Integration of IoT And WBAN for Remote Health Monitoring

by

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19502

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by

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BANDAR SERI ISKANDAR, PERAK

SEPTEMBER 2016

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABDALLAH SADURDEEN KHAN

ABSTRACT

This paper aims at improving remote health monitoring systems that involves Wireless Body Area Networks (WBANs). The limitations of WBANs are analysed and an integration with Internet of Things (IoT) is proposed. The WBAN limitations that IoT could potentially resolve are mainly in the aspect of communication capabilities, computation and memory. A comprehensive integration framework between the two (2) systems is established. The Galvanic Skin Response (GSR) signal is the physiological data sample extracted from the WBAN to test all aspects of the integration framework – Data Extraction, Data Analysis and Cloud computing. The platinum Shimmer Kit is adopted for the WBAN subsystem and IoT is implemented via a Raspberry Pi 3. A successful integration of both systems will result in patients reducing their dependency on doctors and hospitals for routine medical check-ups since the patients required physiological date can be accessed and monitored remotely.

ACKOWLEDGEMENT

I would like to start off by thanking my supervisor Dr.Azlan B Awang for his endless support and contribution towards fulfilling this research. The flexibility and independence coupled with direction and motivation by my supervisor brought out the best in me.

I am grateful to my alma mater Universiti Teknologi PETRONAS (UTP) for providing me the platform, facilities and resources required to fulfil my tasks seamlessly. A special thanks to the Electrical and Electronic department of UTP for giving me the opportunity to utilise the laboratory for a period of seven months and also for the department lecturers and staff for the never hesitating to assist when called upon.

I'll be failing in my duties if not for my parents and family who sacrificed, prayed and inspired me to go the extra mile throughout my tenure in UTP. I'm indeed internally grateful to them.

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ABBREVIATIONS AND

NOMENCALTURES

FYP	Final Year Project
UTP	Universiti Teknologi PETRONAS
WBAN	Wireless Body Area Network
IoT	Internet of Things
WSN	Wireless Sensor Network
GSR	Galvanic Skin Response
API	Application Program Interface
OS	Operating System
GUI	Graphical User Interface
WLAN	Wireless Local Area Network

CHAPTER 1

INTRODUCTION

1.1 Background

Throughout the years, patients have been queuing up in hospitals and clinics to consult with doctors to monitor physiological tests like GSR, ECG, respiratory rate, blood pressure, heart rate etc. Travelling for routine check-ups and doctor consultation can be avoided by further study of remote health monitoring.

Wearable wireless body area sensor networks (WBANs) along with mobile phones have been recognised for their potential in rehabilitation of elderly and for obtaining information about elements such as patient's movement [1].WBAN Remote health monitoring assists doctors in tracking medical conditions of patients remotely. This enables patients to continue routine chores whilst under continuous remote monitoring via WBAN systems that can be accessible to medical specialists. In case of any abnormalities the system can notify the doctor or hospital for a prevention or counter measure. Physiological data monitoring for physical and mental health by wearable sensors collects rich data that if captured frequently, enhanced and improved can revolutionize the health industry.[2]

WBAN is well suited for real-time data capturing and processing in addition to being a reliable tool for continuous remote health monitoring [3] . WBAN systems contain tiny sensor nodes that monitors and then transmits data via Bluetooth or radio waves to a specified destination. The data is then interpreted to determine the exact condition of the patient. Un-interpreted data would only be understood by medical experts at a specified location. To render WBAN systems more user-friendly and personal for patients, this study looks at the possibility of integrating Internet of Things (IoT) to transfer the transmitted data to a server that can be accessed by a micro controller or a mobile device for computation and processing. This will be ultimately synced with the patient's electronic devices like mobile phones, computers, wearables etc. As a proof of concept galvanic skin response (GSR) signals that monitors stress levels is selected as the study sample.

This study focuses on integrating IoT technology to further increase the efficiency of remote health monitoring by adding location independency, improved communication capabilities and cloud computing for storage of physiological data that can be accessed at any time anywhere.

The core study of this project is to develop a framework upon conducting an integration study between WBAN and IoT that will pave way to revolutionize remote health monitoring in a world evolving around the internet.

1.2 Problem Statement

An **aging population** and **rising health costs** demands WBANs **to increase user independence** so the health condition of patients can be monitored **anytime, anywhere** without the need to see a doctor.

There is a need to develop a system that can display the captured data from WBANs sensor nodes so as to render the data useful. This requires the interfacing and sync between the physical devices and WBAN system that combines both the functionalities of computing and communication (IoT).

1.3 Objectives

- To explore the capabilities of WBAN and IoT for the purpose of remote health monitoring.
- To use Galvanic Skin Response readings to establish a framework that serves as a remote health monitoring model for the integration of WBAN and IoT systems.

CHAPTER 2

LITERATURE REVIEW

In this literature review the two main components of interest to facilitate remote health monitoring – Internet of things (IoT) and Wireless Body Area Network (WBAN) were studied. The underlying concepts, functionalities and thought processes behind IoT and WBAN were paid extra attention to in order to determine a feasible integration strategy and loopholes within WBAN to justify the proposed concept of the IoT integration

2.1 Wireless Body Area Network (WBAN)

Wireless Body Area Network (WBAN) is designed with an array of unique sensor networks that operates independently to connect medical sensors within a human body [4]. The two (2) major advantages of WBAN system compared to the conventional way of patient observation systems are patient mobility due to the portable devices and secondly it provides location independent monitoring facility [4]. WBAN is made up of small sensor nodes and a getaway node that communicates with the external database server such as standard telephone networks, mobile phone networks, hospital network via the Wireless Local Area Network (WLAN) [4]. Figure 1 describes a WBAN wearable sensor for remote healthcare monitoring.

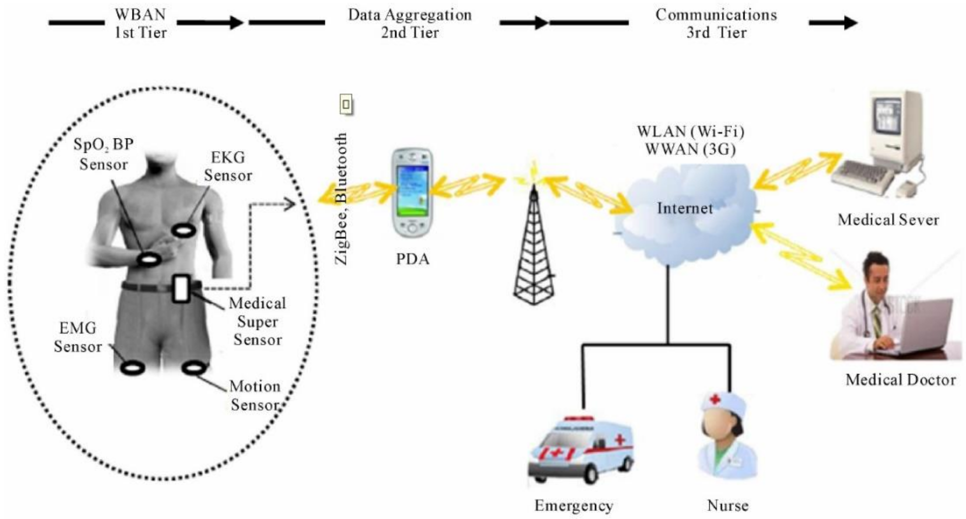


Figure 1 Overview of a remote healthcare monitoring system [3]

2.2 WBAN in Medical Applications

Sensor nodes are implanted beneath the skin, on clothes or directly on the skin to measure the heart rate, blood pressure, temperature, ECG, EEG, respiratory rate, Sp02 levels etc. [5]. This can help patients that require long-term monitoring for chronic conditions, for early detection of emergency conditions or for post-surgery recovery observations [6, 7]. The data collected from the patients can be stored in a centralised location that will serve as a permanent record that can be accessed by physicians [8]. If the condition is critical the WBAN can be commanded to alert or notify the patient via text message, alarm etc. Fig.2 illustrates a sample WBAN connections in a human system. The number of sensor nodes and its position is determined based on the required monitoring specifications.

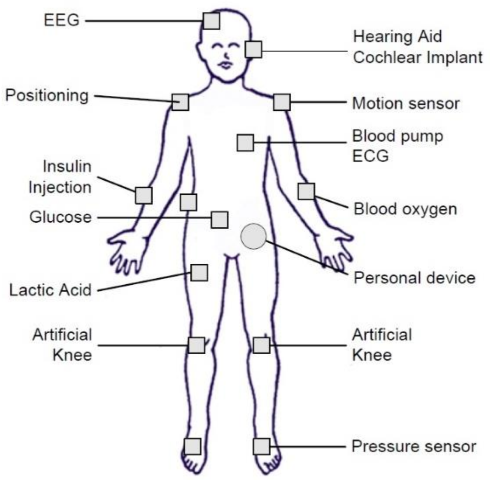


Figure 2 Example of Patient monitoring in a WBAN [6]

Application	Data Rate	Bandwidth	Accuracy
ECG (12 leads)	288 kbps	100-1000 Hz	12 bits
ECG (6 leads)	71 kbps	100-500 Hz	12 bits
EMG	320 kbps	0-10,000 Hz	16 bits
EEG (12 leads)	43.2 kbps	0-150 Hz	12 bits
Blood saturation	16 bps	0-1 Hz	8 bits
Glucose monitoring	1600 bps	0-50 Hz	16 bits
Temperature	120 bps	0-1 Hz	8 bits
Motion sensor	35 kbps	0-500 Hz	12 bits
Cochlear implant	100 kbps	–	–
Artificial retina	50-700 kbps	–	–
Audio	1 Mbps	–	–
Voice	50-100 kbps	–	–

Figure 3 Examples of Medical WBAN Applications [6]

[9] Highlights a medical discipline WBAN can help contribute to:

Heart Diseases

Heart diseases accounts for the highest number of deaths in the developing world [10]. Cardiovascular diseases include heart attack, heart failures, strokes and coronary artery disease. The World Heart Organization states [11] states that 17 million (30%) of the mortalities in this world is due to heart failures. About half of them die within an hour after symptoms and before reaching the hospital. WBANs real-time health monitoring of cardiovascular patients by recording physiological data that can be viewed by the specialists for early diagnosis or intervention when necessary[9].

WBAN systems also play a role in the treatment of Asthma, Cancer detection, Diabetes and Artificial Retina [12].

2.3 Wireless Sensor Networks (WSNs) & Wireless Body Area Network (WBAN)

WSN is a network of nodes connected wirelessly in a multi-hop that contains its own independent sensing unit, memory, Microcontroller, power source and wireless communication network [9]. When such sensor nodes are specifically placed in the human body in a group it gives rise to a WBAN [9]. WBAN systems require a strong communication between the WBAN nodes as opposed to the redundant and ad-hock WSN nodes [8]. More key difference are as follows [8]

- WBAN systems are compact and is void of redundant devices. All nodes should be long lasting, precise and dependable. Each node is independent and cannot retrieve lost data from other nodes
- Data loss is a common phenomenon in WBAN due to its operation environment (Human body). This occurs due to the lossy medium in the implanted sensors that will compel the signal to be attenuated. WSN sensors can complement each other to avoid data loss.
- The tiny sensors in WBAN makes it impossible for it be recharged thus will require a longer lifetime compared to WSN sensors which are larger in size and can be recharged.

Figure 3 illustrates a more broader comparison between WBAN and WSN according to [13]

Challenges	Wireless Sensor Network	Wireless Body Area Network
Scale	Monitored environment (meters / kilometers)	Human body (centimeters / meters)
Node Number	Many redundant nodes for wide area coverage	Fewer, limited in space
Result accuracy	Through node redundancy	Through node accuracy and robustness
Node Tasks	Node performs a dedicated task	Node performs multiple tasks
Node Size	Small is preferred, but not important	Small is essential
Network Topology	Very likely to be fixed or static	More variable due to body movement
Data Rates	Most often homogeneous	Most often heterogeneous
Node Replacement	Performed easily, nodes even disposable	Replacement of implanted nodes difficult
Node Lifetime	Several years / months	Several years / months, smaller battery capacity
Power Supply	Accessible and likely to be replaced more easily and frequently	Inaccessible and difficult to replaced in an implantable setting
Power Demand	Likely to be large, energy supply easier	Likely to be lower, energy supply more difficult
Energy Scavenging Source	Most likely solar and wind power	Most likely motion (vibration) and thermal (body heat)
Biocompatibility	Not a consideration in most applications	A must for implants and some external sensors
Security Level	Lower	Higher, to protect patient information
Impact of Data Loss	Likely to be compensated by redundant nodes	More significant, may require additional measures to ensure QoS and real-time data delivery.

Figure 2 Schematic overview of the differences between WSNs and WBAN [10]

2.4 Galvanic Skin Response using Sensor Network

GSR is a measure of skin conductance. The conductance values from the GSR sensor will depend on the amount a person sweats which is directly proportional to the conductance hence lowering the resistance [14].

2.5 Internet of Things (Iot) In the Health Sector

The introduction of IoT in the health sector paves way for new monitoring standards, investigation and treatment due to improved connectivity of systems to the internet[15]. Therefore one of the widely used applications of IoT is in the health care industry.

It further enhances the endless possibilities of the growing remote and mobile health industry [16]. The pie chart below indicates that by 2020 Healthcare would hold the highest market shares for IoT Applications at 16%.

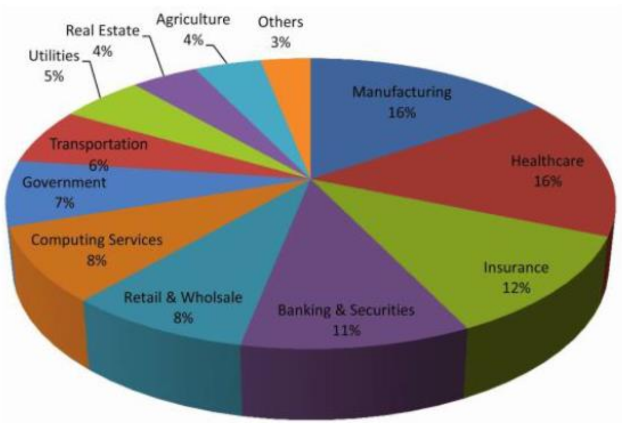


Figure 3 Estimate percentage of IOT Application Market Shares by 2020[17]

RFID tags, Medical Devices (Sensor Nodes, Equipment), smart phones, wearables devices constitutes to the IoT environment that are connected to each other via unique identifiers. Communication takes places within these devices remotely and data is transferred giving rise to the extraction of new data [16]. The retrieved data from remote health monitoring is monitored in real time via intelligence algorithms to identify patterns and have different warning signs (Emergency, normal, Cautious) when required. The data received by the 1000s of patients will account for a huge data volume. With the help of IoT, this big Data can be saved in a server that can be accessed by the relevant stakeholders such as patients, family members, doctors, emergency unit, office etc.

2.6 IoT System Architecture for Remote Health Monitoring

According to [18] , there are two (2) main architectures for remote health monitoring through bio-medical signal. The first architecture implements wireless sensor network based on low-power ZigBee, while the second implements IP-based wireless sensor network using Wi-Fi.

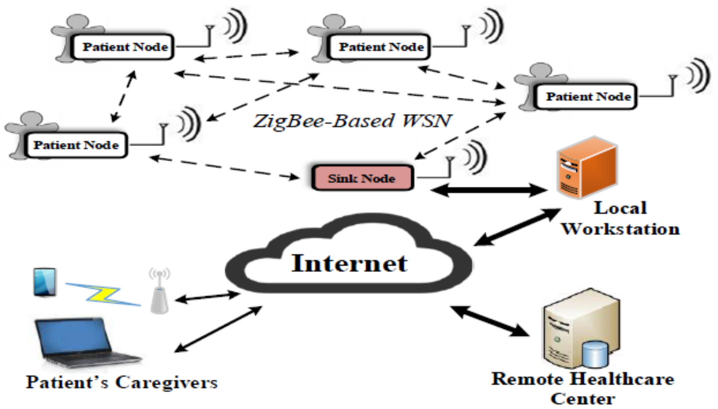


Figure 4 ZigBee Based Health Monitoring System [13]

Based on the low-rate IEEE 802.15.4 standard, ZigBee is specifically designed to be in the lower end of Power, cost and data rate applications. It consists of Patient and Sink Nodes. ZigBee is compatible with Arduino based microcontrollers. There are 4 main areas in this architecture- sensor interface, WSN implementation, database application and webserver application [18].

Sensor interface: Consists of an E-Shield which acts as a medium between the Zigduino (MicroController) and Medical Sensors. Data measured from various sensors are collected by the Zigduino board via the E-health shield.

WSN implementation: Using the on chip radio (2.4 GHz IEEE 802.15.4) in the microcontroller it implements the WSN system which collects data from various sensors (Client) and send wirelessly over ZigBee to the sink (server) node.

Database application: Collected Data is saved in a remote database using a python script from the Sink (Server) node via a computer.

Webserver Application: Web-server application written with PHP accesses the database and updates the web page in real time to be accessed by the relevant stakeholders through their smart phones or computers.

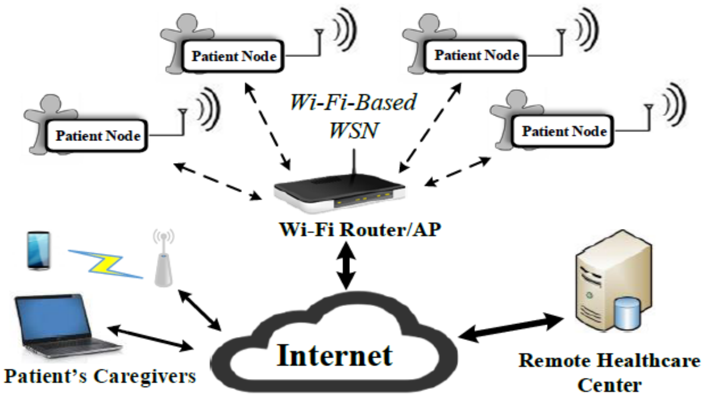


Figure 5 Wi-Fi Based Health Monitoring System [13]

The Wi-Fi based architecture consists of Wi-Fi enabled sensor nodes and Wi-Fi access points (Router). The sensor nodes (Patient node) are designed using an Analog Front-End (AFE, ADS1192 from Texas Instruments, [8]) and Wi-Fi module (RTX4140 Wi-Fi module, [9]). The RTX module is provided with proprietary operating system (ROS). Processor used in the Wi-Fi module is EFM32GG230F1024. The architecture (Figure 5) can be divided into four sections; sensor interface, WSN implementation, database application and webserver application [18].

Sensor interface: Implemented using the AFE to read data from the medical sensors and perform analog to digital conversion. The digital data from the output of AFE is read by RTX4140 through SPI (Serial Peripheral Interface).

WSN implementation: A UDP (User Datagram Protocol) client application running on the RTX4140 sends the UDP data packet to a remote server through Wi-Fi, once the connection to the Wi-Fi access point is established.

Database application: A UDP server application (running on a remote system), written in python, continuously listens to the UDP port, collects the incoming data and updates a remote database.

Webserver application: Web-server application written with PHP accesses the database and updates the web page in real time to be accessed by the relevant stakeholders through their smart phones or computers. (Same as ZigBee)

Based on the research conducted and the comparison study between WBAN systems and IoT, both have many concepts in common and are complementary. What WBAN lacks on its own is the storage of big data received by the nodes and providing real-time data analysis while making this information readily accessible by the patient. Cloud storage in IoT platforms and remote connectivity are the two (2) integration elements in this research. This research hopes to integrate both systems successfully and develop an efficient data analysis system whilst enabling the user to have reduce dependency on doctors/hospitals with an enhanced user experience system.

CHAPTER 3

METHODOLOGY

This section lists down the proposed research methodology to meet our required objectives in the given timeframe. The sample selected to actualize the integration between IoT and WBAN is the GSR signal. A quantitative approach is deemed most appropriate to establish the integration framework.

3.1 System Methodology

The chart below illustrates the various steps of the integration process. Each step is explained in detail from the background study till the final system integration.

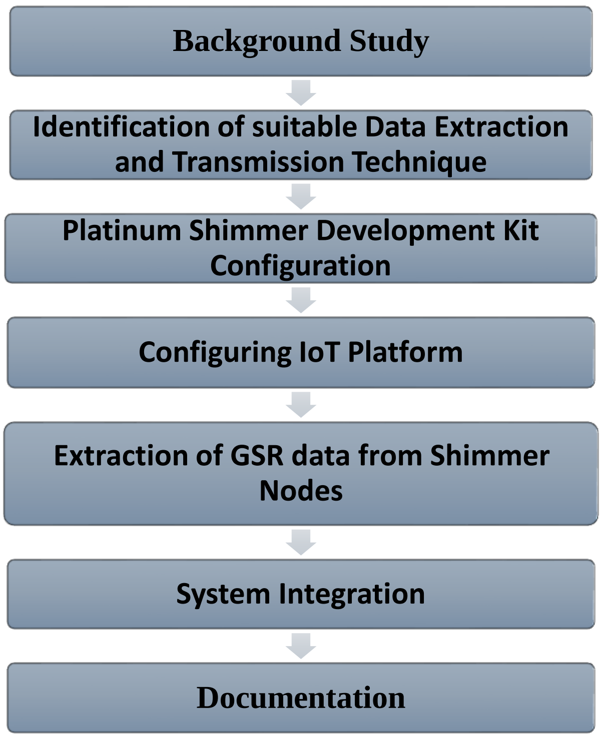


Figure 6 Integration Process Chart

Background Study

An in-depth background study has to be conducted to understand the existing application and working structure of WBAN and IOT in the field of remote health monitoring. Both systems have similarities which makes it crucial to understand the functionalities, challenges and strengths of the each system. The study focuses on the limitations of WBAN to function independently justifying the need to utilize components from the IoT platform. For data interpretation purposes previous studies involving GSR signals are recorded for a comparison study to the GSR data extracted from this research.

Identification of suitable Data Extraction and Transmission Technique

A WBAN system is required for data extraction. The platinum shimmer kit is selected for the process. The platinum shimmer kit consists of a wide range of sensor nodes capable of extracting over fifteen different physiological data including GSR data. The extracted data is processed and sent to the internet through the raspberry Pi 3.

Platinum Shimmer Development Kit Configuration

Data extraction will be via Platinum Shimmer development Kit. The tiny sensor nodes has to be tested and suitable locations should be identified to record accurate readings. GSR samples require two electrodes that is positioned across two fingers connected to a central sensor node.

Configuring IoT Platform

The raspberry Pi 3 microprocessor has to be configured initially with the shimmer kit to ensure smooth and efficient data transfer. The Bluetooth channel is setup and a secure Wi-Fi connection is established. For data interpretation and instance computation, a suitable algorithm should is devised and implemented using python.

Extraction of GSR data from Shimmer Nodes

GSR data is recorded from one sample in a range of environments like when the patient is relaxed, focused, stresses and anxious. The data is sent to the raspberry pi and tabulated prior to transmitting it to the cloud server for storage and analysis.

System Integration

Transmission of the GSR data from the raspberry pi to the IoT platform completes the integration. The IoT platform in this system is Thingspeak. The data is mapped graphically to be viewed by the patient, doctors or hospitals remotely.

Documentation

The results of the process is recorded after each transmission attempt. Each significant step and findings will be recorded to facilitate further research.

3.2 Framework Architecture

The integration design is divided into four subsystems; Wireless Body Area Networks (WAN), Data extraction technique, data transmission method and IoT adaptation. The overview of the system architecture is described in Figure 7

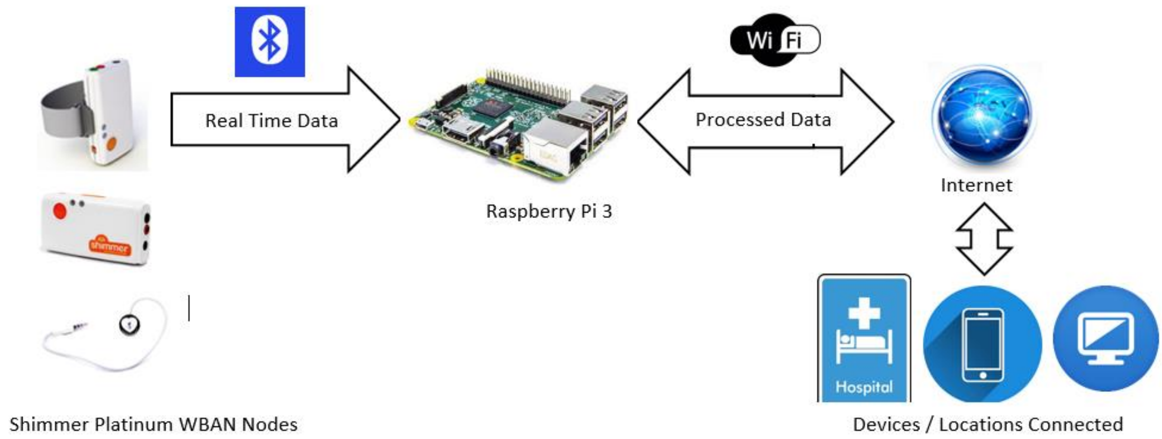


Figure 7 Framework Architecture

3.3 Hardware, Software and Tools Used

3.3.1 Hardware Components

3.3.1.1 Raspberry Pi 3

Figure 8 Raspberry Pi 3 [Source: https://www.raspberrypi.org/]

For IoT implementation, the Raspberry Pi 3 Model B was selected. The Raspberry Pi 3 is equipped with 2.4 GHz WiFi 802.11n (150 Mbit/s) and Bluetooth 4.1 (24 Mbit/s) in addition to the 10/100 Ethernet port. The advanced network capability was the underlying factor behind this selection. The Raspberry Pi 3 also uses a Broadcom BCM2837 SoC with a 1.2 GHz 64-bit quad-core ARM Cortex-A53 processor, with 512 KB shared L2 cache. This enables efficient high speed data processing capabilities.

3.3.1.2 Platinum Shimmer Development Kit

Figure 9 Platinum Shimmer Development Kit [19]

The platinum Shimmer kit is a collection of WBAN sensors and utilities. The data extraction is carried out via the Shimmer Nodes (figure 10). The shimmer node is places in the wrist and two (2) electrodes are attached to the fingers to acquire the GSR signal

Figure 10 Shimmer Nodes [19]

The shimmer nodes transmit the extracted data to the Raspberry Pi 3 through Bluetooth.

3.3.2 Software Components

3.3.2.1 Raspbian OS

Raspbian is an operating system based on Linux Debian optimized for the Raspberry Pi platform. This operating system is installed in the SD card and attached to the Raspberry Pi to boot. The environment for the sink node is set up in the Raspbian OS so that it can be executed directly to the Raspberry Pi 3 .The GUI of Raspbian is as display in Figure 11.

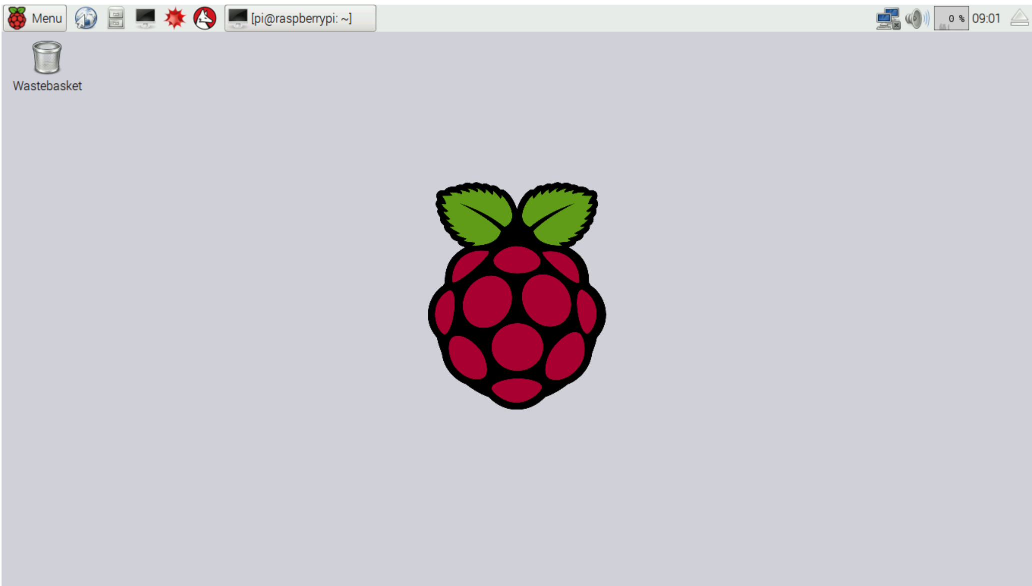


Figure 11 GUI for Raspian OS

3.3.2.4 Python

Python programming is used in the Raspbian environment to script data transmission and computation. It is an open-source high-level programming language with a broad range of OS support and user friendly command syntax. The python programming will handle the data received from the shimmer platinum sensor nodes and transmit it to ThingSpeak.com

3.3.2.5 ThingSpeak

ThingSpeak is an open-source data platform and API for the IoT. The sink will communicate data fetched to this platform application. The application will be used for data update channel and data presentation for end-user access. The features include sensor data collect to the cloud, analyse and visualize the data and trigger a reaction based on data collected.

3.3.2.4 VNC Server

Virtual Network Server (VNC) is a remote desktop sharing platform that allows multiple devices to be accessed remotely by an authorised user. The raspberry Pi 3 is operated remote via VNC in the host computer.

3.3.2.5 ShimmerConnect

ShimmerConnect is a host side (PC) application that allows users to display and save data received from Shimmer devices streaming over Bluetooth. The application allows the configuration of a range of parameters on the Shimmer, and is primarily designed to demonstrate Shimmer's functionality. ShimmerConnect is cross platform, working equally well in Microsoft Windows environments and Linux. Figure 12 illustrates the ShimmerConnect interface.

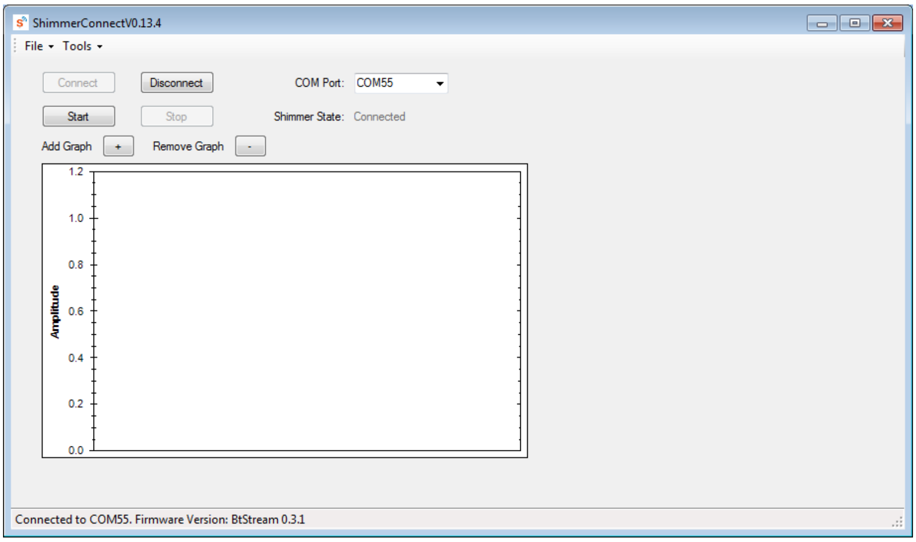


Figure 12 ShimmerConnect Window

3.3.2.6 ShimmerCapture

ShimmerCapture is a host side (PC) application that allows users to display and save data received from Shimmer devices streaming over Bluetooth. The application allows the configuration of a range of parameters on the Shimmer3, and is primarily designed to demonstrate Shimmer's functionality. ShimmerCapture works in conjunction with the Shimmer3 LogAndStream firmware to allow simultaneous streaming of data over Bluetooth as well as the logging of data to the on-board microSD card. Figure 13 illustrates the ShimmerCapture interface.

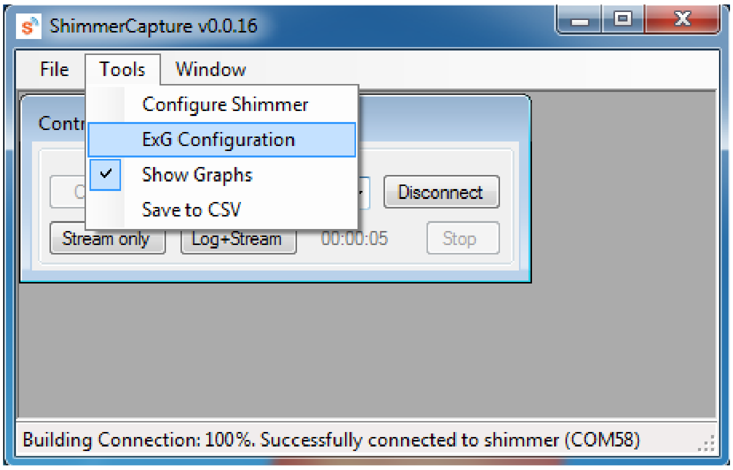


Figure 13 ShimmerCapture Window

3.4 Gantt Chart

3.4.1 Timeline for FYP I

No.	Details/ Week		FYP 1													
			W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12	W13	W14
1	Preliminary Research															
2	Literature Review															
3	Proposal Defense															
4	Identification of suitable Data Extraction and Transmission Technique															
5	Platinum Shimmer Development Kit Configuration															
6	Configuring IoT Platform															
7	Documentation	Extended proposal														
		Interim Report														

Key Milestone

Process

3.4.2 Timeline for FYP II

No.	**Details/ Week**		FYP 1													
			W01	W02	W03	W04	W05	W06	W07	W08	W09	W10	W11	W12	W13	W14
1	Extraction of GSR data from Shimmer Nodes		■	■												
2	IoT Implementation (Python Coding)				■	■	■	■	■	■						
3	System Integration							■	■	■	■	■	■			
4	Documentation	Progress Report							●							
		Draft Final Report											●			
		Dissertation (soft copy)												●		
		Technical Paper												●		
		Dissertation														●

● Key Milestone

■ Process

CHAPTER 4

RESULTS AND DISCUSSION

The results are documented in three stages throughout the integration process – GSR Data Extraction, GSR data transmission and IoT implementation for remote health monitoring.

4.1 GSR Data Extraction

The physiological data sample to test integration is GSR. GSR measures stress levels of patients by measuring the level of skin conductance in different scenarios like during rest, impulses and triggers. This step is performed by the shimmer kit using two electrodes connected to a WBAN node as illustrated in the figure 14 below.

Figure 14 GSR extraction using shimmer nodes

A Low Sampling Rate of 10.2 Hz is selected as shown in figure 15. Low sampling rate generates low frequency signals without any signs of aliasing resulting in a clear signal

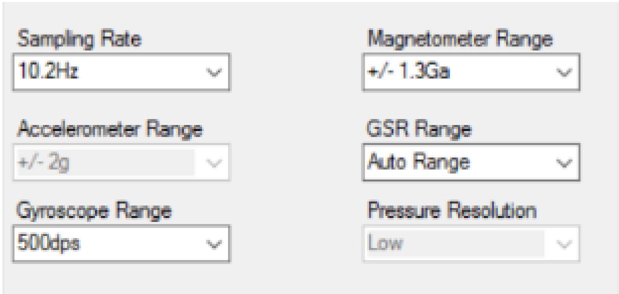


Figure 15 Configuration table of ShimmerConnect

GSR range is set to auto in order to use the most suitable range as per the selected environment. The sensor nodes determines which range is most appropriate for the patient depending on his skin conductance during the initial and relaxed period.

Table 1 Range of legitimate setting values for GSR range

Setting	Full Scale Range (Ω ohm)
0	10k – 56k
1	56k – 220k
2	220k – 680k
3	680k – 4.7M
4	Auto-Range

4.11 Calculating Skin Conductance (GSR)

Skin resistence is calculated using the Analog to Digital conversion (ADC) values in the GSR module of the shimmer kit. The shimmer module comprises of a 12 bit ADC reading from 0 to 4095 which is propotional to skin conductance. Each full scale range setting is mapped to a linear function which is used to calculate the skin conductance value

$$y = p1*x + p2 \qquad (1)$$

where x = ADC output, y = Skin Conductance measured in µS (Siemens) , p1 and p2 are parameters specific to the range setting.

The skin resistance can be calculated simply by getting the inverse of the skin conductance output:

$$\text{Resistence} = 1 / \text{Conductance} \qquad (2)$$

The conductance value output by the linear function is measured in µS, so resistance in Ohms (Ω) will be

$$\text{Resistence} = 1e\text{^}6 / \text{Conductance } (\mu S) \qquad (3)$$

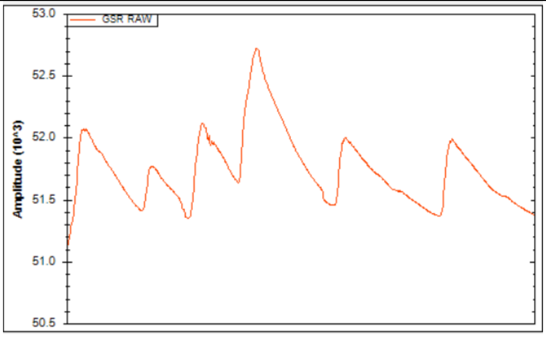
The calculated values are obtained from the samples stimuli response elaborated in figures 16,17 and 18 are tabulated in a .csv file as shown in table 2. The data is queued and waits to be prompted by the python script to start transmission to the cloud server

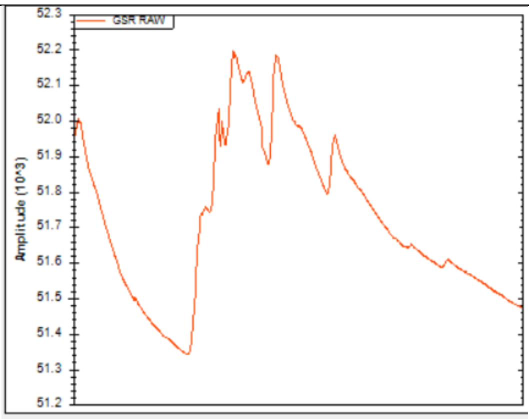
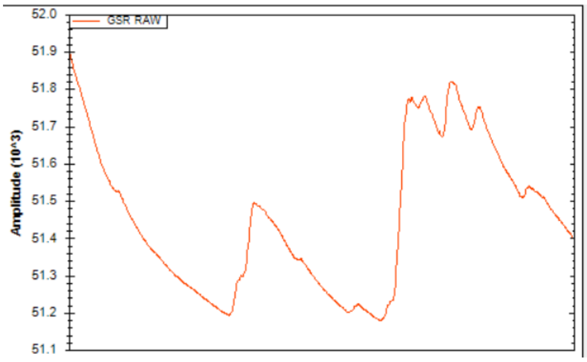
Table 2 Tabulated GSR Data with timestamp

Time (msec)	GSR (RAW)	**GSR (kΩ ohm)**
0	49152	**-3131.850924**
98.02246094	17299	**1203.659124**
196.0449219	34262	**810.1758082**
294.0673828	52514	**849.4538004**
392.0898438	52516	**848.8118993**
490.1123047	52516	**848.8118993**
588.1347656	52519	**847.8508647**
686.1572266	52524	**846.2539671**
784.1796875	52531	**844.0283898**
882.2021484	52540	**841.1840763**
980.2246094	52549	**838.3588686**
1078.24707	52559	**835.2419238**
1176.269531	52567	**832.7650059**
1274.291992	52576	**829.9959749**
1372.314453	52584	**827.5500276**
1470.336914	52593	**824.8155117**
1568.359375	52599	**823.0025188**
1666.381836	52602	**822.0990078**
1764.404297	52604	**821.4977685**
1862.426758	52608	**820.2979243**

1960.449219	52609	**819.9985107**
2058.47168	52614	**818.5047153**
2156.494141	52615	**818.2066091**
2254.516602	52618	**817.3135919**
2352.539063	52618	**817.3135919**
2450.561523	52618	**817.3135919**
2548.583984	52618	**817.3135919**
2646.606445	52618	**817.3135919**
2744.628906	52616	**817.9087199**
2842.651367	52615	**818.2066091**
2940.673828	52612	**819.1015799**

The extracted data is displayed in the ShimmerConnect window simultaneously with the data log in the .csv file. These operations are done in the raspberry Pi 3. Three (3) different stimuli were introduced to the patient. Sample A was recorded while the patient was relaxed, sample B when exposed to a sudden impulse (loud music) and sample C during a forced task (reading). Simultaneausluy

#	GSR Graphs	Explaination
Sample A	 *Figure 16 GSR signal when patient is relaxed*	The y axis corresponds to the amplitude of the resistance and x axis denotes time in seconds. The subject is relaxed and breaths consistently as illustrated by the consistent peaks. The sudden excited peak occurs when the subject takes a deep breath.

Sample B	 *Figure 17 When exposed to sudden explosive impulse (Loud Music)*	The y axis corresponds to the amplitude of the resistance and x axis denotes time in seconds. The sudden spike in amplitide marks the sudden introduction of loud music that causes a few ripples and eventually settles down
Sample C	 *Figure 18 when patient is focused (Reading)*	The y axis corresponds to the amplitude of the resistance and x axis denotes time in seconds. The spikes are a result of moments when the reader is touched or pauses to think whilst reading.

The results were compared to GSR results from previous studies for data validation to ensure the transmitted data GSR data is accurate. [20] included a series of tests involving GSR to monitor stress levels. A slightly different approach of observing voltage difference instead of resistance was used. In principal the working methodology is consistent. The results for a subject recorded while reading displayed in figure 18 matches the pattern obtain in this paper's research as illustrated in figure 17.

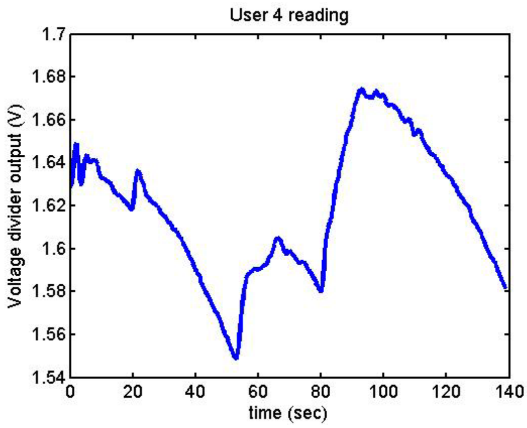


Figure 19 GSR signal when subject is focused (reading) [14]

4.2 Data Transmission And IoT Implementation

This phase involves fetching the analysed and computed GSR data in the raspberry pi and tranmitted through the internet using Wi-Fi to ThingSpeak to be stored and accessed online. The primary platform in this stage is the Raspberry Pi 3.

4.2.1 Raspberry Pi Environemnt for IoT

The single chip computer- raspberry pi is the heart of WBAN and IoT integration. It's considered as the sink node. Several tools and methods have to be executed to configure the IoT to peform IoT operations.

4.2.1.1 Environment Setup

An HDMI cable, monitor, keyboard, mouse and the SD card are requried for the first time as labelled in figure 20 . Subsequently, the raspberry Pi can be remotely accessed by a Virtual Network Computing (VNC) connection. The IP address of the raspberry pi must be knownSome other way to access the Raspberry Pi is to enable the and the remote connection can be accessed through the address of the Pi.

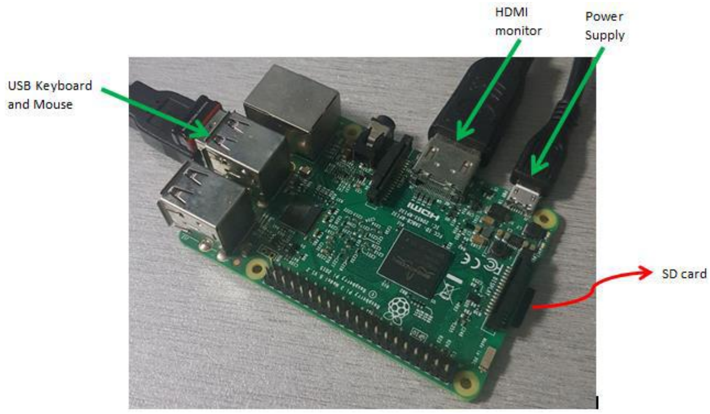


Figure 20 Hardware setup for Raspberry Pi 3

Raspian operating system (OS) installed in the SD card runs the raspberry pi. The Linux envioremnt supported by the Pi provides a solid platfrom to implement python scripts. Python scripts prompt task execution on sink node. Stable internet connection is imperative to avoid delays and data loss during transmission to thingspeak. To ensure consistent Wi-Fi connection a script will run for a predefined period to refresh and establish aconnection. A startup file is created for internet connection every time the Raspberry Pi boots to auto establish the internet connection and execute the main program.

4.3 Received Data through IoT Channel

A channel is created in ThingSpeak to receive, display and store GSR data. Upto eight (8) different channels can be created to recieve multiple data simultaneuouly. The channel created in the project is captured in figure 21

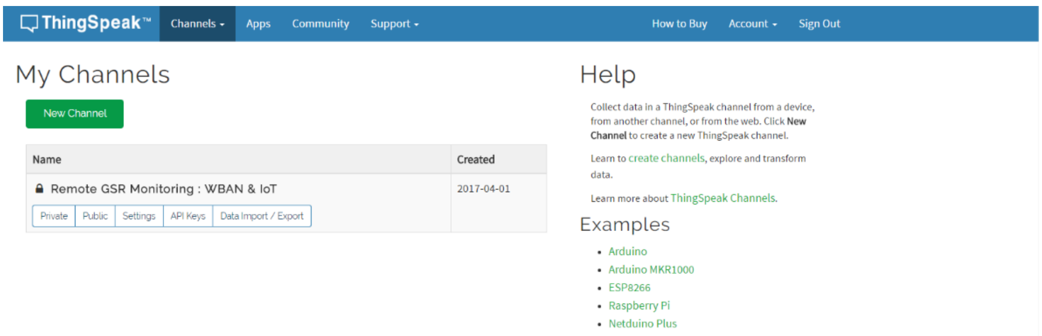


Figure 21 Remote Health Monitoring Channel in ThingSpeak

Each channel is assigned a unique channel ID, write API key and read API key (figure 22). The write API key serves as an authorization code to write and transmit data to the channel. To access and read details of the received data the read API key is required. This is to ensure that the data is secure in the internet.

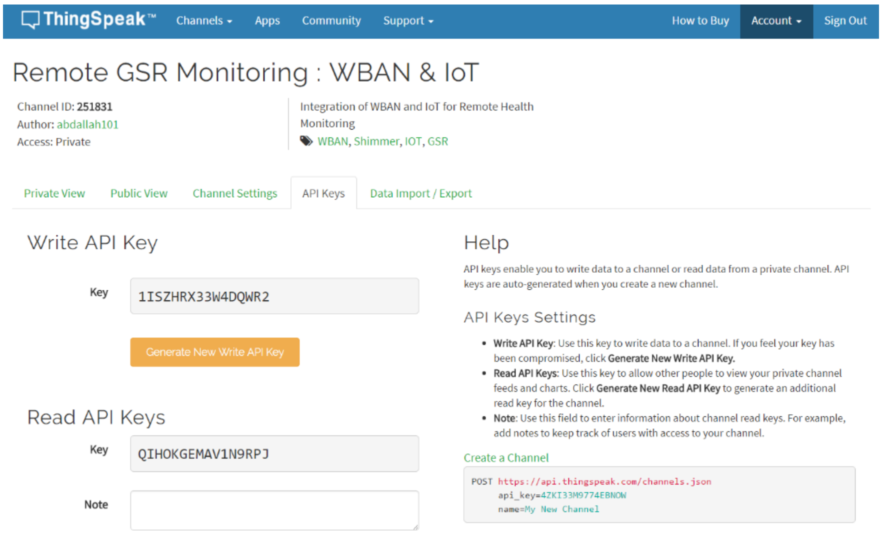


Figure 22 Write API Key to ping Channel

Lastly figure 23 displays the GSR readings extarcted by the platinum shimmer kit (WBAN) online that can be readily accessed by patients and doctors remotely thereby completing the integration between WBAN and IoT for remote health monitoring. The channel is made public and can be viewed online using a mobile or personal computer via https://thingspeak.com/channels/251831

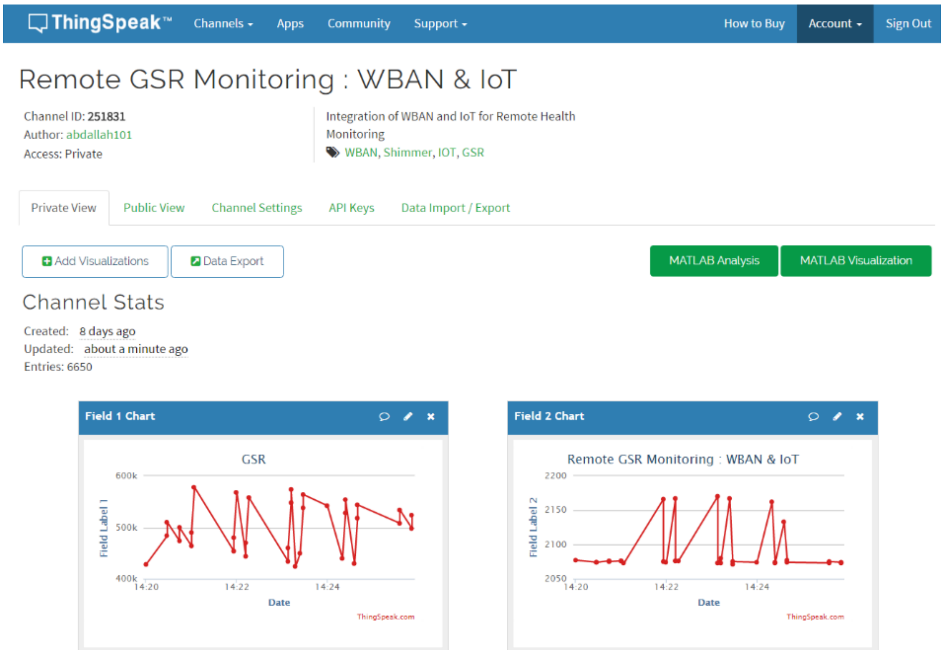


Figure 23 Transmitted GSR data displayed in ThingSpeak

4.4 Final Prototype

Figure 24 displays the final prototype of this remote health monitoring system

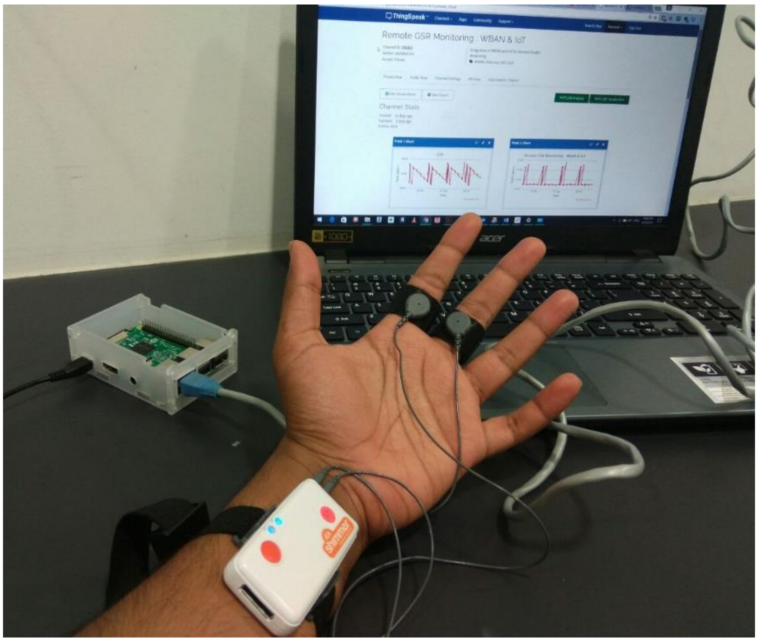


Figure 24 Final prototype of WBAN - IoT integration Remote Health Monitoring

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A successful integration between WBAN and IoT opens a wide range of endless possibilities in the area of remote health monitoring. With unlimited data storage in clouds that can be readily accessible by doctors and specialists, trends can be studied to prevent chronic illnesses through early detection. This can possibly inflict a drastic change in the conventional health care system. It can revolutionize the industry with more people becoming aware of their health due to the easy access and data interpretation of WBAN system at the convenience of their mobile devices.

Limitations of using GSR signal is that there are many inconsistencies. External factors like excessive heat, or sweaty hands might result is varied readings. Even though GSR is a good sample to test a framework, it will still require a medical practitioner to interpret the results unlike certain physiological data like heartrate.

The main highlight of the IoT implementation is the unlimited data storage through the cloud. WBAN sensors on its own have very limited storage that limits its effectiveness. Secondly since WBAN sensors can only transmit data though radio waves and Bluetooth, integration with IoT enables direct access remotely making location irrelevant as long as there is internet connectivity.

The objectives of this research were met. The integration and implementation of WBANs and IoT was successful based on the results achieved in the stipulated time frame.

5.2 Recommendations

For future studies, multiple node data extraction like ECG, EEG, heartrate, temperature, respiratory rate can be incorporated to the existing framework besides

GSR. This would serve as a platform to perform analysis with different physiological data to make devise early detection and prevention of specific health conditions.

The current framework requires a medical expert to interpret and make sense of the extracted data. Through more research a personalised internet application can be developed so that a patient can be alerted when any abnormalities occur. The data be simplified to different stages such as healthy, potential hazard and danger based on developed algorithms.

The delay between data extraction and transmission can be further decreased from 5 mins to real-time. Real-time transmission can result in more efficient date analysis systems and quicker response time.

Lastly with the WBANs now connected to the internet, it can be synchronised with other physical or electronic avenues like in cars, homes and schools. For instance if a driver's heartrate reaches a dangerous level, the health monitoring system will alert the car to warn the driver to pull over or drive to the nearest hospital.

REFERENCES

[1] F. Mohamedali and N. Matoorian, "Support Dementia: Using Wearable Assistive Technology and Analysing Real-Time Data," pp. 50-54, 2016.

[2] M. Hassanalieragh, A. Page, T. Soyata, G. Sharma, M. Aktas, G. Mateos*, et al.*, "Health Monitoring and Management Using Internet-of-Things (IoT) Sensing with Cloud-Based Processing: Opportunities and Challenges," pp. 285-292, 2015.

[3] D. M. Barakah and M. Ammad-uddin, "A Survey of Challenges and Applications of Wireless Body Area Network (WBAN) and Role of a Virtual Doctor Server in Existing Architecture," in *2012 Third International Conference on Intelligent Systems Modelling and Simulation*, 2012, pp. 214-219.

[4] J. Y. K. a. M. R. Yuce, *Wireless Body Area Network (WBAN) for Medical Applications, New Developments in Biomedical Engineering, Domenico Campolo (Ed.)*

The University of Newcastle Australia, 2010.

[5] S. Ullah, H. Higgins, B. Braem, B. Latre, C. Blondia, I. Moerman*, et al.*, "A comprehensive survey of wireless body area networks," *Journal of medical systems,* vol. 36, pp. 1065-1094, 2012.

[6] H. Alemdar and C. Ersoy, "Wireless sensor networks for healthcare: A survey," *Computer Networks,* vol. 54, pp. 2688-2710, 2010.

[7] A. Milenković, C. Otto, and E. Jovanov, "Wireless sensor networks for personal health monitoring: Issues and an implementation," *Computer communications,* vol. 29, pp. 2521-2533, 2006.

[8] K. Baskaran, "A survey on futuristic health care system: WBANs," *Procedia Engineering,* vol. 30, pp. 889-896, 2012.

[9] A. NA, A. A O, A. K K, and N. HO, "Using wearable sensors for remote healthcare monitoring system," *Journal of Sensor Technology,* vol. 2011, 2011.

[10] D. Lloyd-Jones, R. Adams, M. Carnethon, G. De Simone, T. B. Ferguson, K. Flegal*, et al.*, "Heart disease and stroke statistics—2009 update a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee," *Circulation,* vol. 119, pp. e21-e181, 2009.

[11] W. H. O. Ageing and L. C. Unit, *WHO global report on falls prevention in older age*: World Health Organization, 2008.

[12] G. Wolgast, C. Ehrenborg, A. Israelsson, J. Helander, E. Johansson, and H. Manefjord, "Wireless Body Area Network for Heart Attack Detection [Education Corner]," *IEEE Antennas and Propagation Magazine*, vol. 58, pp. 84-92, 2016.

[13] G.-Z. Yang and M. Yacoub, "Body sensor networks," 2006.

[14] R. T. Ltd. (2014). *GSR+ Expansion Board User Guide*. Available: www.shimmersensing.com

[15] P. Chatterjee and R. L. Armentano, "Internet of Things for a Smart and Ubiquitous eHealth System," pp. 903-907, 2015.

[16] S. H. Almotiri, M. A. Khan, and M. A. Alghamdi, "Mobile Health (m-Health) System in the Context of IoT," in *2016 IEEE 4th International Conference on Future Internet of Things and Cloud Workshops (FiCloudW)*, 2016, pp. 39-42.

[17] S. H. Shah and I. Yaqoob, "A survey: Internet of Things (IOT) technologies, applications and challenges," in *2016 IEEE Smart Energy Grid Engineering (SEGE)*, 2016, pp. 381-385.

[18] Anurag, S. R. Moosavi, A. M. Rahmani, T. Westerlund, G. Yang, P. Liljeberg, *et al.*, "Pervasive health monitoring based on Internet of Things: Two case studies," in *Wireless Mobile Communication and Healthcare (Mobihealth), 2014 EAI 4th International Conference on*, 2014, pp. 275-278.

[19] R. T. Ltd. (2014). *Shimmer User Manual*. Available: www.shimmersensing.com

[20] M. V. Villarejo, B. G. Zapirain, and A. M. Zorrilla, "A stress sensor based on Galvanic Skin Response (GSR) controlled by ZigBee," *Sensors (Basel)*, vol. 12, pp. 6075-101, 2012.