VISVESVARAYA TECHNOLOGICAL UNIVERSITY

JNANA SANGAMA, BELAGAVI – 590 018.

PROJECT REPORT

ON

"WEARABLE PHYSIOLOGICAL MONITORING SYSTEM FOR COVID-19 USING CDP"

Submitted in the partial fulfilment of the requirement for the Award of the Degree

BACHELOR OF ENGINEERING
IN
ELECTRONICS AND INSTRUMENTATION ENGINEERING

Submitted by

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Carried out at

BANGALORE INSTITUTE OF TECHNOLOGY
DEPARTMENT OF ELECTRONICS AND INSTRUMENTATION ENGINEERING
K.R. ROAD, V.V. PURA, BENGALURU – 560 004.
2020-2021

BANGALORE INSTITUTE OF TECHNOLOGY

(Affiliated Visvesvaraya Technological University)

K.R. Road, V.V. Pura, Bangalore – 560 004.

CERTIFICATE

This is to certify that that Project work entitled **"WEARABLE PHYSIOLOGICAL MONITORING SYTEM FOR COVID-19 USING CDP"**, bonafide work carried out by **PIYUSH RAJ (1BI17EI021), RITWIK BANERJEE (1BI17EI026), SHANTANU N GHODGAONKAR (1BI17EI033)** and **SUMANTHA M. ALSE (1BI17EI038)**, bonafide students of **Bangalore Institute of Technology** in the partial fulfillment for the award of **Bachelor of Engineering** in **Electronics & Instrumentation Engineering** under **Visvesvaraya Technological University, Belagavi** during the year 2020-2021. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report deposited in the department library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the Bachelor of Engineering Degree.

100

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DECLARATION

We, **PIYUSH RAJ (1BI17EI021), RITWIK BANERJEE (1BI17EI026), SHANTANU N GHODGAONKAR (1BI17EI033)** and **SUMANTHA M. ALSE (1BI17EI038)**, the students of VIII Semester **B.E** in **Electronics and Instrumentation Engineering**, **Bangalore Institute of Technology** declare that the Project work entitled **"WEARABLE PHYSIOLOGICAL MONITORING SYTEM FOR COVID-19 USING CDP"** has been carried out by us at **Bangalore Institute of Technology** as a partial fulfillment of academic requirement of **Bachelor of Engineering** in **Electronics and Instrumentation Engineering** under **Visvesvaraya Technological University, Belagavi** during Academic year 2020-2021.

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ABSTRACT

In recent times, sensor technology has grown in leaps and bounds, creating newer avenues for engineers to develop novel systems using said devices. With sensor networks now in place for more than a decade now, the advancement in the domain of wireless communications has opened up a whole new application space for sensors. Sensors and transducers integrated with wireless communication and mobile computing provide for a sensor platform which is inexpensive to install and vastly versatile.

Currently we are living in an age controlled by the novel Coronavirus, which has been spreading due to close contact between the infected and healthy. First characterised in the 1960s, the Coronavirus are responsible for substantial proportion of upper respiratory tract infections in children. Since 2003, at least 5 new human coronaviruses have been identified, including the severe acute respiratory syndrome coronavirus, which caused a significant number of fatalities. More recently, in the December of 2019, a mutated form of the virus took birth and has been causing havoc ever since. Scientifically termed, the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) causes the Coronavirus Disease 2019 (COVID-19) characterised by fever, difficulty in breathing and loss of smell. By October 2020 it had estimated to have claimed 37.5 million confirmed cases and about 1.07 million deaths, worldwide.

With the rise of the SARS-CoV-2 and the pandemic that it caused, there has been a severe need for out-of-the box thinking to help mitigate the crisis.

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INTRODUCTION

One of the most impactful healthcare industry applications today is wearables, which are Internet of Things (IoT) medical monitoring devices that patients can wear. These healthcare wearables allow for remote monitoring of various vital signs and health statistics. Wearable healthcare devices allow providers and facilities to stay connected to patients, and patients gain better visibility into their health status, resulting in better treatment outcomes and improved quality of life. The healthcare industry has been quick to adopt healthcare wearables because they can help providers offer a better standard of care while improving efficiency and lowering operational costs.

1.1 BENEFITS OF WEARABLE DEVICES

Wearable medical devices are in high demand because they improve visibility into relevant aspects of an individual's health status to make more informed decisions about their health. The benefits of using these healthcare wearables include:

1) Real-Time Health Monitoring

Individuals can monitor different fitness, health and wellness factors to track their progress toward medically recommended goals.

2) Monitor Vulnerable Patients' Health with Status Alerts and Alarms

IoT medical devices closely monitor and track the patient's health indicators and generate notifications when their status changes and important reminders.

3) Patient-Physician Information Sharing

The wearable medical device sends information to the patient's healthcare providers, so physicians and other medical staff have a more detailed understanding of the patient's condition.

As the age profile of many societies continues to increase, in addition to the increasing population of people affected by chronic diseases, including diabetes, cardiovascular disease, obesity, and so on, supporting health, both mentally and physically, is of increasing importance if independent living is to be maintained. Sensing, remote health monitoring, and, ultimately, recognising activities of daily living have been a promising solution.

From a technical perspective, the Internet of Things (IoT) is gaining a rapidly growing attention in many disciplines, especially in personalised healthcare. Meanwhile, body area sensor network (BASN) under the IoT framework has been widely applied for ubiquitous health monitoring, for example.

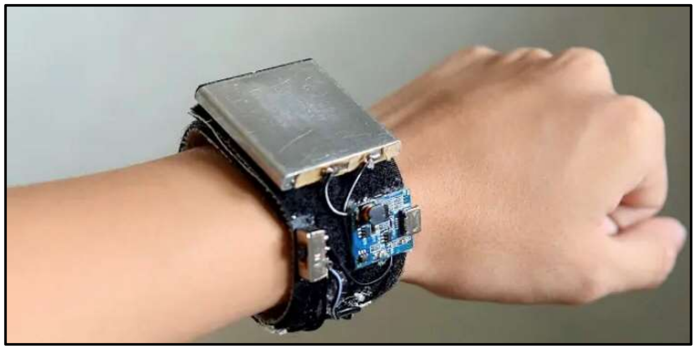


Figure 1: Wearable Health Monitoring System Prototype

A WISE (Wearable IoT-cloud-based health monitoring system) adopts the BASN (body area sensor network) framework in the support of real-time health monitoring. Several wearable sensors have been embedded, including the heartbeat, body temperature, and the blood pressure sensors. Secondly, the majority of existing wearable health monitoring systems requisite a smart phone as data processing, visualisation, and transmission gateway, which will indeed impact the normal daily use of the smart phone. Whilst in WISE, data gathered from the BASN are directly transmitted to the cloud, and a lightweight wearable LCD can be embedded as an alternative solution for quick view of the real-time data.

1.2 WIRELESS COMMUNICATION IN IOT

Internet of Things has gained the attention of almost everybody due to its capability of monitoring and controlling the environment. IoT helps making decisions supported by real data collected using large number of ordinary day-to-day devices that have been augmented with intelligence through the installation of sensing, processing and communication capabilities. One of the main and important aspects of any IoT device is its communication capability for transferring and sharing data between other devices. IoT devices mainly use wireless communication for communicating with other devices.

Sl. No.	Wireless Technology	Benefits	Drawbacks
1.	Bluetooth	- Able to handle large amounts of data - Able to create ad-hoc connections - Universally standardized - Free band	- Relatively low data rate - High power consumption - Always up - Relatively short range - Vulnerable to outside attacks
2.	Bluetooth Low Energy (BLE)	- Low power consumption - High data rate - No single point of failure - Better scalability - Better reliability - Faster (automatic) reconfiguration	- Limited data handling capacity - Takes longer to setup - Limited range of operation - Limited connection handling capacity (only seven devices per master/slave connection) - Susceptible to attacks - Only star topology - No security implemented
3.	ZigBee	- Easy to setup - No central control - Supports load distribution across multiple nodes/links - Low power consumption - Low cost - Low latency - Multiple band support - Supports different data rates	- No security - Short range - Low data rates - Suffers from compatibility issues

4.	LTE	- Operates in licensed band increases throughput and reduces interference from other devices - Narrow band operation reduces power consumption - Low cost on end device and base station - Reuses existing cellular spectrum increasing the density of devices in a given area	- Cellular data-plans may increase usage charges
5.	LoRa	- Very large ranges possible - Supports star-of-stars topology - Large number of clients per gateway module - Supports variable data rates - Has the ability to trade-off between range and data rate - Offers three types (classes) of devices supporting different purposes - Larger areas can be covered with a few gateway nodes - Supports interoperability with other standards	- Only point to point (no mesh) connection - Low bandwidth support

1.3 THE CORONAVIRUS

First characterised in 1960s, the human coronaviruses are responsible for a substantial proportion of upper respiratory tract infections. In early 2020, after a December 2019 outbreak in China, the World Health Organization identified SARS-CoV-2 as a new type of coronavirus. The outbreak quickly spread around the world.

COVID-19 is a disease caused by SARS-CoV-2 that can trigger what doctors call a respiratory tract infection. It can affect your upper respiratory tract (sinuses, nose, and throat) or lower respiratory tract (windpipe and lungs).

It spreads the same way other coronaviruses do, mainly through person-to-person contact. The virus can also spread after infected people sneeze, cough on, or touch surfaces, or objects, such as tables, doorknobs and handrails. Other people may become infected by touching these contaminated surfaces, then touching their eyes, noses or mouths without having cleaned their hands first.

One should get tested for COVID-19 if (s)he experiences the following symptoms – fever, dry cough, tiredness, diarrhoea, loss of taste or smell, difficulty in breathing, chest pain and speech loss.

The test for COVID-19 is carried out by taking a sample either the subject's saliva or the mucus. Infection with the virus causing COVID-19 (SARS-CoV-2) is confirmed by the presence of viral RNA detected by molecular testing, usually RT-PCR. Detection of viral RNA does not necessarily mean that a person is infectious and able to transmit the virus to another person.

With the recent development in sensor and battery technology, building wearable devices has become a simpler task. Nowadays, small sensors that are accurate enough for collecting readings for medical purposes whilst consuming very little power, are easily available. Paring such low powered versatile sensors with high capacity, small sized batteries can yield highly capable wearable devices that can monitor a variety of physiological parameters that can help keep track of patients even after being discharged from the hospital.

Especially, with the pandemic situation, the affected maintaining home quarantine is essential to the safety of all those who haven't contracted the virus. And to ensure the speedy recovery of all those in home quarantine, a simple wearable monitoring system that keeps track of the physiological status of the patient by a doctor, remotely, is a rather simple task.

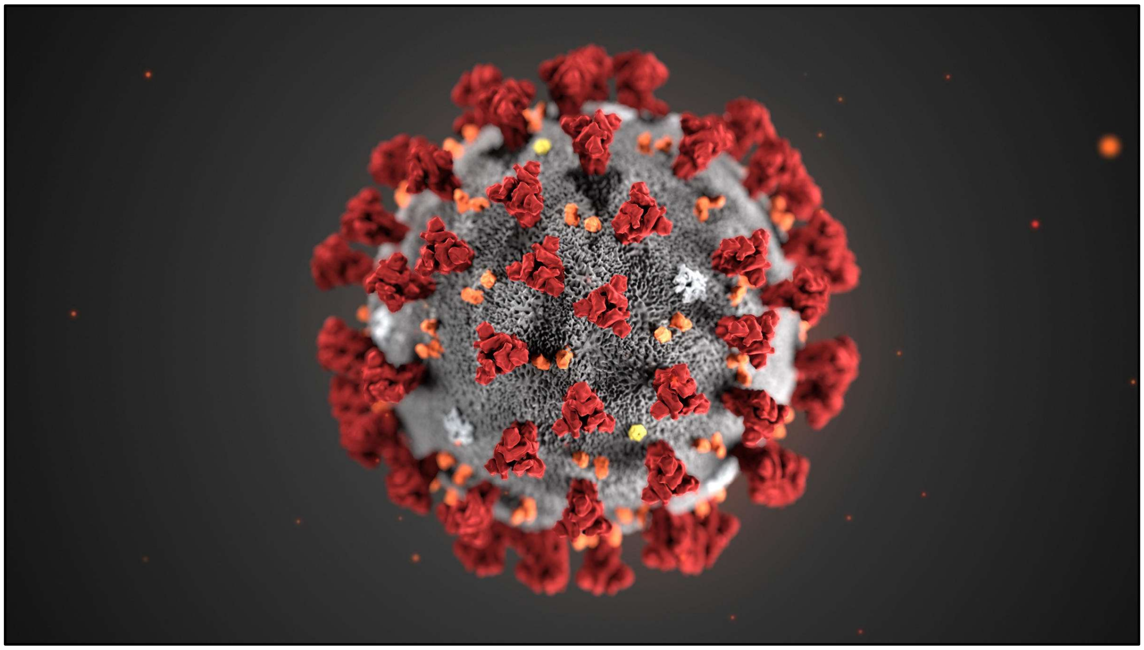


Figure 2: The Coronavirus Crown Structure

1.4 SYSTEM DESIGN

1.4.1 EXISTING SYSTEM

The existing wearable devices have the facility to voluntarily sign up for a medical consultant, but you need to pay extra amount of money for it. They are expensive because they were launched in the market for commercial purpose. When you sign up for a medical consultant, most of the times it is either a bot replying to the patient's queries or it takes a few hours to even days for a medical consultant to give a medical advice.

1.4.2 PROPOSED SYSTEM

The proposed system creates an ad-hoc network in a locality which creates a network between the patient and the doctor. As soon as a patient requests to consult a doctor, an ad-hoc network is created by CDP and a doctor available in that network will respond immediately. Any doctor available in the network could examine the patient remotely. As the patients will be remotely examined, the possibility of the medical professionals contracting the virus reduces. As the patients can stay in home quarantine, they will save a lot of money in hospital bills.

CHAPTER 2

LITERATURE REVIEW AND OBJECTIVES

2.1 LITERATURE REVIEW

D. I. Shin, S. J. Huh and P. J. Pak (Patient Monitoring System using Sensor Network Based on the ZigBee Radio, 2007 6th International Special Topic Conference on Information Technology Applications in Biomedicine) discussed about a variety of networking topologies and radios that may be used to develop a sensor network for patient monitoring.

O. Khutsoane, B. Isong and A. M. Abu-Mahfouz (IoT devices and applications based on LoRa/LoRaWAN, IECON 2017 - 43rd Annual Conference of the IEEE Industrial Electronics Society, 2017) have proposed that LoRa is a viable communication technology for applications that needs long-range links and deployed in a distributed manner.

A. I. Petrariu, A. Lavric and E. Coca (LoRaWAN Gateway: Design, Implementation and Testing in Real Environment, 2019 IEEE 25th International Symposium for Design and Technology in Electronic Packaging) developed a fully-operational LoRaWAN based IoT device to run in real environment, registered with LoRa alliance

G. van de Beek, R. Liem, H. J. van der Horst and M. van Genuchten (Building and Deploying a COVID-19 Monitoring Solution in March IEEE Software Volume: 37, Issue: 5, Sept.-Oct. 2020) have proposed a device targeted towards the monitoring of all the physiological parameters affected in patients suffering from COVID-19.

S. S. Vedaei (COVID-SAFE: An IoT-Based System for Automated Health Monitoring and Surveillance in Post-Pandemic Life, IEEE Access, Volume: 8 2020) has proposed a detailed design and implementation of an IoT based device built to monitor physiological parameters affected in patients suffering from COVID-19 using GSM 4G network.

Limitations of the above mentioned papers are:

Sl. No.	Author & Year	Title	Limitations
1.	D. I. Shin, S. J. Huh and P. J. Pak | IEEE 2007	Patient Monitoring System using Sensor Network Based on the ZigBee Radio	Very generalised and employs ZigBee radio
2.	O. Khutsoane, B. Isong and A. M. Abu-Mahfouz | IEEE 2017	IoT devices and applications based on LoRa/LoRaWAN	Lacks data about certain characteristics of a few LoRa modules
3.	A. I. Petrariu, A. Lavric and E. Coca | IEEE 2019	LoRaWAN Gateway: Design, Implementation and Testing in Real Environment	High investment
4.	G. van de Beek, R. Liem, H. J. van der Horst and M. van Genuchten | IEEE 2020	Building and Deploying a COVID-19 Monitoring Solution in March	Fully software based system, lacking data about hardware employed
5.	S. S. Vedaei et al. | IEEE 2020	COVID-SAFE: An IoT-Based System for Automated Health Monitoring and Surveillance in Post-Pandemic Life	Implementation using unreliable GSM 4G network

2.2 OBJECTIVES

- The first objective of this project is to develop a wearable patient monitoring system to monitor the body vitals of a patient suffering from COVID-19.
- Monitoring will be done by tracking the patient's body temperature, oxygen saturation in blood and pulse rate.
- A variety of non-invasive sensors including a temperature sensor, pulse rate detector and a pulse oximeter will be placed on the wrist of the patient to constantly monitor their physiological status.
- The sensor data will then be collected and transmitted over a network of LoRaWAN cards to a doctor sitting in a hospital for remote monitoring of patient status.
- The main objective is to establish a network in a locality, connecting all the patients in home quarantine with the available doctors at various hospitals in that locality without the use of mobile 4G services.

CHAPTER 3
SYSTEM ARRANGEMENT

3.1 PROBLEM DESCRIPTION

With the onset of the Novel Coronavirus, social distancing became a necessity. Without maintaining a distance of at least 6 feet between any two individuals and wearing a face mask, the probability of contracting the virus is very high. In such a situation, monitoring the physiological status of patients suffering from COVID-19 became a tough job, especially given the fact that many of them were placed in home quarantine. To make the job of doctors and nurses easier, the necessity arose for a device that can monitor and keep track of the physiological status of patients in home quarantine, not in the vicinity of the hospital responsible for their speedy recovery.

3.2 PRODUCT DESIGN

3.2.1 BLOCK DIAGRAM

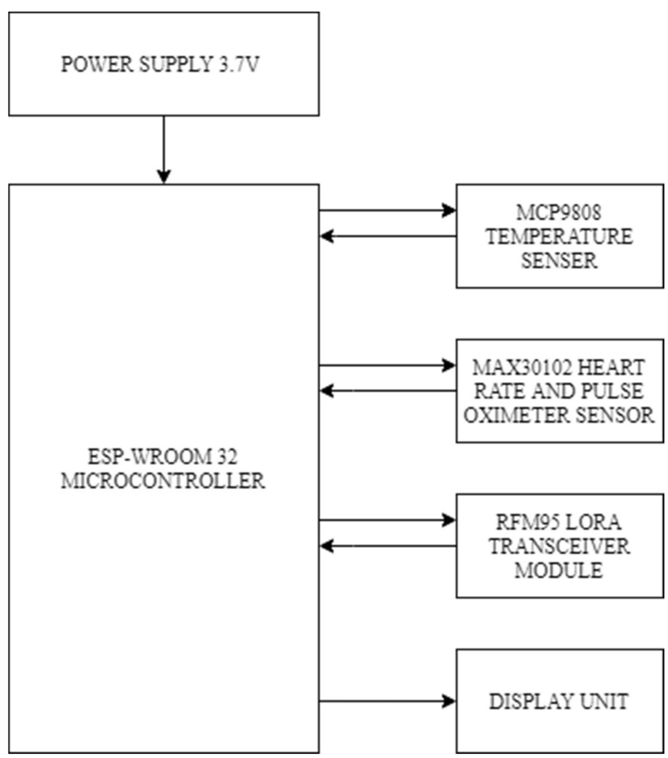


Figure 3: Block Diagram of the Proposed Model

1. MICROCONTROLLER: Our choice of microcontroller board for this project was ESP32-WROOM32. We opted this particular board as it had all the necessary features required for this project with the exception of LoRa. It has a dual core CPU, which makes the process much smoother and efficient. The detailed specifications of this board is discussed in upcoming chapters.

2. POWER SUPPLY UNIT: Since all of the components used in this project work at the voltage of 3.3V, we have used a 3.7V rechargeable LiPo Pouch Battery along with the TP4046 charger module which comes with a protection circuit inbuilt. A MCP1700-3302E LDO for voltage regulation. A low-dropout voltage regulator is used here because using a typical linear voltage regulator to drop the voltage from 4.2V to 3.3V isn't a good idea, because as the battery discharges to, for example 3.7V, your voltage regulator would stop working, because it has a high cut-off voltage.

3. RFM95 LORA TRANSCEIVER MODULE: The RFM95 LoRa transceiver module is used for the communication of sensor data from patient's module to the UI available at the clinics/hospitals. The operating range of RFM95 is 865-867MHz, which is the available bandwidth for license-free use in India.

4. SENSOR: The parameters measured by the device we are developing are temperature, heart-rate, blood oxygen saturation level. To achieve this, we have used two sensors: MAX30102 and MCP9808. The MAX30102 sensor is used for the measurement of the heart-rate and blood oxygen saturation level and the MCP9808 sensor is used for the measurement of temperature.

5. DISPLAY UNIT: A webapp and a smartphone app have been developed for viewing the data of the patients. Using this app, the patient can view only their data, whereas the doctor has access to the data of all the patient under his care. Thus, the data privacy is also maintained.

3.2.2 FUNCTIONAL DIAGRAM

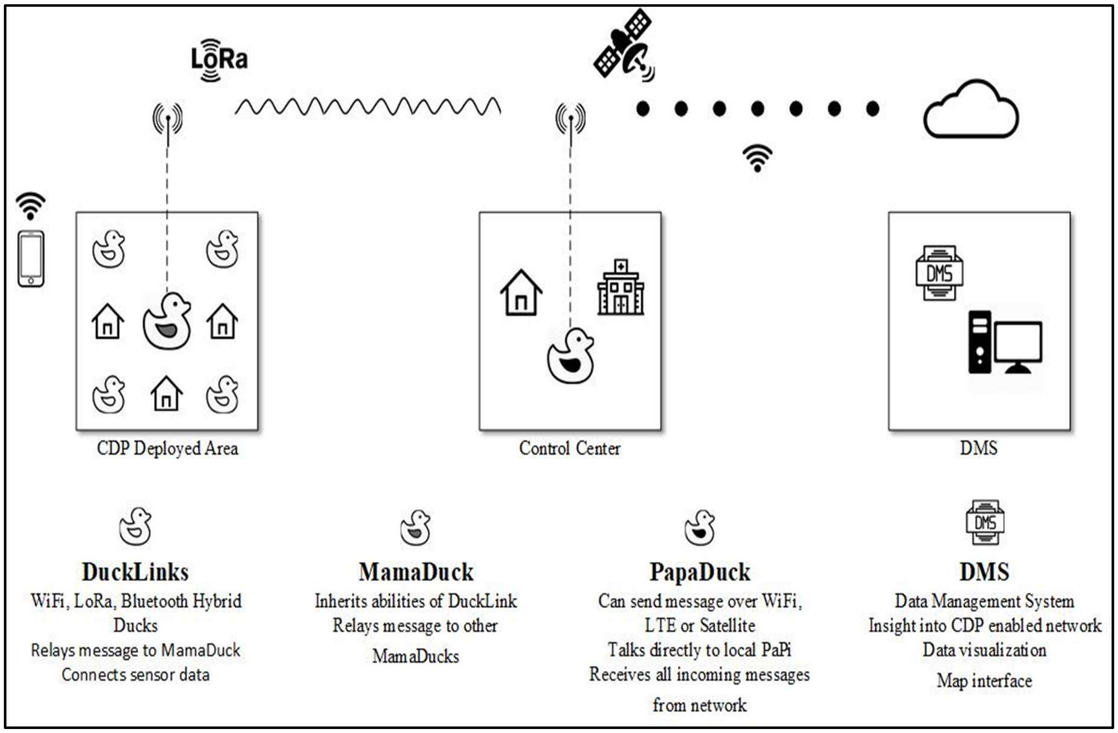


Figure 4: Functional Diagram of ClusterDuck Protocol

The MAX30102, MCP9808 sensors and the RFM95 LoRa Transceiver module are interfaced with the ESP32-WROOM32 microcontroller. This setup, in ClusterDuck Protocol, is termed as DuckLink. These DuckLinks are the wearable devices that are in possession of the patients. The main function of this arrangement is to connect the sensor data and to relay the same to MamaDuck via LoRaWAN.

MamaDuck is an arrangement that is similar to DuckLink, but it is setup in the area clinics/nursing homes. The function of this arrangement is to collect the data that is sent from the DuckLink and display it via UI at the clinic. The data collected by the DuckLink is visible only to the patient in whose possession that particular DuckLink is in, whereas, the doctor accesses the data of all patients under his care via MamaDuck.

This whole arrangement of multiple DuckLinks and MamaDucks is setup in a single locality, and similar arrangements will be setup in all the localities.

All the MamaDucks then relays the collected information to PapaDuck using LoRa. PapaDuck is an arrangement consisting of a RFM95 LoRa Transceiver module interfaced with the ESP32-WROOM32 microcontroller. The function of this is to receive all incoming data and messages from a network, and send this data to a Data Management System or can be uploaded to the cloud for further uses. This arrangement is to be setup in a place where there is availability of WiFi/LTE for the uploading of data.

3.3 METHODOLOGY

For the ease of understanding, we have divided our methodology into five stages:

- **Stage 1:** The virus must first be detected in the person by means of a COVID-19 test or by observing for 2-3 days to verify if the symptoms of the illness match the diagnosis.

- **Stage 2:** The sensors acquire the physiological parameters of the patient. This data is in raw format and needs to be processed and converted to digital form to make it available in the GUI.

- **Stage 3:** The raw data is sampled, processed and converted to a digital form. This digital form is presentable to the patient as well as the doctor. Now the physiological parameter readings of the patient are ready.

- **Stage 4:** An ad-hoc network is created when the patient requests to consult a doctor. Any doctor in the network can accept the request. As soon as the doctor accepts the request, all the parameters will be displayed to the doctor in the GUI.

- **Stage 5:** In this stage, the doctor can thoroughly examine all the parameter percentages and suggest the patient to do the needful. The prescription prescribed by the doctor would be made available to the patient in the GUI. Also, in case of emergency, immediate help can be sent.

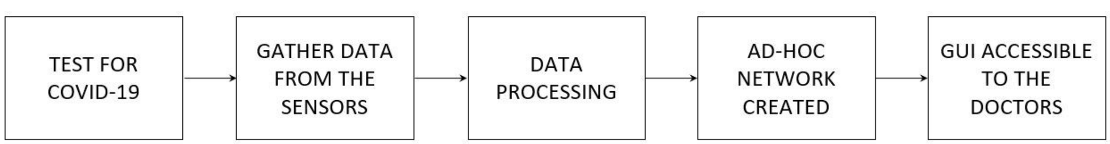


Figure 5: Methodology

CHAPTER 4
HARDWARE REQUIREMENTS

4.1 ESP32-WROOM-32D

- ESP32-WROOM-32D is a powerful, generic Wi-Fi+BT+BLE MCU module that target a wide variety of applications, ranging from low-power sensor networks to the most demanding tasks, such as voice encoding, music streaming and MP3 decoding.
- At the core of the modules is the ESP32-D0WD chip that belongs to the ESP32 series of chips. The chip embedded is designed to be scalable and adaptive. There are two CPU cores that can be individually controlled and the CPU clock frequency is adjustable from 80 MHz to 240 MHz.
- The user may also power off the CPU and make use of the low-power co-processor to constantly monitor the peripherals for changes or crossing of thresholds.
- ESP32 integrates a rich set of peripherals, ranging from capacitive touch sensors, Hall sensors, SD card interface, Ethernet, high-speed SPI, UART, I²S and I²C.

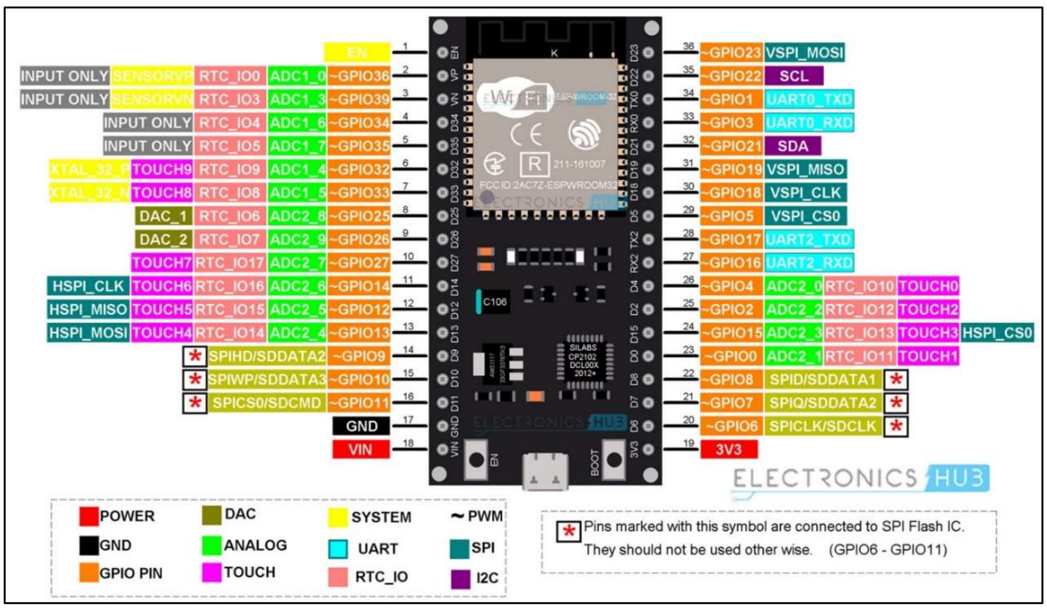


Figure 6: ESP32-WROOM-32D

KEY FEATURES

- Dual-core Xtensa® 32-bit LX6 MCU
- 80 MHz Crystal Oscillator
- 448 KB ROM for booting and core functions
- 520 KB of on-chip SRAM for data and instructions
- Wi-Fi 802.11 b/g/n (802.11n up to 150 Mbps) with frequency range of 2.4 GHz ~ 2.5 GHz
- Bluetooth v4.2 BR/EDR and BLE specification
- Operating Voltage: 3.0 V ~ 3.6 V
- Operating Current (Average): 80 mA

4.2 RFM LORAWAN TRANSCEIVER

- The RFM95 (W) transceivers feature the LoRa long range modem that provides ultra-long range spread spectrum communication and high interference immunity whilst minimising current consumption.
- RFM95 (W) can achieve a sensitivity of over -148dBm using a low-cost crystal and bill of materials.
- The high sensitivity combined with the integrated +20 dBm power amplifier yields industry leading link budget making it optimal for any application requiring range or robustness.
- Its key features include:
    - LoRa™ Modem
    - 68 dB maximum link budget
    - 20 dBm - 100 mW constant RF output vs. V supply
    - Programmable bit rate up to 300 kbps
    - High sensitivity: down to -148 dBm
    - Excellent blocking immunity
    - Low RX current of 10.3 mA
    - Built-in temperature sensor and low battery indicator
    - Module Size：16*16mm
    - LoRa Frequency available for use in India - 865 MHz to 867 MHz

Figure 7: RFM95 LoRa Transceiver

4.3 MAX30102 PULSE OXIMETER

- The MAX30102 is a complete pulse oximetry and heart-rate sensor system solution designed for the demanding requirements of wearable devices.
- The MAX30102 provides very small total solution size without sacrificing optical or electrical performance.
- Minimal external hardware components are needed for integration into a wearable device.
- The MAX30102 operates from 1.8V and 3.3V power sup-plies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.
- Benefits & Features –
    - Complete Pulse Oximeter and Heart-Rate Sensor Solution Simplifies Design
    - Integrated LEDs, Photo Sensor, and High-Performance Analogue Front –End
    - Tiny 5.6mm x 2.8mm x 1.2mm 14-Pin Optically Enhanced System-in-Package
    - Ultra-Low-Power Operation Increases Battery Life for Wearable Devices
    - Programmable Sample Rate and LED Current for Power Savings
    - Ultra-Low Shutdown Current (0.7µA, typ)

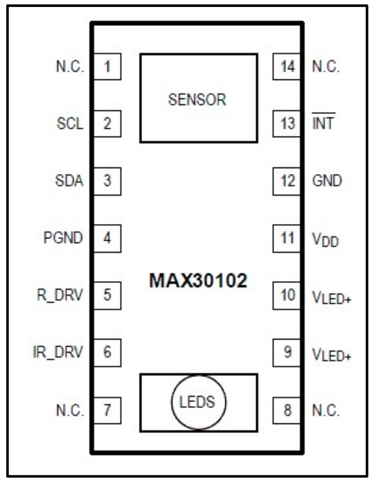


Figure 8: MAX30102 Pulse Oximeter

4.4 TEMPERATURE SENSOR

- Microchip Technology Inc.'s MCP9808 digital temperature sensor converts temperatures between -20°C and +100°C to a digital word with ±0.25°C/±0.5°C (typical/maximum) accuracy.

- The MCP9808 comes with user-programmable registers that provide flexibility for temperature sensing applications.

- The registers allow user-selectable settings such as Shutdown or Low-Power modes and the specification of temperature Alert window limits and critical output limits.

- MCP9808 sensor is suitable for medical applications and its dimensions are perfect for our proposed model.

- Key features of MCP9808 temperature sensor are:
    - Accuracy: ±0.25 (typical) from -40°C to +125°C
    - User-Programmable Temperature Alert Output
    - Operating Voltage Range: 2.7V to 5.5V
    - Operating Current: 200 µA (typical)
    - Shutdown Current: 0.1 µA (typical)
    - 2-wire Interface: I2C™ Compatible

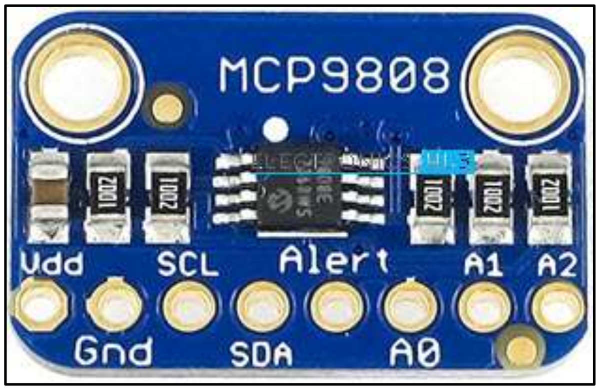


Figure 9: MCP9808 temperature sensor

4.5 MCP1700 LDO

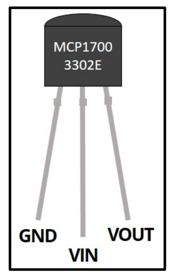


Figure 10: MCP1700 LDO

- The MCP1700 is a family of CMOS low dropout (LDO) voltage regulators that can deliver up to 250 mA of current while consuming only 1.6 µA of quiescent current.
- It is an ideal choice for two and three primary cell battery-powered applications, as well as single cell Li-Ion-powered applications.
- Overcurrent limit and overtemperature shutdown provide a robust solution for any application.
- Key features of MCP1700 LDO are:
    - AEC-Q100 Qualified and PPAP Capable
    - 1.6 µA Typical Quiescent Current
    - Input Operating Voltage Range: 2.3V to 6.0V
    - Output Voltage Range: 1.2V to 5.0V
    - 250 mA Output Current for Output
    - Low Dropout (LDO) Voltage
        - 178 mV Typical @ 250 mA for VOUT = 2.8V
    - 0.4% Typical Output Voltage Tolerance
    - Standard Output Voltage Options:
        - 1.2V, 1.8V, 2.5V, 2.8V, 2.9V, 3.0V, 3.3V, 5.0V
    - Stable with 1.0 µF Ceramic Output Capacitor
    - Short Circuit Protection
    - Overtemperature Protection

4.6 TP4056 LI-ION BATTERY CHARGER

- The TP4056 is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Its SOP package and low external component count make the TP4056 ideally suited for portable applications.
- Furthermore, the TP4056 can work within USB and wall adapter.
- No blocking diode is required due to the internal PMOSFET architecture and have prevent to negative Charge Current Circuit. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature.
- Key features of TP4056 are:
    - Programmable Charge Current Up to 1000mA
    - No MOSFET, Sense Resistor or Blocking Diode Required
    - Complete Linear Charger in SOP-8 Package for Single Cell Lithium-Ion Batteries
    - Constant-Current/Constant-Voltage
    - Charges Single Cell Li-Ion Batteries Directly from USB Port
    - Preset 4.2V Charge Voltage with 1.5% Accuracy
    - Automatic Recharge
    - Two Charge Status Output Pins
    - C/10 Charge Termination
    - 2.9V Trickle Charge Threshold (TP4056)
    - Soft-Start Limits Inrush Current

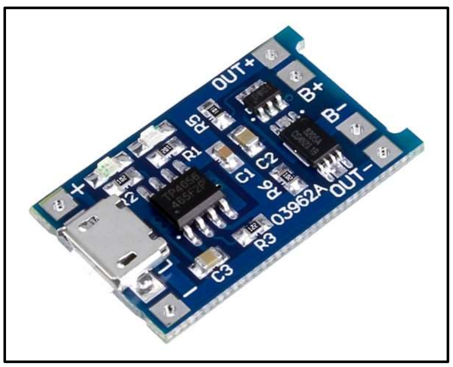


Figure 11: TCP4056 Li-Ion Battery Charger

CHAPTER 5
SOFTWARE REQUIREMENTS

5.1 ARDUINO IDE

- The open-source Arduino Software (IDE) makes it easy to write code and upload it to the board. This software can be used with any Arduino or ESP board.
- It is an official Arduino software, making code compilation easy that even a common person with no prior technical knowledge can get their feet wet with the learning process.
- It is easily available for operating systems like MAC, Windows, and Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing and compiling the code in the environment.
- A range of Arduino modules available including Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro, ESP8266, ESP32 and many more.
- Each of them contains a microcontroller on the board that is actually programmed and accepts the information in the form of code.
- The main code, also known as a sketch, created on the IDE platform will ultimately generate a Hex File which is then transferred and uploaded in the controller on the board.
- The IDE environment mainly contains two basic parts, Editor and Compiler where former is used for writing the required code and later is used for compiling and uploading the code into the selected module.
- This environment supports both C and C++ languages.

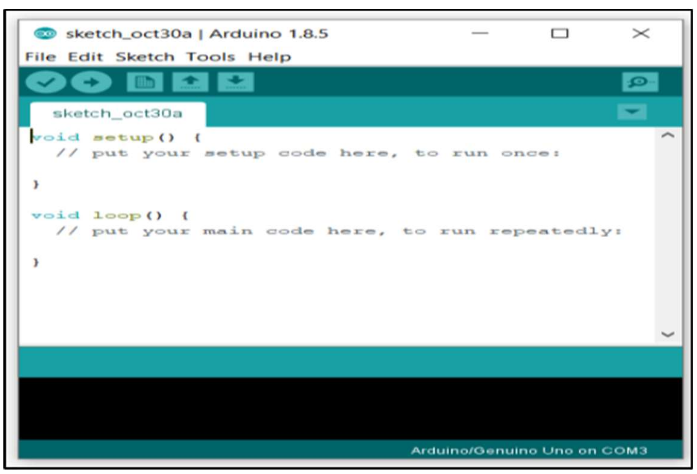


Figure 12: Arduino IDE

5.2 ANDROID STUDIO

- Android Studio is the official integrated development environment (IDE) for Google's Android operating system, built on JetBrains' IntelliJ IDEA software and designed specifically for Android development.
- It is available for download on Windows, MacOS and Linux based operating systems or as a subscription-based service in 2020.
- It is a replacement for the Eclipse Android Development Tools (E-ADT) as the primary IDE for native Android application development.
- The following features are provided in the current stable version:
  - Android-specific refactoring and quick fixes
  - Template-based wizards to create common Android designs and components
  - A rich layout editor that allows users to drag-and-drop UI components, option to preview layouts on multiple screen configurations
  - Support for building Android Wear apps
  - Built-in support for Google Cloud Platform, enabling integration with Firebase Cloud Messaging (Earlier 'Google Cloud Messaging') and Google App Engine
  - Android Virtual Device (Emulator) to run and debug apps in the Android studio.

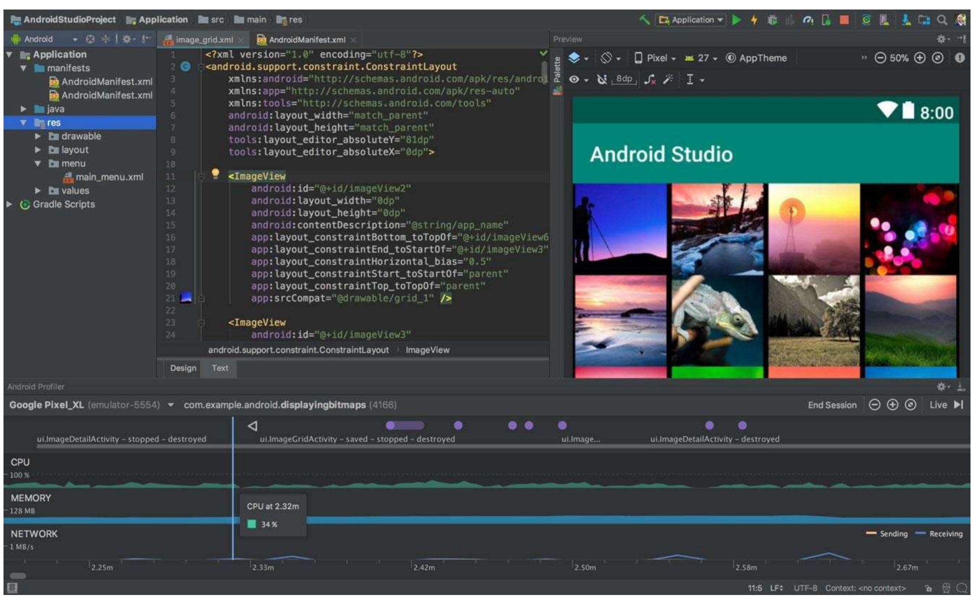


Figure 13: Android Studio

CHAPTER 6
SYSTEM DEVELOPMENT

6.1 SYSTEM CONNECTION

6.1.1 ESP32 and MCP9808

The Serial Clock pin (SCL) of the MCP9808 is connected to pin 22 of the ESP32 microcontroller. And the Serial Data pin (SDA) of the MCP9808 is connected to the pin 21 of the ESP32 microcontroller. This is because these two pins are the default pins mapped to one of the two I2C buses available in the ESP32.

6.1.2 ESP32 and MAX30102

Similarly, the MAX30102 Pulse Oximeter is interfaced to the ESP32 by means of the second I2C bus. This is possible due to the presence of the dual core processor of the ESP32, each of which can host a single I2C bus. Now, we can be certain that neither of the sensor data are getting mixed as the data lines of each of the sensors is isolated from the other. The pins 32 and 25 of the ESP32 are connected to the SCL and SDA pins of the MAX30102 sensor, respectively.

6.1.3 ESP32 and RFM95

The RFM95 is connected to the ESP32 as per the table shown below:

RFM9X	ESP32
DIO0	D26
DIO1	D33
Reset	D14
CS	D5
MOSI	D23
MISO	D19
SCK	D18
ground	GND
Power	3V3

Figure 14: ESP32 and RFM95 Connections

The various pins of the RFM95 have the following descriptions:

1. DIO0: Digital I/O, software configured
2. DIO1: Digital I/O, software configured
3. Reset: Reset Trigger Input
4. CS or NSS: SPI Chip Select Input
5. MOSI: SPI Data Input (Master Output Slave Input)
6. MISO: SPI Data Output (Master Input Slave Output)
7. SCK: SPI Clock Input
8. Ground: Ground Pin
9. Power: 3.3V Power Supply Input

The RFM95 is interfaced to the ESP32 by means of the SPI protocol. Please make a note that none of the pins the ESP32 have been used for multiple purposes in this application.

6.1.4 POWER SUPPLY

For the power supply circuitry, a 3.7V pouch style LiPo battery has been used as it provides stable current and has high power density. Its main drawback is the fact that it has to be protected from both overvoltage and undervoltage conditions. In case the battery gets overcharged (overvoltage condition), there is a chance that the battery might explode. As the battery level reduces, the voltage supplied but it decreases. If the voltage supplied by the battery reaches its lower threshold (undervoltage condition), it loses its capacity to be recharged and becomes useless.

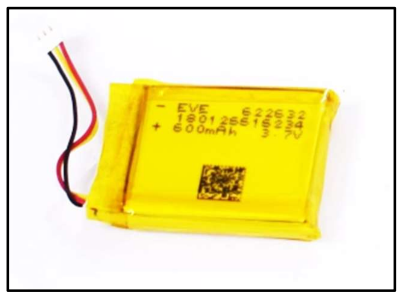


Figure 15: Battery Pack

To protect it from these conditions, a TP4056 standalone Linear Battery Charger has been employed. It ensures that the batter never reaches the overvoltage or undervoltage conditions. But the output from the charging module is not regulated.

In order to obtain regulated DC 3.3V voltage, the output from the TP4056 is connected to the input of a MAX 1700-3302E LDO voltage regulator as it is perfect for the low voltages of the LiPo battery.

Its specialty is the fact that even if the voltage output from the battery drops slightly below 3.3V even if the battery has not reached undervoltage condition, the LDO (Low Dropout) voltage regulator doesn't cut off the supply of power. The output terminals of the voltage regulator are connected to two capacitors in parallel (100nF ceramic disc and 100µF electrolytic capacitor) in order to get a perfect DC 3.3V output.

The positive terminal of the 100µF electrolytic capacitor is connected to the 3V3 pin of the ESP32 and the negative terminal of the electrolytic capacitor to the GND terminal of the ESP32.

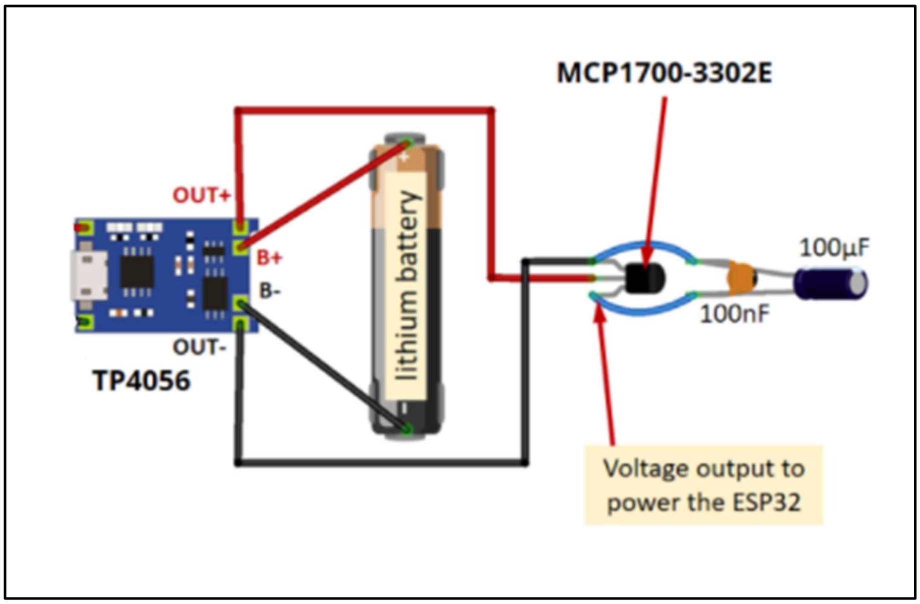


Figure 16: ESP32 Power Supply Connections

6.2 WORKING PROCEDURE

Upon switching on the power supply, which is done by means of a latching push button connected between the power supply's positive terminal and the 3V3 pin of the ESP32, firstly, the sensors and the RFM95 are initialised, i.e., the addresses of each of the sensors is assigned to each of the I2C buses of the ESP32 and it is verified that the sensors are present and are able to communicate with the microcontroller. If this doesn't happen, the next part of the execution will not take place until the faulty sensor is replaced.

Next, the various parameters which are required to setup the sensors are assigned. For example, the resolution is set for the MCP9808, the sampling rate is set for the MAX30102 or informing the MAX30102 to use both of its LEDs (Red LED and IR LED).

Once that is done, the RFM95's pins are set and detected for using special functions that are available in the ClusterDuck Protocol Library. Until the "SETUP OK" signal is not received from the ESP32 regarding the setting up the RFM95, the execution does not move ahead.

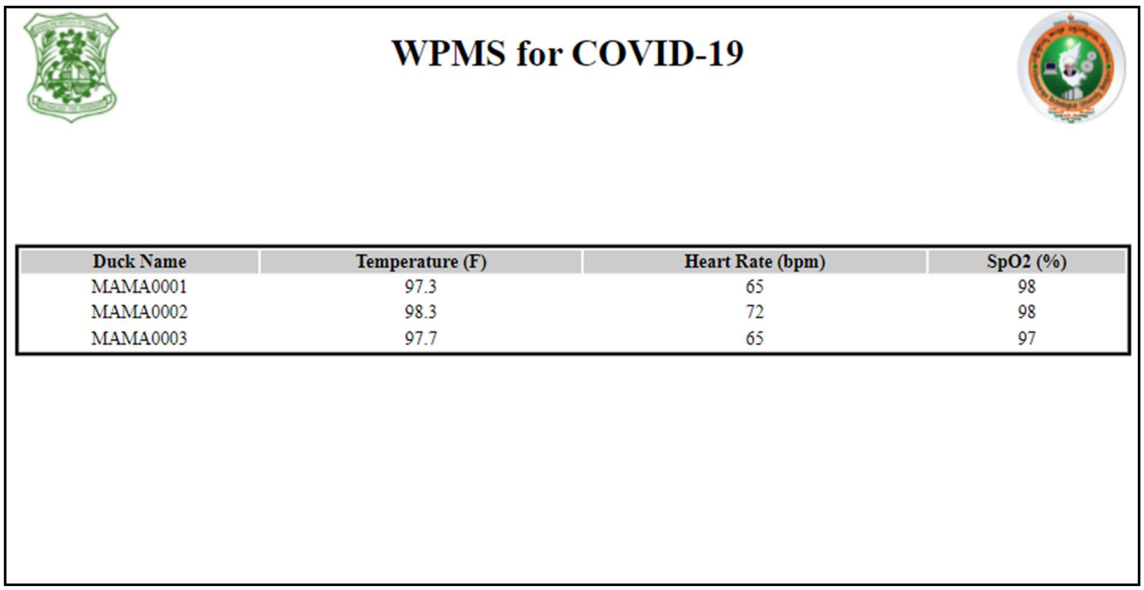
After all the setting up of all the peripherals of the microcontroller is completed, it switches on its inbuilt Wi-Fi and behaves as an access point, thus becoming an asynchronous web server. It hosts a HTML webpage saved in the internal file system (SPIFFS) of the microcontroller itself. This webpage requests sensor data collected by the microcontroller 10 second intervals. The time period of 10 seconds is chosen because as the sensors require about 3-4 seconds to obtain a set of values which are then averaged out by the microcontroller to obtain an accurate value.

To view this hosted data, one simply has to load the developed android application into his/her smartphone and connect to the Wi-Fi signal being hosted by the ESP32. Then, upon opening the application, it automatically obtains the IP address on which the HTML page is being hosted and displays the obtained sensor data to the user. The HTML page being hosted on the client's device requests data in the form of HTTP requests, which need to be fulfilled by the microcontroller.

All the aforementioned processing is carried out by a single core (CORE 1) of the microcontroller. The other core of the microcontroller (CORE 0) takes responsibility of sending packets of sensor data over the network created using the ClusterDuck Protocol.

At intervals of 60 seconds, the microcontroller runs a function that gets sensor data from each of the sensors and sends it serially over the network, along with a unique identification number so that the receiver can easily distinguish between the various data that it receives. This functionality is given to the Mama Duck. The Papa Duck is the one that is responsible for receiving the data that is being sent over the network by various Mama Ducks.

A variation of the same android application has been written specifically for the Papa Duck which has a capability to append new data received by it and display it on a special HTML page, which displays all the received data in a table format.



WPMS for COVID-19

Duck Name	Temperature (F)	Heart Rate (bpm)	SpO2 (%)
MAMA0001	97.3	65	98
MAMA0002	98.3	72	98
MAMA0003	97.7	65	97

Figure 17: Papa Duck Android Application Output
(Image taken in landscape mode to accommodate more data)

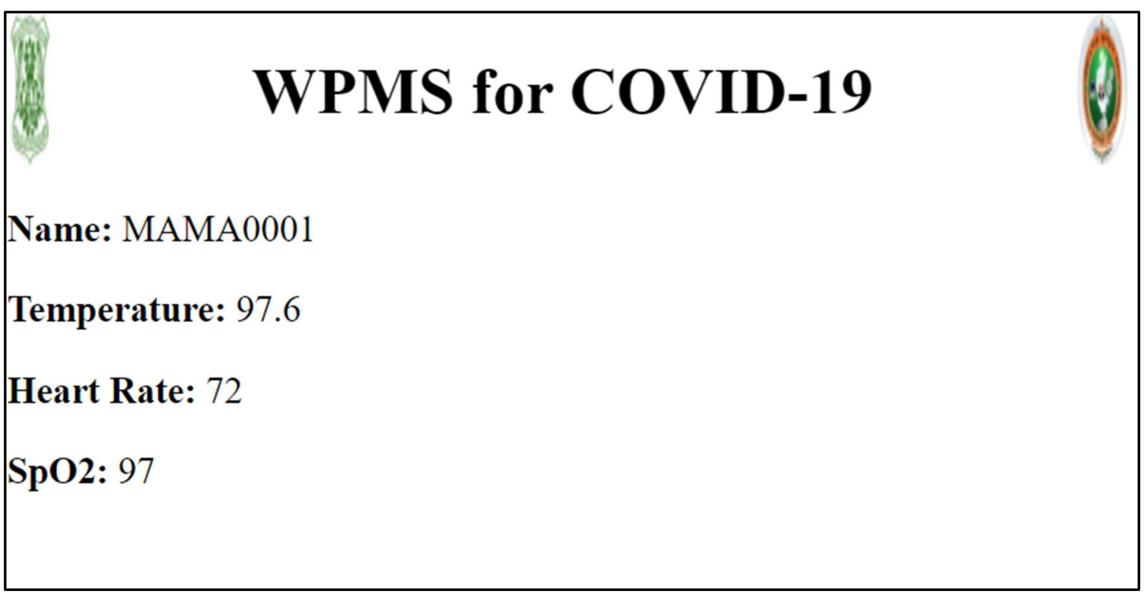


Figure 18: Mama Duck Android Application Output
(Image taken in landscape mode to accommodate more data)

CHAPTER 7
RESULTS AND APPLICATIONS

7.1 RESULT

Our proposed model was successfully completed with the following results:

1. The temperature sensor MCP9808 placed around wrist senses the body temperature and returns the value in both Fahrenheit and Celsius scale.
2. The pulse oximeter MAX30102 placed around the wrist senses the oxygen saturation in blood and calculates the heart rate in beats per minute (BPM).
3. The ESP32 module in the DuckLink successfully gathers the sensor data and transmits this data over on the ad-hoc LoRa network through the RFM95 transceiver module.
4. The PapaDuck receiver module in the hospital accepts the sensor data from the ad-hoc mesh network.
5. The doctor present in the hospital will be able to monitor the vital sign status of patients in real-time.

Figure 19: MCP9808 and MAX30102 sensor placement in wrist band

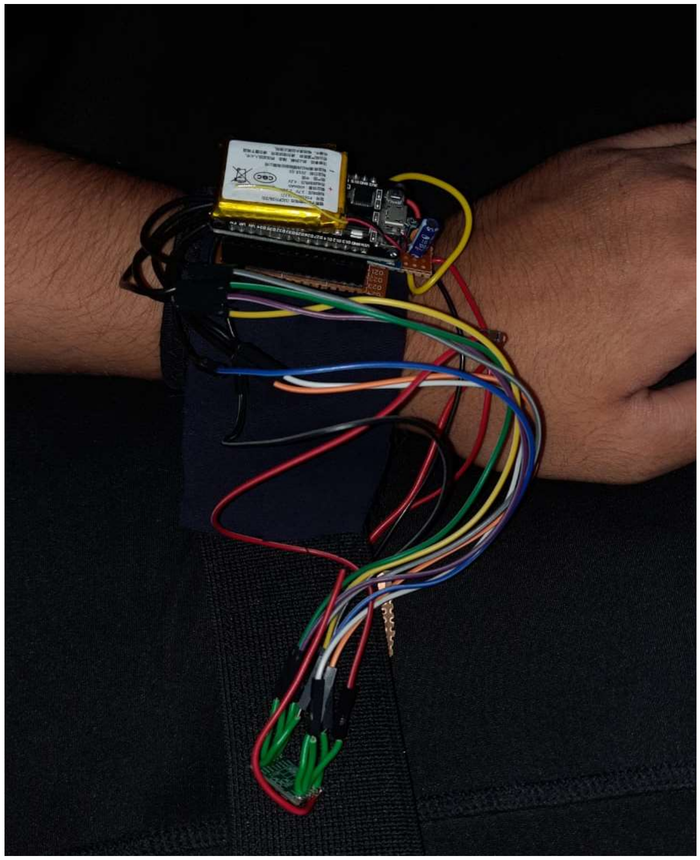


Figure 20: Prototype of proposed model placed on the wrist of a subject

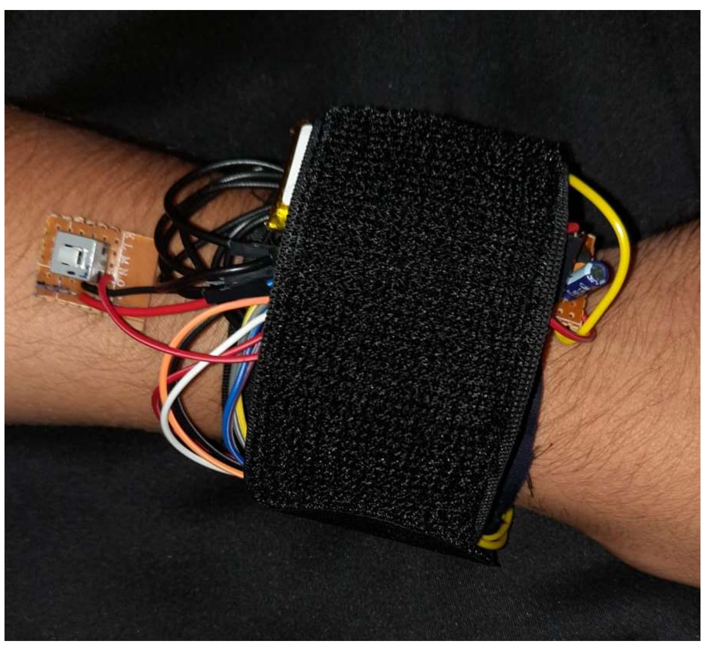


Figure 21: Prototype worn around wrist

7.2 APPLICATIONS

The proposed model has the following applications:

1. The proposed model can be used to monitor status of patients suffering from COVID-19 while maintaining home isolation.
2. This project could be extended for patients suffering from chronic disorders.
3. In case of aged people, this project can be employed for continuous monitoring of their body vitals.
4. In some exceptional cases, patients after going through a surgery could be monitored for a few weeks after they are discharged.
5. This device can be used to keep track of the status of those who have volunteered for drug and vaccination testing to keep track of the effects of the new drug on the human body.

CHAPTER 8

ADVANTAGES AND DISADVANTAGES

8.1 ADVANTAGES

- Wearable devices offer a hands-free way to communicate information, ensuring a sterile environment.
- Low power owing to CDP and LoRaWAN technology. Transparency of results because both doctor and patient have access to all data.
- If a patient is at risk but not seriously ill enough to be in the hospital, wearable tech can be used to monitor the patient at home to ensure no problems occur.
- People will become much more engaged with their own health if they are able to use wearable tech to monitor themselves.

8.2 DISADVANTAGES

- Having access to a large amount of data about your health can make users become obsessive or even hypochondriac.
- Much like Googling your symptoms may be misleading, having access to data, that could have errors, could lead to irrational fears and health scares
- Repair and replacement of damaged equipment is a difficult task owing to the possibility of contracting the virus
- In case of an emergency, provision of aid might be time consuming
- Upon expiry of use case, the device might be an addition to e-waste which would be difficult to dispose

FUTURE SCOPE

The futuristic model of this wearable device will be compact and lighter in weight which could monitor a few more parameters of the patients. As per experts, India might have to face a third wave of COVID-19. With such a wearable health monitoring system, we can be prepared for the third wave. A COVID-19 self-testing kit could be provided with this wearable device. An ad-hoc mesh network of nearby pharmacies could be created which would deliver medicines as soon as possible.

CONCLUSION

Giving back to the society must be on the to-do list of every engineer. Engineering is a profession that gives you the ability to bring changes for the betterment of society for a sustainable future. Through our project, we have been able to understand more about the Internet of Medical Things and how it could help our front-line workers and medical professionals who come in contact with COVID patients every day.

Our idea for the final year project was to make a wearable monitoring system for COVID patients so that they could stay in home quarantine and can be treated remotely. This would reduce the risk of medical professionals from contracting the virus. As the phases of the project moved on, we were able to understand various new technologies and processes that could be utilised in establishing a wearable monitoring system that would keep an eye on the vitals of the patient.

The wearable device technology has been rapidly growing with new products being launched every year and this technology will continue to grow.

Through this project, we have been able to work as team by delegating tasks among ourselves which also helped us to work individually. Also, we have understood that with technology, unimaginable wonders can be produced.