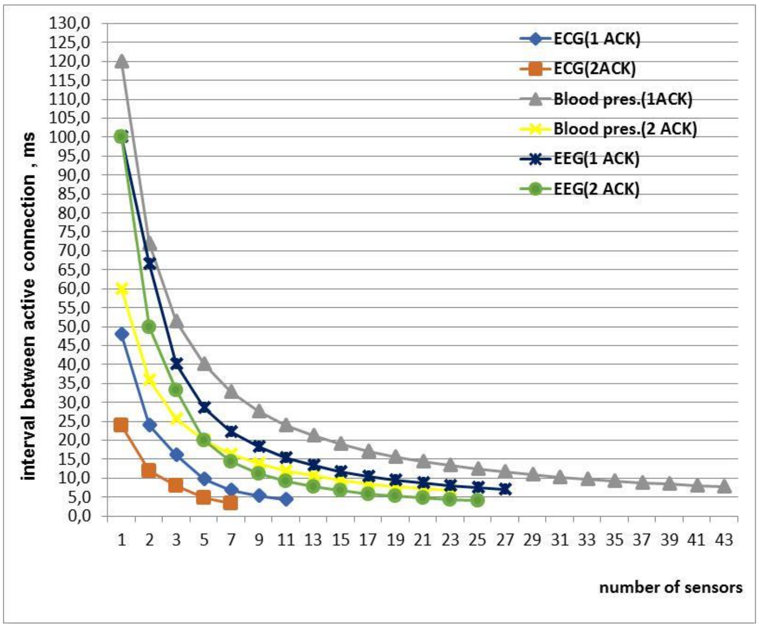


**Figure 4.4 Interval between activate connection versus number of sensors**

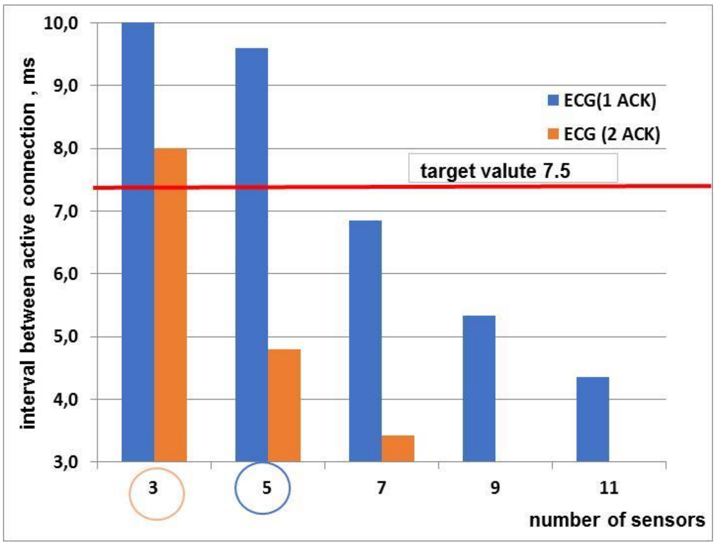


Figure 4.5 Maximum numbers of sensors for ECG application

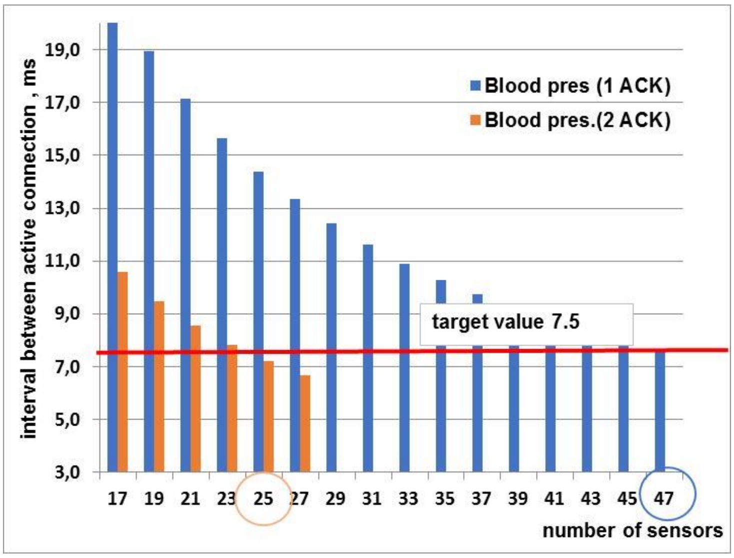


Figure 4.6 Maximum numbers of sensors for blood pressure application

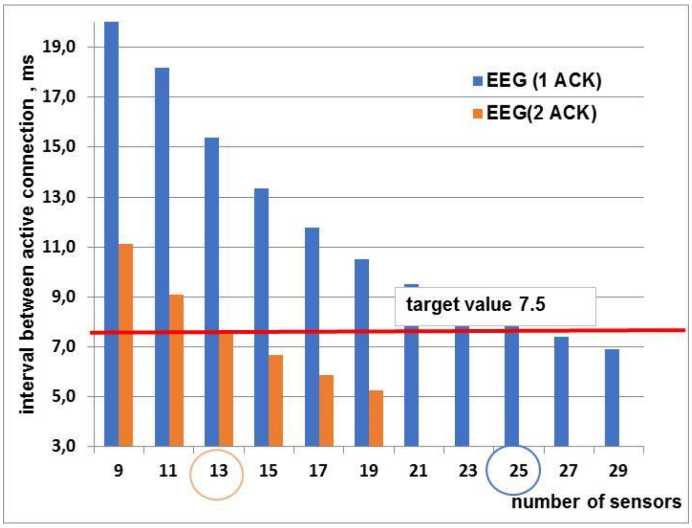


Figure 4.7 Maximum numbers of sensors for EEG application

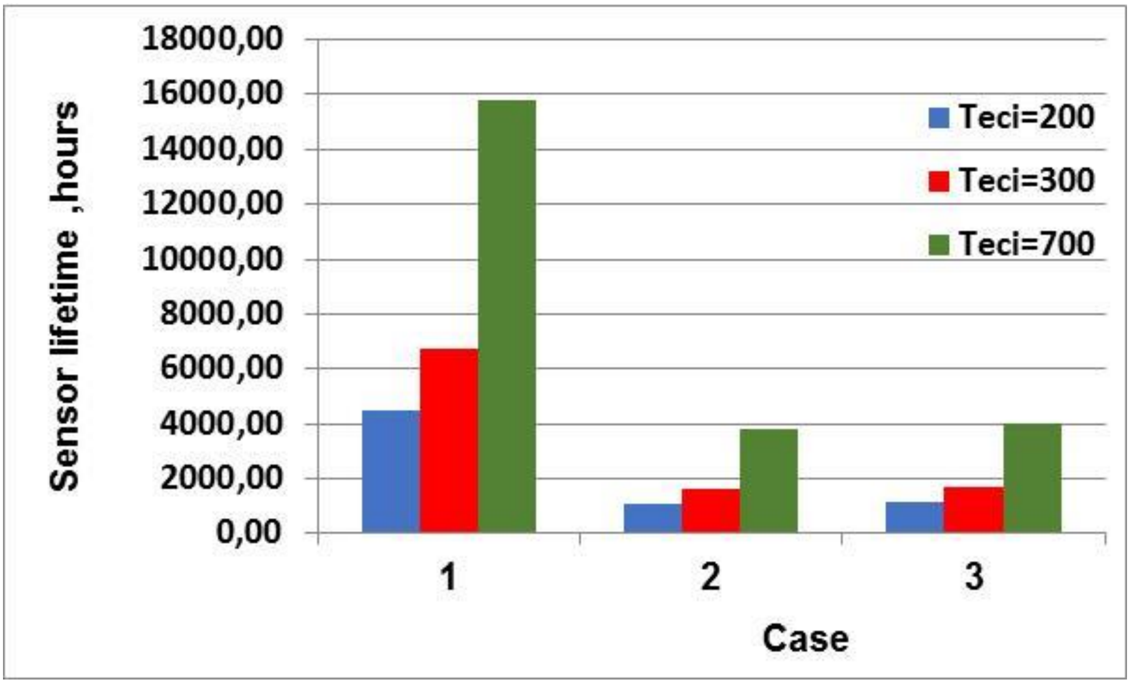


**Figure 4.8 Sensor lifetime in 3 case of signals transmission between a master and sensors**

In Figure 4.5, you can see that graph plot between interval between active connection and number of sensors minimum target time or value is 7.5. I have ECG, blood pressure and EEG sensors graph as shown in Figure 4.5, 4.6 and 4.7. you can see that how many minimum number of slaves can send the data at a time. For ECG application, you can send maximum 5 sensors data at a time with Ack 1 and 3 with Ack 2, for blood pressure application, you can send maximum 47 sensors data at a time with Ack1 and 25 sensors data with Ack2 and for EEG application, you can send maximum 25 sensors data at a time with Ack1 and 13 sensors data with Ack2.

Now in Figure 4.8, I have plot graph sensor life time with different interval between active connection (200ms, 300ms and 700ms). There are three cases of signal transmission between master and slave. In first case, maximum value at (T*eci*=700) is approximately 16000,00 hours lifetime of the sensors, but in second and third case, maximum value at (T*eci*=700) is approximately 4000,00 hours lifetime of the sensor. (T*eci*=200) value is less in every case as compared to others.

# 5 WBAN patient health monitoring

## 5.1 Prototype of health monitoring application

My system is the solution to monitor patient health from a remote area. I also have developed android based mobile application and PC through which the user(doctor/patient) can see that information in a chart. The doctor can monitor patients.

One of the first steps that every software developer should take before starting the implementation of the application is creating a prototype.

Use case diagram is the first step of software requirement analysis to final achievement, and it expresses how people use a system. Use case (Figure 5.1) shows users, what kind of service users require and services are offered by clients to the system.

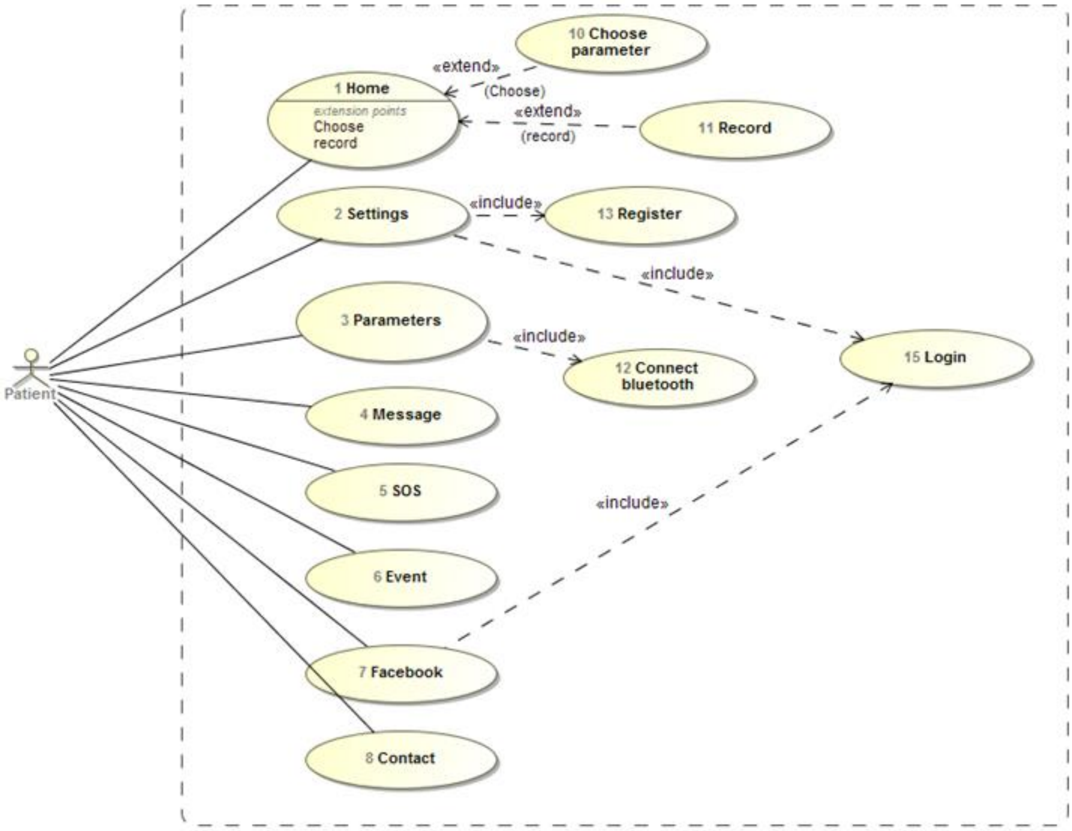


**Figure 5.1 Created mobile application "eHealth" use case diagram**

From Figure 5.1 it can be see that user can have 8 actions respectively, which include create account, login, record. The next step is creating sequence diagram. Sequence diagrams specify the dynamics of use cases in terms of interactions between system components. Sequence diagrams visualize objects communication in a sequence of messages. Our mobile application communication sequence diagram is shown in Figure 5.2.

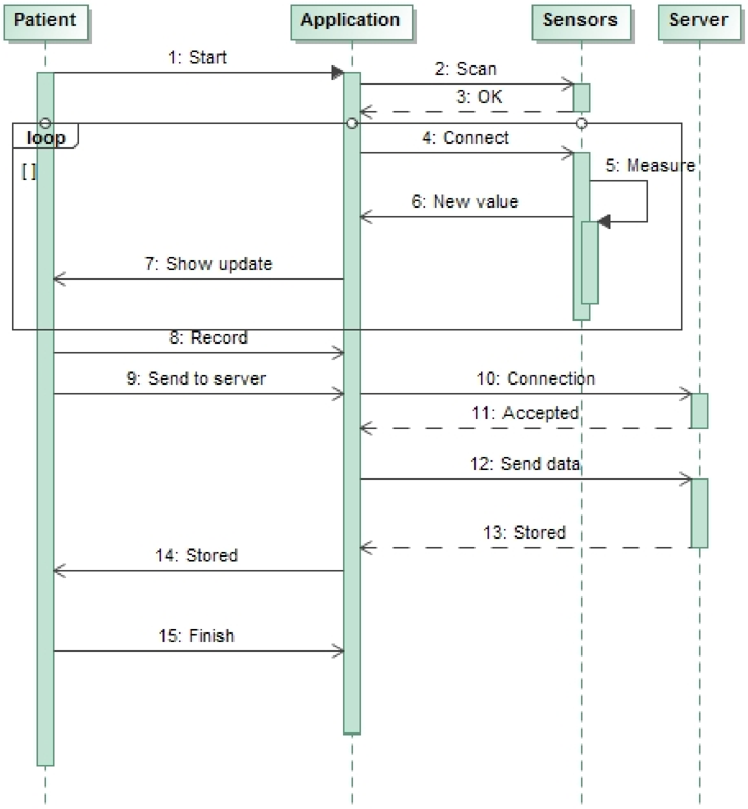


**Figure 5.2 Application communication sequence diagram**

With a sequence diagram, it is easier to understand the data and messages flow between the activity, manager, and service package objects. Prototyping is an important part of designing software applications and is often used in iterative processes. The prototyping phase is performed in many iterations where design concepts, ideas and requirements are explored. To create mobile application prototype was used program Mockplus. It is a fast-growing alternative for rapid prototyping. It is a desktop-based mockup tool allows you to create interactive mobile mockups. The main screen and features in this application is presented in Figure 5.3. As I can see, according use case diagram (Figure5.1) the application has 8 activities and integration communication connection Bluetooth.  The Main screen can redirect the user to:

- home,
- settings,
- parameters,
- message,
- SOS,
- event,
- Facebook,
- contact.

Figure 5.4 show, that patient can see the health parameter, which are measured using sensors. He can change which of parameter is main (in our case – pulse). All measure can be recording (puss RECORD). The Settings activity is shown in Figure 5.5. The Home screen is shown in Figure 5.4 and The settings view consists of 6 parts. There are two main parts: edit profile and connect to healthkit. Using this activity patient can see his common health level, daily and weekly. These parameters could be sent to remotes server manual or automatically. Before sending, patent need to be registered (Figure 5.6). The application features is flexibility of choosing and showing patient health parameters. Using the Parameters activity it is possible to change parameters, to see the dynamic of parameters on diferent type of charts. The sceen's vizualization is presented in Figure 5.7. Other activities screens are shown in Figure 5.8 and the created prototype of application helps to monitor patent health, send the parameters to remote server for doctor. If need arises, the patient can to have immediate help of professional doctor or hospital using SOS activity. Using this prototype was done real mobile application using Android studio software was done and implemented in smart phone.

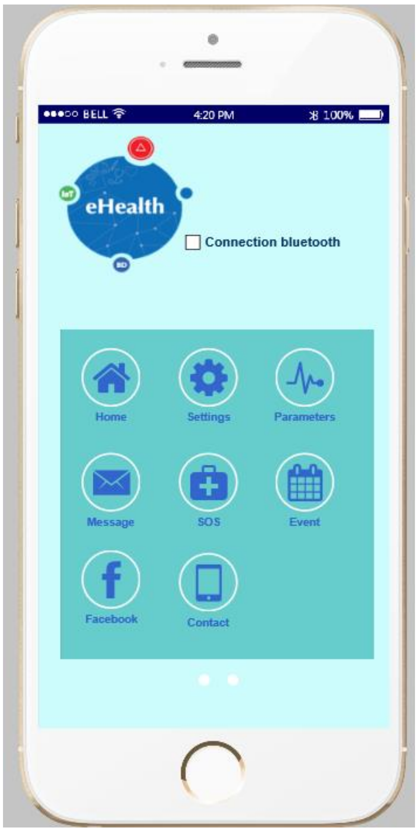


Figure 5.3 Application “eHealth” main screen

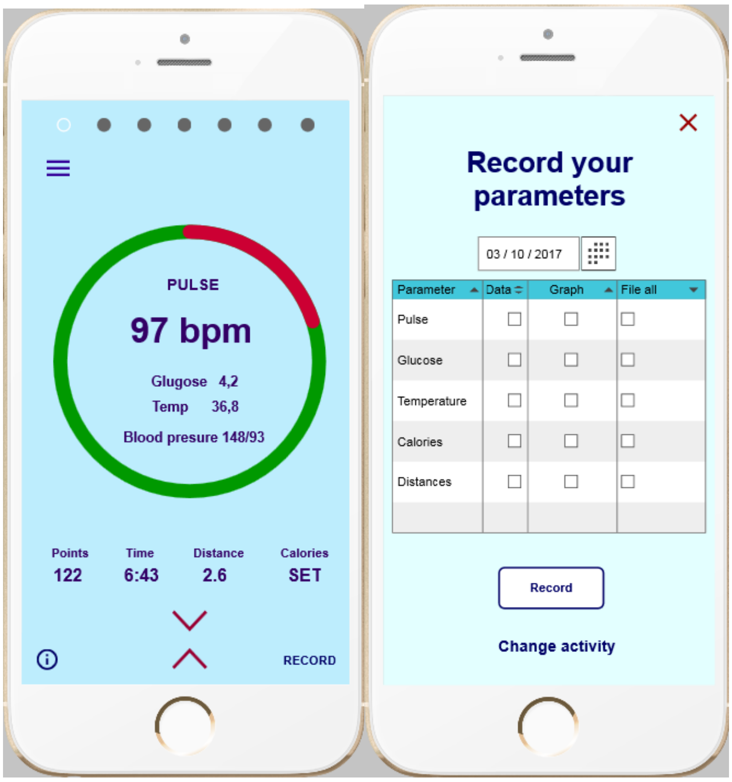


Figure 5.4 Home screen of the application “eHealth”

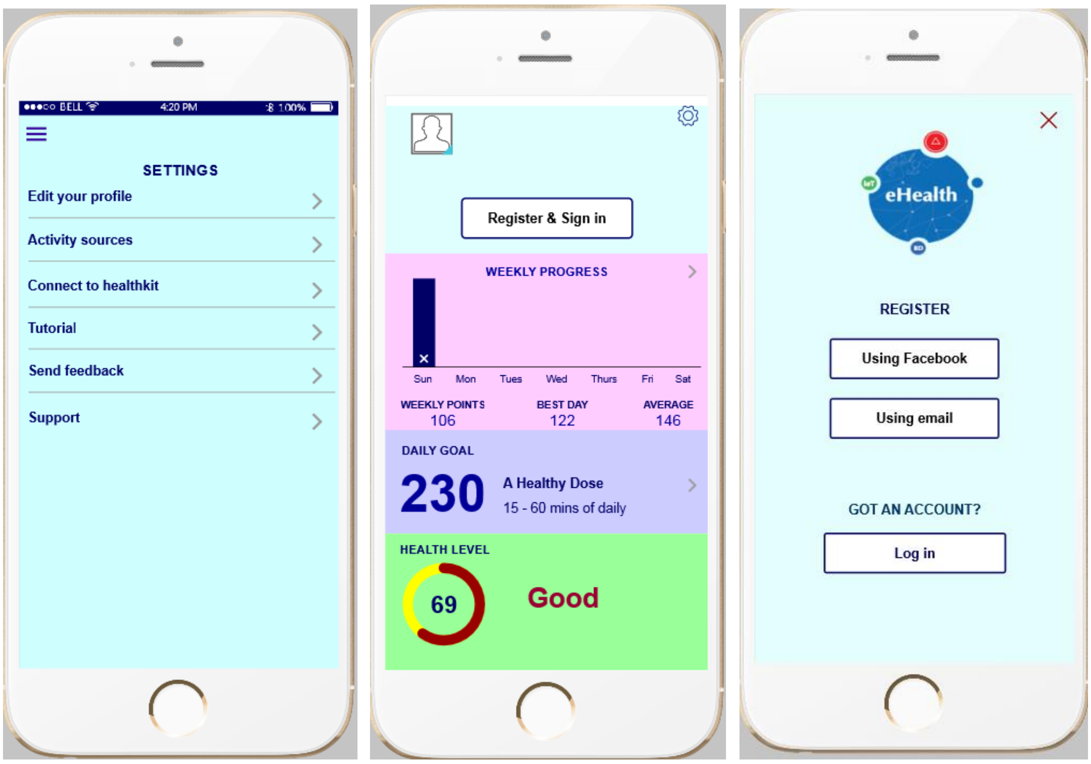


Figure 5.5 Settings screens of the application “eHealth”

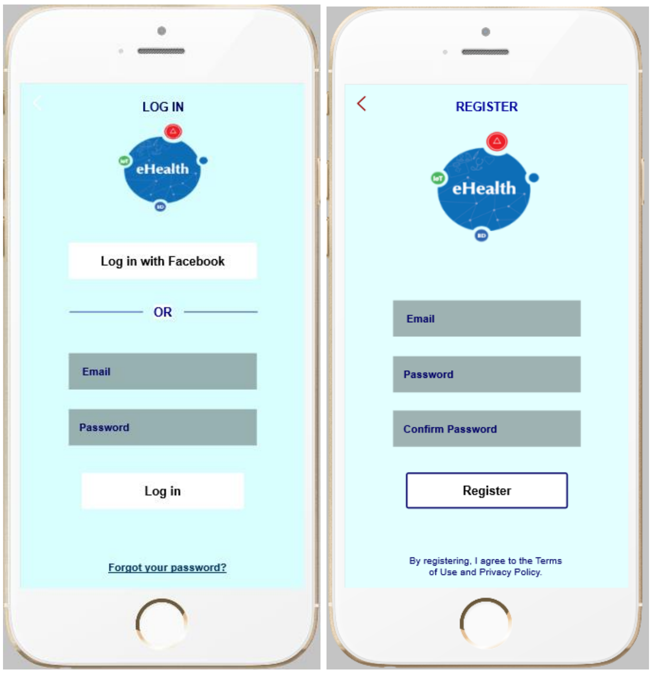
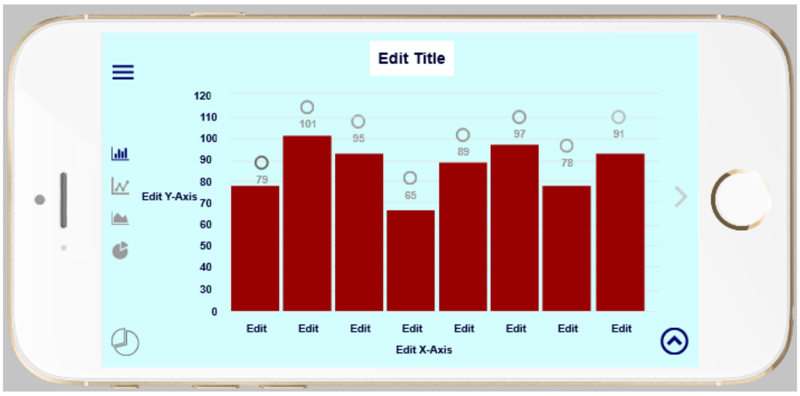


Figure 5.6 Login and register screens of the application “eHealth”



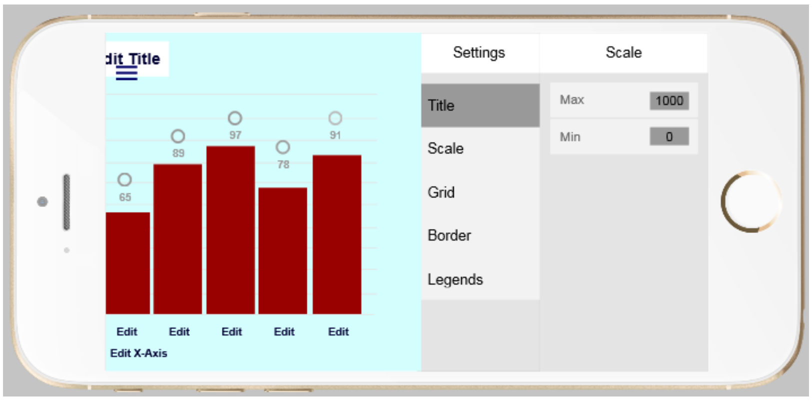
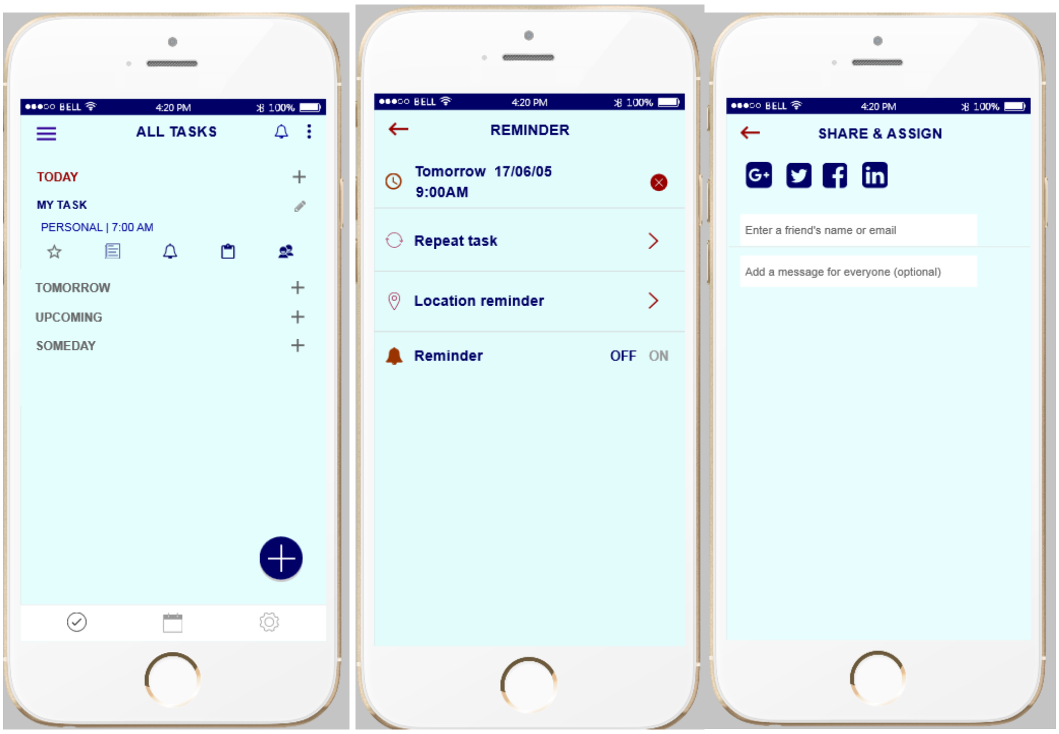
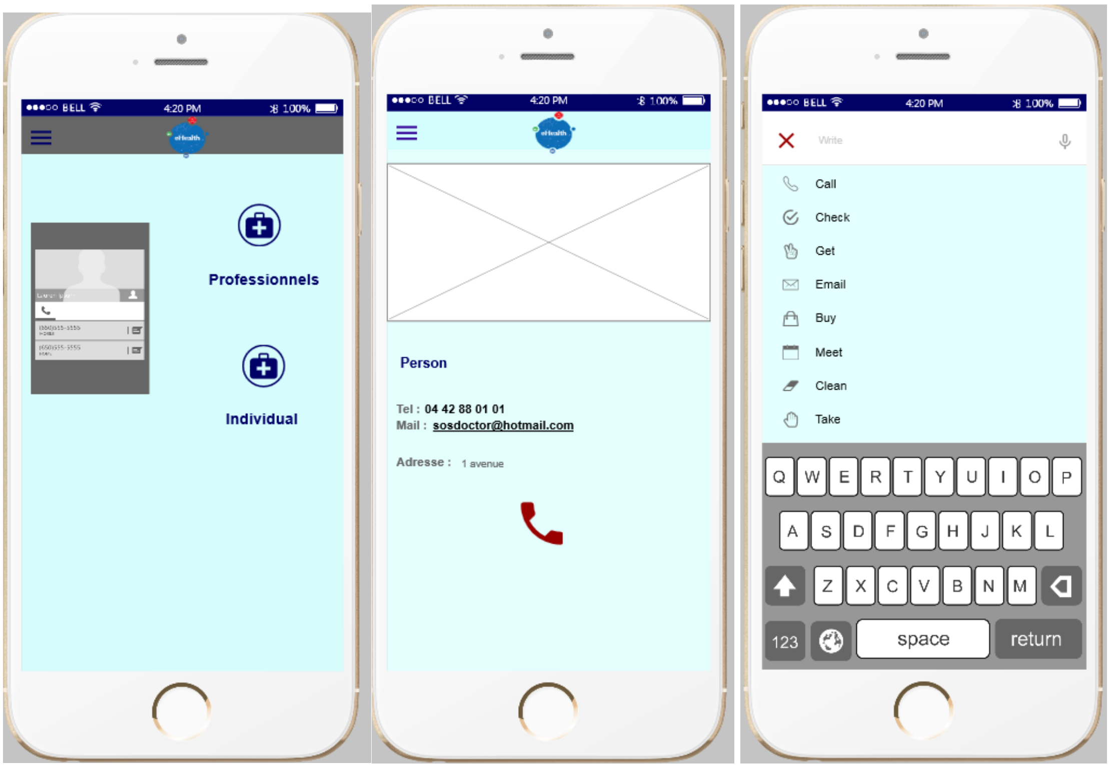


**Figure 5.7 Parameters screens of the application "eHealth"**



Tomorrow 17/06/05 9:00AM



Tel : 04 42 88 01 01
Mail : sosdoctor@hotmail.com
Adresse : 1 avenue

**Figure 5.8 Other screens of the application "eHealth"**

## 5.2 Sensors data monitoring via internet website using Wi-Fi module

The next step of this system research is sensors data monitoring via internet website. The flow chart of this process is shown in Figure 5.9 and the structure of connected scheme is presented in Figure 5.10

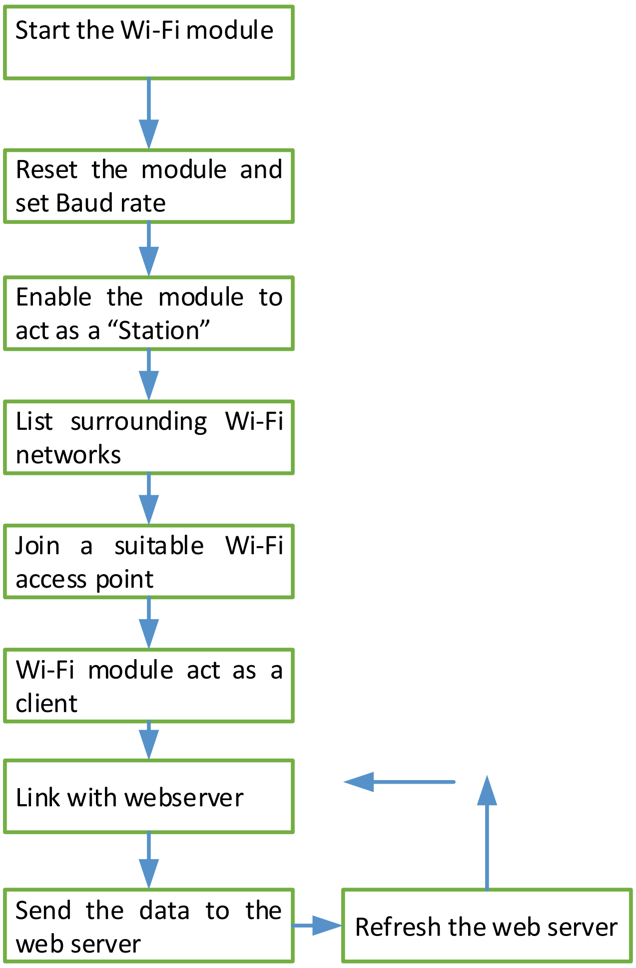


**Figure 5.9 The flow chart of sensors data monitoring via internet website**

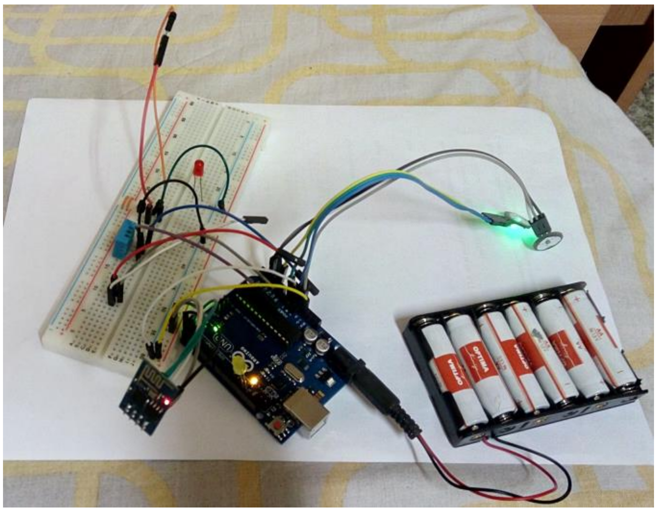


**Figure 5.10 Sensors WiFi connected scheme**

Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller. simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

"Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards, and the reference model for the Arduino platform for an extensive list of current, past or outdated boards see the Arduino index of boards.

The ESP8266 Wi-Fi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, meaning, you can simply hook this up to your Arduino device and get about as much Wi-Fi-ability as a Wi-Fi Shield offers (and that’s just out of the box)! The ESP8266 module is an extremely cost-effective board with a huge and ever-growing community.

The hardware connections required to connect to the ESP8266 module are straight-forward but there are a couple of important items to note related to power. The ESP8266 requires 3.3V power–do not power it with 5 volts. The ESP8266 needs to communicate via serial at 3.3V and does not have 5V tolerant inputs, so you need level conversion to communicate with a 5V microcontroller.

Connect sensors to the Arduino and send the data of the sensors to the internet website via ESP8266 module. I connect Wi-Fi ESP8266 module to Arduino and connect sensors to the Arduino. I collect sensor data and send the all data to the internet website. I used 5 sensors: ECG signal, Blood Pressure (BP), EEG, Body Temperature and EMG (Electromyogram).

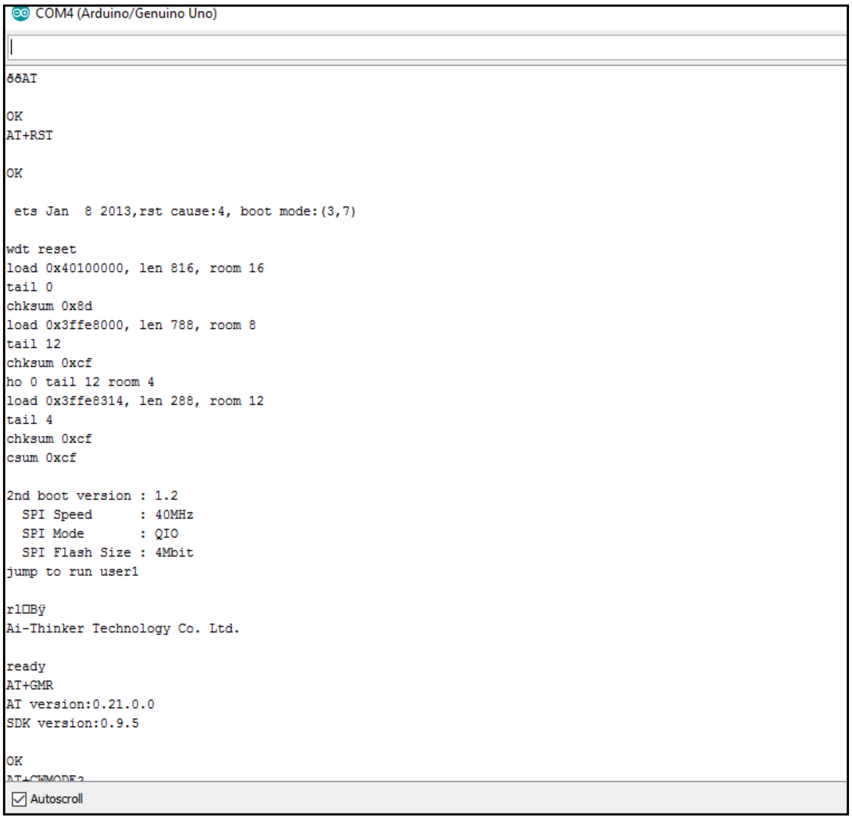
Now describe the steps, whose are shown in Figure 5.9.

1. Start Wi-Fi module

Connect Wi-Fi module to Arduino UNO also connect all sensors to the Arduino using Bread board. Install Arduino program and read the values of the sensors and start the Wi-Fi module. Check the module by sending AT command to the serial monitor if get OK reply means module is install properly and can star further.

2. Reset the module and set Baud rate

After start, the Wi-Fi module is sent AT+RST to reset the module and then Set the baud rate of the module using AT+CIOBAUD. Also check version of the module using AT+GMR.



```
ððAT

OK
AT+RST

OK

 ets Jan  8 2013,rst cause:4, boot mode:(3,7)

wdt reset
load 0x40100000, len 816, room 16
tail 0
chksum 0x8d
load 0x3ffe8000, len 788, room 8
tail 12
chksum 0xcf
ho 0 tail 12 room 4
load 0x3ffe8314, len 288, room 12
tail 4
chksum 0xcf
csum 0xcf

2nd boot version : 1.2
  SPI Speed      : 40MHz
  SPI Mode       : QIO
  SPI Flash Size : 4Mbit
jump to run user1

rl□Bÿ
Ai-Thinker Technology Co. Ltd.

ready
AT+GMR
AT version:0.21.0.0
SDK version:0.9.5

OK
AT+CWMODE?
```

3. Enable the module to act as a “Station”

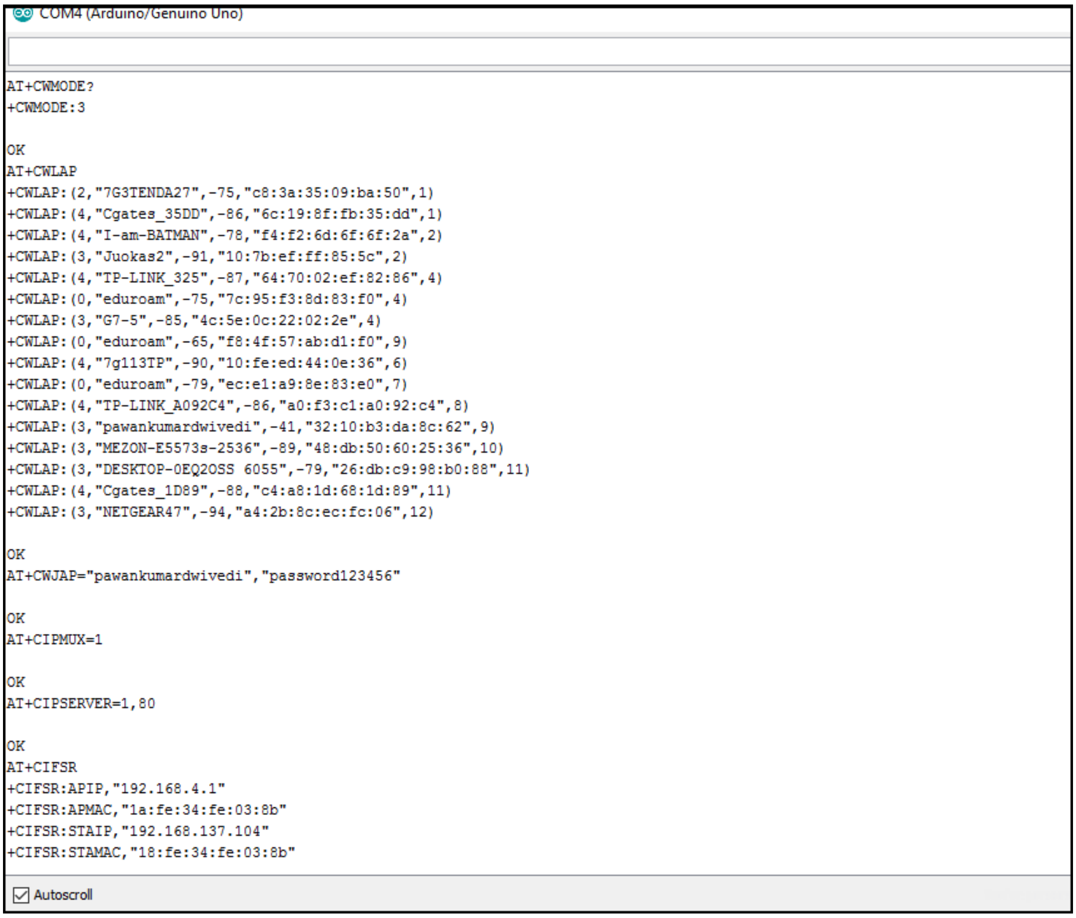
Module has 3 modes: “Station”, “Access Point” and Both “Station” and “Access Point”. In this case, I want to connect the module to the Access Point So, I switch the “Station” Mode by using AT+CWMODE=1.

4. List surrounding Wi-Fi networks

After enabling the module to “Station” mode, list all surrounding Wi-Fi networks by using AT+CWLAP. Check the network which one wants to connect.

5. Join a suitable Wi-Fi access point

To join a suitable Access point, use this command along with SSID and Password of the network AT+CWJAP="pawankumardwivedi","password123456". Here “pawankumardwivedi” is SSID of the network and “password123456” is password of the network. If you want to check your current IP address use AT+CIFSR command.



```
AT+CWMODE?
+CWMODE:3

OK
AT+CWLAP
+CWLAP:(2,"7G3TENDA27",-75,"c8:3a:35:09:ba:50",1)
+CWLAP:(4,"Cgates_35DD",-86,"6c:19:8f:fb:35:dd",1)
+CWLAP:(4,"I-am-BATMAN",-78,"f4:f2:6d:6f:6f:2a",2)
+CWLAP:(3,"Juokas2",-91,"10:7b:ef:ff:85:5c",2)
+CWLAP:(4,"TP-LINK_325",-87,"64:70:02:ef:82:86",4)
+CWLAP:(0,"eduroam",-75,"7c:95:f3:8d:83:f0",4)
+CWLAP:(3,"G7-5",-85,"4c:5e:0c:22:02:2e",4)
+CWLAP:(0,"eduroam",-65,"f8:4f:57:ab:d1:f0",9)
+CWLAP:(4,"7g113TP",-90,"10:fe:ed:44:0e:36",6)
+CWLAP:(0,"eduroam",-79,"ec:e1:a9:8e:83:e0",7)
+CWLAP:(4,"TP-LINK_A092C4",-86,"a0:f3:c1:a0:92:c4",8)
+CWLAP:(3,"pawankumardwivedi",-41,"32:10:b3:da:8c:62",9)
+CWLAP:(3,"MEZON-E5573s-2536",-89,"48:db:50:60:25:36",10)
+CWLAP:(3,"DESKTOP-0EQ2OSS 6055",-79,"26:db:c9:98:b0:88",11)
+CWLAP:(4,"Cgates_1D89",-88,"c4:a8:1d:68:1d:89",11)
+CWLAP:(3,"NETGEAR47",-94,"a4:2b:8c:ec:fc:06",12)

OK
AT+CWJAP="pawankumardwivedi","password123456"

OK
AT+CIPMUX=1

OK
AT+CIPSERVER=1,80

OK
AT+CIFSR
+CIFSR:APIP,"192.168.4.1"
+CIFSR:APMAC,"1a:fe:34:fe:03:8b"
+CIFSR:STAIP,"192.168.137.104"
+CIFSR:STAMAC,"18:fe:34:fe:03:8b"
```

6. Wi-Fi module act as a client

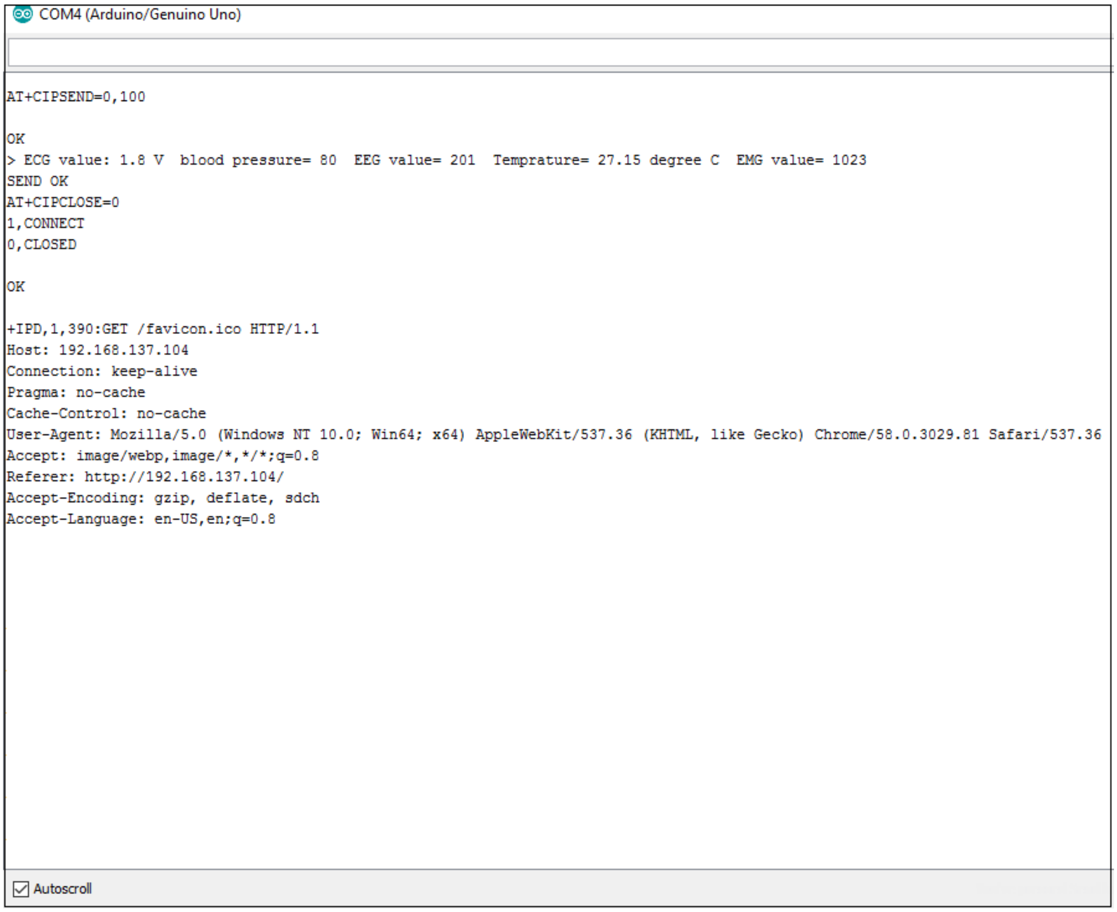
You can connect to an internet server after joining the Access Point. To enable multiple connections, use AT+CIPMUX=1.

7. Link with webserver

Specify which connection channel you wish to connect on (0-4), the protocol type (TCP/UDP), the IP address (or domain with DNS access) and the port number using the CIPSTART command: AT+CIPSTART=4,” TCP”,”192.168.137.104”,80. You should receive the response ok followed by Linked.

8. Send the data to the web server

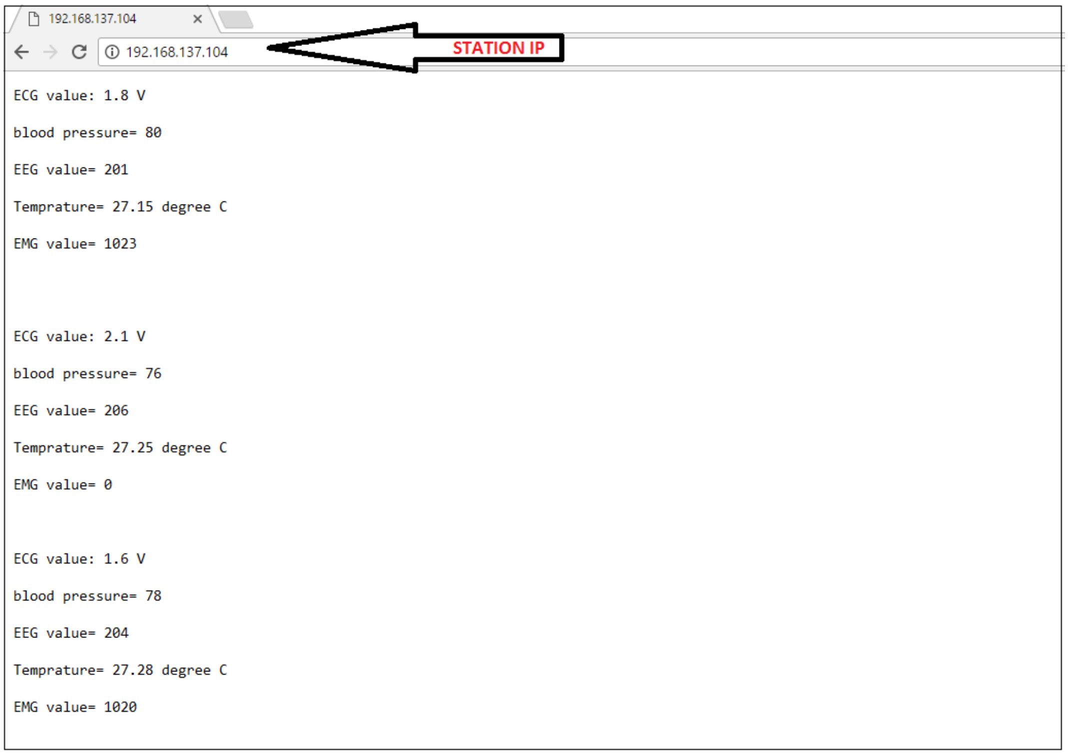
Next you need to specify how much data you wish to send (after specifying the channel) using the command AT+CIPSEND=0,100. This time, instead of an “OK” response you will get > prompt.



```
AT+CIPSEND=0,100

OK
> ECG value: 1.8 V  blood pressure= 80  EEG value= 201  Temprature= 27.15 degree C  EMG value= 1023
SEND OK
AT+CIPCLOSE=0
1,CONNECT
0,CLOSED

OK

+IPD,1,390:GET /favicon.ico HTTP/1.1
Host: 192.168.137.104
Connection: keep-alive
Pragma: no-cache
Cache-Control: no-cache
User-Agent: Mozilla/5.0 (Windows NT 10.0; Win64; x64) AppleWebKit/537.36 (KHTML, like Gecko) Chrome/58.0.3029.81 Safari/537.36
Accept: image/webp,image/*,*/*;q=0.8
Referer: http://192.168.137.104/
Accept-Encoding: gzip, deflate, sdch
Accept-Language: en-US,en;q=0.8
```

9. Refresh the web server:

You need to refresh the server to send the data again to the web server. After refresh, you will get the request from the web server to send the data again.



```
ECG value: 1.8 V

blood pressure= 80

EEG value= 201

Temprature= 27.15 degree C

EMG value= 1023



ECG value: 2.1 V

blood pressure= 76

EEG value= 206

Temprature= 27.25 degree C

EMG value= 0


ECG value: 1.6 V

blood pressure= 78

EEG value= 204

Temprature= 27.28 degree C

EMG value= 1020
```

After analyzing the Wi-Fi network and Security. The flow chart of security analysis is presented in Figure 5.11. This part was done on my internship Tomas Bata University in Zlín Czech, 2016 summer.

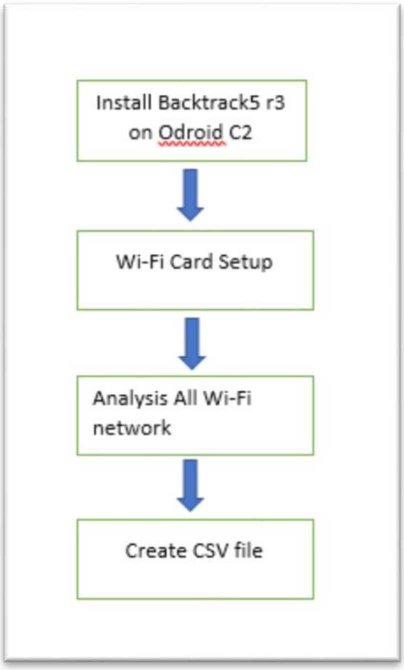


**Figure 5.11 Sensors WiFi flow chart of security analyzing**

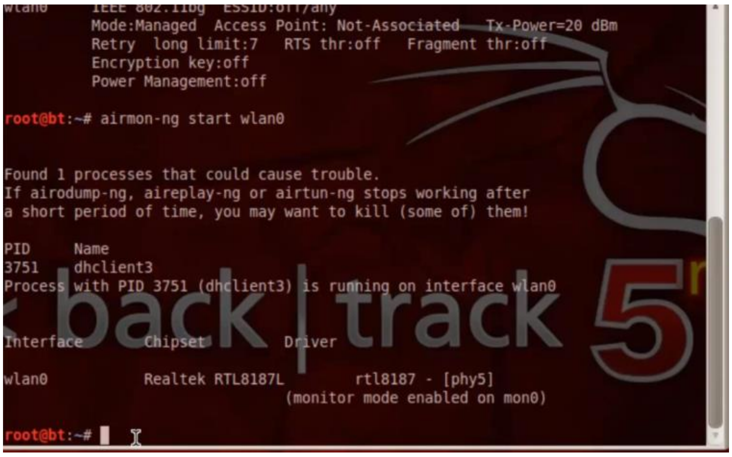
1. Install Backtrack5 r3 On Odroid C2

Download the ISO file of Backtrack5 r3 from internet and install it in the Odroid C2 SD card. After install backtrack5 r3 configure the operating system and insert Wi-Fi card into the Odroid C2.

2. Wi-Fi Card Setup

After insert Wi-Fi card switch Wi-Fi card into the monitor mode and change the mac address by using some Commands as mention below:

```
Ifconfig
ifconfig wlan0 down
macchanger -m 00:11:22:33:44:55 wlan0
ifconfig wlan0 up
iwconfig wlan0
airmon-ng start wlan0
iwconfig mon0
airdump-ng mon0
airdump-ng --bssid 00:23:69:98:AC:05 -c 4 -w hackwpa mon0
```



```
wlan0     IEEE 802.11bg  ESSID:off/any
          Mode:Managed  Access Point: Not-Associated   Tx-Power=20 dBm
          Retry  long limit:7   RTS thr:off   Fragment thr:off
          Encryption key:off
          Power Management:off

root@bt:~# airmon-ng start wlan0


Found 1 processes that could cause trouble.
If airodump-ng, aireplay-ng or airtun-ng stops working after
a short period of time, you may want to kill (some of) them!

PID     Name
3751    dhclient3
Process with PID 3751 (dhclient3) is running on interface wlan0


Interface       Chipset         Driver

wlan0           Realtek RTL8187L        rtl8187 - [phy5]
                                (monitor mode enabled on mon0)

root@bt:~# 
```

3. Analyze all Wi-Fi network structure

To analyze the Wi-Fi network, I have 4 stations, one Access point, and Odroid C2 with Wi-Fi card. All stations are connected to the Access point and Odroid C2 performs analysis of by using some commands. The structure of the network is shown in Figure 5.12

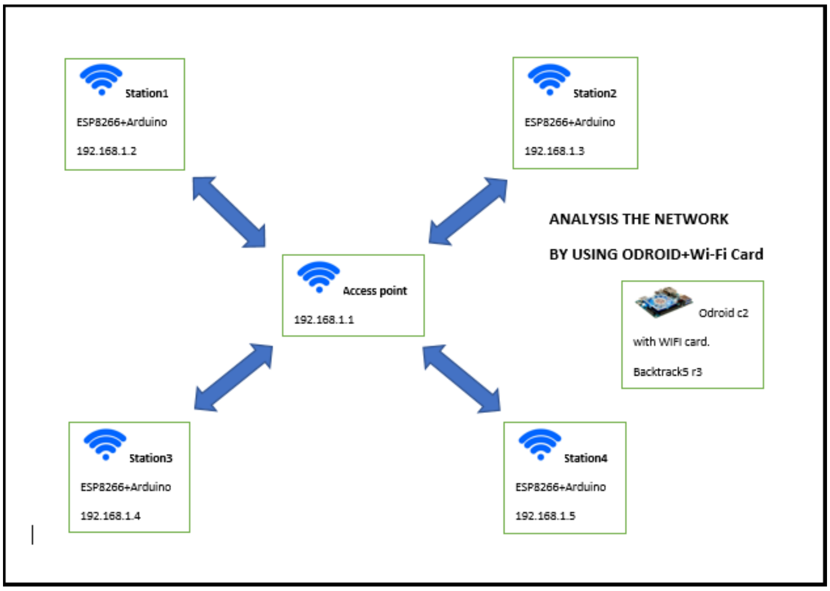
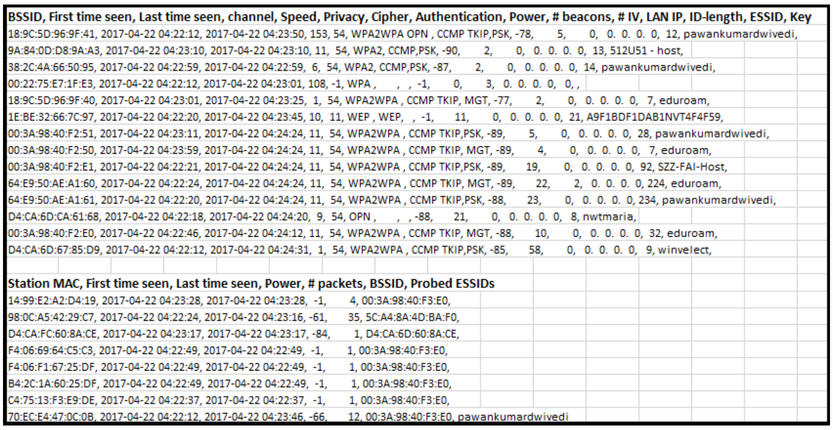


**Figure 5.12 Analyse the Wi-Fi network**

4. Network Details in CSV format



```
BSSID, First time seen, Last time seen, channel, Speed, Privacy, Cipher, Authentication, Power, # beacons, # IV, LAN IP, ID-length, ESSID, Key
18:9C:5D:96:9F:41, 2017-04-22 04:22:12, 2017-04-22 04:23:50, 153, 54, WPA2WPA OPN , CCMP TKIP,PSK, -78,       5,       0,   0.  0.  0.  0,  12, pawankumardwivedi,
9A:84:0D:D8:9A:A3, 2017-04-22 04:23:10, 2017-04-22 04:23:10, 11,  54, WPA2, CCMP,PSK, -90,       2,       0,   0.  0.  0.  0,  13, 512U51 - host,
38:2C:4A:66:50:95, 2017-04-22 04:22:59, 2017-04-22 04:22:59,  6,  54, WPA2, CCMP,PSK, -87,       2,       0,   0.  0.  0.  0,  14, pawankumardwivedi,
00:22:75:E7:1F:E3, 2017-04-22 04:22:12, 2017-04-22 04:23:01, 108, -1, WPA ,      ,   ,  -1,       0,       3,   0.  0.  0.  0,   0, ,
18:9C:5D:96:9F:40, 2017-04-22 04:23:01, 2017-04-22 04:23:25,  1,  54, WPA2WPA , CCMP TKIP, MGT, -77,       2,       0,   0.  0.  0.  0,   7, eduroam,
1E:BE:32:66:7C:97, 2017-04-22 04:22:20, 2017-04-22 04:23:45, 10,  11, WEP , WEP,   ,  -1,      11,       0,   0.  0.  0.  0,  21, A9F1BDF1DAB1NVT4F4F59,
00:3A:98:40:F2:51, 2017-04-22 04:23:11, 2017-04-22 04:24:24, 11,  54, WPA2WPA , CCMP TKIP,PSK, -89,       5,       0,   0.  0.  0.  0,  28, pawankumardwivedi,
00:3A:98:40:F2:50, 2017-04-22 04:23:59, 2017-04-22 04:24:24, 11,  54, WPA2WPA , CCMP TKIP, MGT, -89,       4,       0,   0.  0.  0.  0,   7, eduroam,
00:3A:98:40:F2:E1, 2017-04-22 04:22:21, 2017-04-22 04:24:24, 11,  54, WPA2WPA , CCMP TKIP,PSK, -89,      19,       0,   0.  0.  0.  0,  92, SZZ-FAI-Host,
64:E9:50:AE:A1:60, 2017-04-22 04:22:24, 2017-04-22 04:24:24, 11,  54, WPA2WPA , CCMP TKIP, MGT, -89,      22,       2,   0.  0.  0.  0, 224, eduroam,
64:E9:50:AE:A1:61, 2017-04-22 04:22:20, 2017-04-22 04:24:24, 11,  54, WPA2WPA , CCMP TKIP,PSK, -88,      23,       0,   0.  0.  0.  0, 234, pawankumardwivedi,
D4:CA:6D:CA:61:68, 2017-04-22 04:22:18, 2017-04-22 04:24:20,  9,  54, OPN ,      ,   , -88,      21,       0,   0.  0.  0.  0,   8, nwtmaria,
00:3A:98:40:F2:E0, 2017-04-22 04:22:46, 2017-04-22 04:24:12, 11,  54, WPA2WPA , CCMP TKIP, MGT, -88,      10,       0,   0.  0.  0.  0,  32, eduroam,
D4:CA:6D:67:85:D9, 2017-04-22 04:22:12, 2017-04-22 04:24:31,  1,  54, WPA2WPA , CCMP TKIP,PSK, -85,      58,       0,   0.  0.  0.  0,   9, winvelect,

Station MAC, First time seen, Last time seen, Power, # packets, BSSID, Probed ESSIDs
14:99:E2:A2:D4:19, 2017-04-22 04:23:28, 2017-04-22 04:23:28,  -1,       4, 00:3A:98:40:F3:E0,
98:0C:A5:42:29:C7, 2017-04-22 04:22:24, 2017-04-22 04:23:16, -61,      35, 5C:A4:8A:4D:BA:F0,
D4:CA:FC:60:8A:CE, 2017-04-22 04:23:17, 2017-04-22 04:23:17, -84,       1, D4:CA:6D:60:8A:CE,
F4:06:69:64:C5:C3, 2017-04-22 04:22:49, 2017-04-22 04:22:49,  -1,       1, 00:3A:98:40:F3:E0,
F4:06:F1:67:25:DF, 2017-04-22 04:22:49, 2017-04-22 04:22:49,  -1,       1, 00:3A:98:40:F3:E0,
B4:2C:1A:60:25:DF, 2017-04-22 04:22:49, 2017-04-22 04:22:49,  -1,       1, 00:3A:98:40:F3:E0,
C4:75:13:F3:E9:DE, 2017-04-22 04:22:37, 2017-04-22 04:22:37,  -1,       1, 00:3A:98:40:F3:E0,
70:EC:E4:47:0C:0B, 2017-04-22 04:22:12, 2017-04-22 04:23:46, -66,      12, 00:3A:98:40:F3:E0, pawankumardwivedi
```

## 5.3 Graphical user interface for health monitoring on PC

Visual Studio is a comprehensive collection of tools and services to help developers to create a wide variety of apps, both for the Microsoft platform and beyond. In Windows Forms, a form is a visual surface which displays information to the user. A control is a user interface element that displays data or accepts data input. A form can be enhanced with controls to create the appropriate user interface while adding code to manipulate data. The graphical user interface is designed by using Visual studio 2015, C# for displaying the sensor values of that place is shown in Figure 5.13. At first designed a login, register and configuration form for patient with unique Name and all patient data based on this I will create a database and store the patient health information. If you have login a user account after will fill other two activities, which are using for data sending and patient data base. When all activities are filled, user can connect to port and measure and collect sensor data (Figure 5.14). Applications have menu items that help to choose the desired action (Figure 5.15) and Every half an hour I will generate the patient's record are generated in web pages, can be send via email or txt. file to doctor and using menu "Show" can see the statistic and common health level ((Figure 5.16).

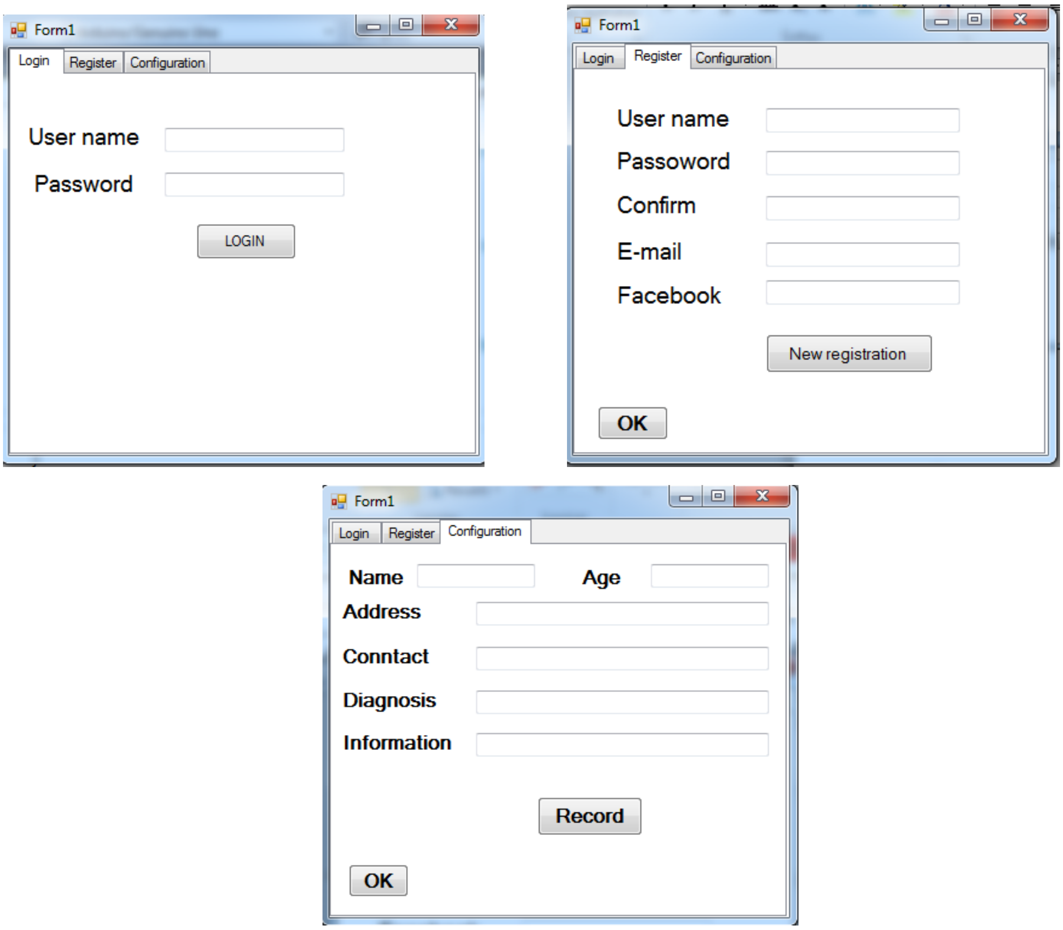


Figure 5.13 Screens of PC application "eHealth"

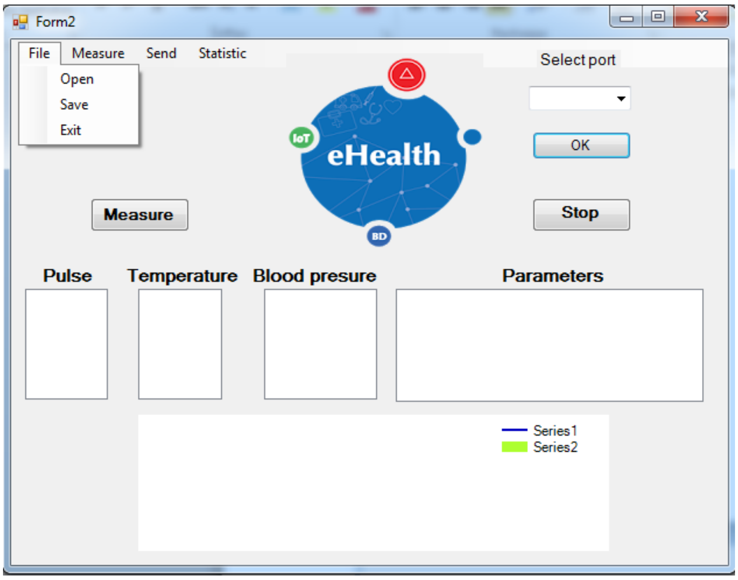


Figure 5.14 Main screen of PC application “eHealth”

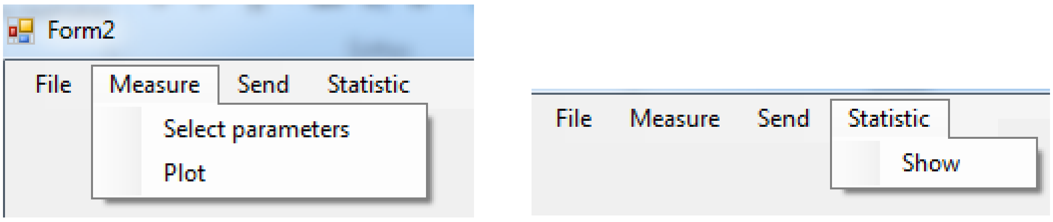


Figure 5.15 Menu screen of PC application “eHealth”

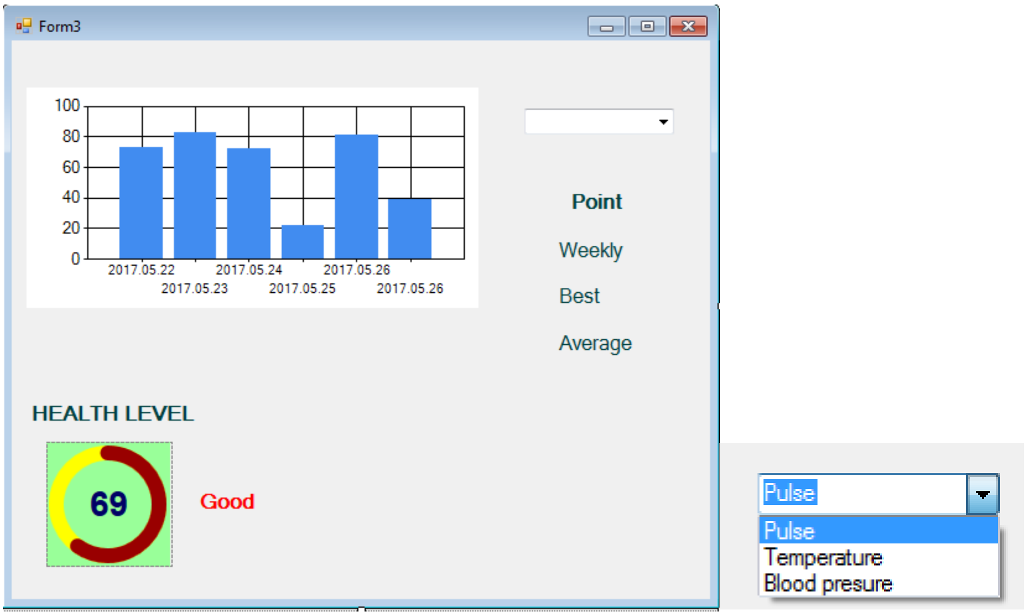


Figure 5.16 “Statistic” screen of PC application “eHealth”

# 6 Conclusion

1. In Bluetooth signal strength level experiment, there are three zones, Good zone- until 4 meters, accepted zone- until 8 meters and bad zone- more than 8 meters and Signal strength level increases suddenly because of reflection of the signal from the wall of the hospital as we go far from the Bluetooth device.
2. In Bluetooth signal strength level experiment, the Maximum signal level and minimum signal level of Bluetooth in air, glass door, wood door and wall medium are -48dBm to -94dBm, - 53dBm to -91dBm, -54dBm to -92dBm and -55dBm to -93dBm respectively.
3. In Bluetooth Experiment, Bad position area is back in every medium and good position area in air, glass door, wood door and wall medium are shoulder, head, chest and knee respectively. Also analyze mathematical model for each case.
4. In WBAN Bluetooth sensor energy consumption model, minimum number of slaves can send the data at a time, For ECG, we can send maximum 5 sensors data at a time with Ack1 and 3 sensors with Ack2 and for EEG application, we can send maximum 25 sensors data at a time with Ack1 and 13 sensors data with Ack2.
5. eHealth" application is designed and developed as prototype, for the desktop and mobile application.
6. Search of WBAN was investigate by perform analysis of the wi-fi network and which enable to detect the client connecting to the network and create the csv file with all details of the wi-fi network like, BSSID, ESSID, Authentication, beacons, power, channel, speed etc.

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