Developing a mesh network in a wooded area

A Final year project Submitted Towards Consideration
for a Bachelor of Engineering

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Listings

Glossary

APD	Avalanche PhotoDiode
API	Application Programming Interface
ASK	Amplitude Shift Keying
AWG	Agile Waveform Generator
B2B	Back-2-Back
BBP	Baseband Processor
BER	Bit Error Ratio
BL	Bandwidth-Length
BLAST	Bell Labs LAyered Space Time
BT	Time Bandwidth Product
CD	Chromatic Dispersion
CDMA	Code Division Multiple Access
CPM	Continuous Phase Modulation
CSI	Channel State Information
D	Dispersion Coefficient
DD	Direct Detection
DECT	Digital Enhanced Cordless Telecommunications
DPO	Digital Phosphorous Oscilloscope
DPM	Digital Phase Modulation
DSP	Digital Signal Processing
EDFA	Eridium Doped Fiber Amplifier
FBMC	Filter Bank Multi-Carrier
FDM	Frequency Division Multiplex
FDMA	Frequency Division Multiple Access
FEA	Finite Element Analysis
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
FRS	Full Response Signalling
FTTx	Fiber To The x
GASK	Gaussian Amplitude Shift Keying
GFDM	Generalised Frequency Division Multiplexing
GIPO	General Purpose Input/Output
GLPF	Gaussian Low-Pass Filter
GMSK	Gaussian Minimum Shift Keying
GSM	Global System for Mobile Communications
GVD	Group Velocity Dispersion
IFFT	Inverse Fast Fourier Transform
IIR	Infinite Impulse Response
IMDD	Intensity Modulation Direct Detection
ISI	InterSymbol Interference
IVI	Interchangeable Virtual Intruments
LAN	Local Area Network
LD	Dispersion Length
LD	Laser Diode
LUT	Look-Up Table
MC	Multiple-Carrier
MIMO	Multiple Input Multiple Output
MLSE	Maximum Likelihood Sequence Estimation
MMF	Multi Mode Fiber
MSK	Minimum Shift Keying
MSO	Mixed Signal Oscilloscope
MZI	Mach-Zehnder Interferometer
MZM	Mach-Zehnder Modulator
NGPON	Next Generation Passive Optical Network
NLSE	Non-Linear Schrödinger Equation
NRZ	Non-Return to Zero
ODN	Optical Distribution Network
OFDM	Orthogonal Frequency Division Multiplexing
OOK	On Off Keying
OSA	Optical Spectrum Analyzer
OSNR	Optical Signal to Noise Ratio
PAPR	Peak to Average Power Ratio
PD	Photo Diode
P-i-N	P-doped Intrinsic N-doped Photodiode
PON	Passive Optical Network
PRS	Partial Response Signalling
QMDD	Quadrature Modulation Direct Dectection
RF	Radio Frequency
RIN	Relative Intensity Noise
SCPI	Standard Commands for Programmable Instruments
SISO	Single Input Single Output
SMF	Single Mode Fiber
SNR	Signal to Noise Ratio
SOA	Semiconductor Optical Amplifier
SPM	Self Phase Modulation
SS	Spread Spectrum
SSFM	Split-Step Fourier Method
SSSFM	Symmetricised Split Step Fourier Method
TCM	Trellis Coded Modulation
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TFM	Tamed Frequency Modulation
TIA	TransImpedance Amplifier
UFMC	Universal Filtered Multiple Carrier
USB	Universal Serial Bus
VISA	Virtual Instrument Software Architecture
WDM	Wave Division Multiplex

Abstract

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Chapter 1

Introduction

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Chapter 2

Literature Review

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2.1 Introduction

The following literature review explores mesh networks in a wooded area, when communicating from two devices across a network there are a lot of issues associated with this communication such as signal loss due to:

- Environmental conditions such as rain .lighting etc
- If the device's antenna is in line of sight with each other
- Even if the devices are in the line of sight we can still reflections from a multi-path environment
- Possibility of trees falling obstructing the path of the signal causing more attenuation in the signal strength

In this project I want to explore mesh networks and transmit data across them, a mesh network is a type of network where no node(a node is just a device which has a transceiver) in the network acts as a master. As we look at the environment in which this project aims to be, we expect different phenomena to occur such as Attenuation According to ITU **?** "attenuation due to vegetation varies widely due to the irregular Nature of the medium and the wide range of species, densities and water content obtained in practice" when transmitting any radio wave it takes energy another factor to consider is whether wind which will cause a delay in the signal. this report aims to show my findings and try to count for Environmental conditions

2.1.1 Overview

This section provides a brief overview of my project on mesh networks in a forest the following question is:

1. What frequencies can transmit in a forest
    - What are the Disadvantages of transmitting at this range

- What are the effects of the multi-path environment when there is a line of sight
- What happens to Non-line of sight

2. What sensors /senor modules do we use

   - What sensors will give us a good range in an Irish forest
   - What are the limitations on the board we use
   - Do we need to have any additional hardware to accommodate a specific board

3. What microprocessor/hardware do we use?

   - What advantages/Disadvantages of Arduino vs Raspberry Pi
   - What is the major factor in the choice
   - How are the sensors wired to the processor
   - How to read the data
   - What is the effective Resolution needed for each application

2.1.2 Mesh network

A mesh network is a type of network that uses multiple devices to relay data between each other, making a decentralized network the mesh we looking to use is a wireless mesh network which is created through the connection of wireless access point(WAP) nodes. wireless mesh networks work through mesh nodes, mesh clients and gateways:

1. Mesh node nodes act as mesh routers and endpoints
2. Mesh clients these are end devices
3. Gateways data passes through the gateway as it enters or exits a network

The following is a block diagram of a mesh network each node will be attached to a tree each

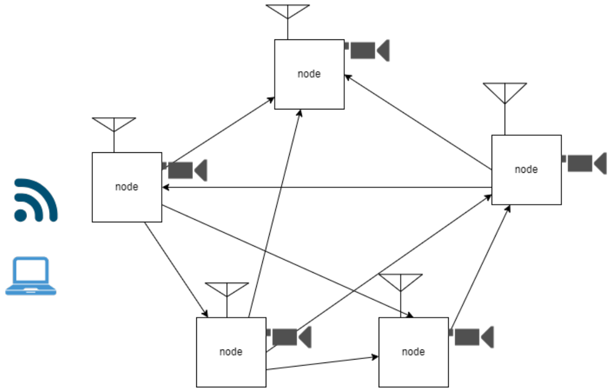


Figure 2.1: Basic block diagram of a mesh network

having a transceiver

2.2 Hardware Consideration

In this project we need to have data to transmit firstly let's describe what we want our network to have:

1. we want our mesh network to transmit data for example temperature, humidity and light and camera
2. I want there to be data read every hour and stored as a CSV file the image file will depend on the module I pick
3. I want to have a motion to detect any animal that passes the node

the following is a rough circuit diagram for the project: firstly let's establish the following:

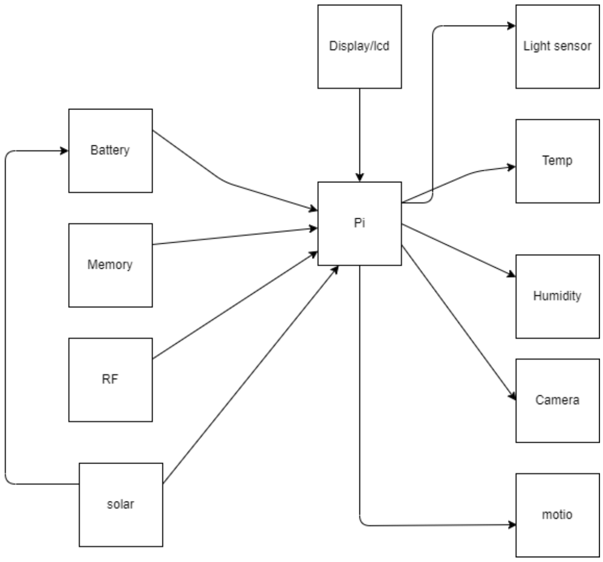


Figure 2.2: Rough circuit diagram for project

1. I can't use PCB due to the ordering process taking too long to come due to the time given to me
2. using any type of board like wire wrap would take too long and is outside of the goals of this project
3. This leaves with a choice of either the Arduino or pi

This section will Dicuss the following:

1. The sensors we will use in the project
2. the ADC we will have to will have to consider
3. the camera i picked considation for in this project
4. the memory module condestrations
5. the battery i picked
6. Considering the ardunio vs PI

2.2.1 Sensor considerations

In this section, we will discuss the process of considering each commponet of the sensors these sensor will be the following:

1. Temperature
2. Humdity
3. Light
4. Motion

Temperature & Humidity sensor

In our consideration for this sensor we can establish that we want our sensor to work in the following conditions:

1. our mesh node will be outside
2. Our device is in Ireland
3. Our device is in a forest

From that knowledge, I researched the temperature range in Ireland,

According to Met eireann**?**, we get the following table which the highest temperature in a Shaded

Highest Shaded Air (°C)	Station	Date
18.5°C	Dublin (Glasnevin)	10th 1998
18.1°C	Dublin (Phoenix Park)	23rd 1891
23.6°C	Dublin (Trinity College)	28th 1965
25.8°C	Donegal (Glenties)	26th 1984
28.4°C	Kerry (Ardfert Liscahane)	31st 1997
33.3°C	Kilkenny (Kilkenny Castle)	26th 1887
33.0°C	Dublin (Phoenix Park)	18th 2022
31.7°C	Carlow (Oak Park)	12th 2022
29.1°C	Kildare (Clongowes Wood College)	1st 1906
25.2°C	Kildare (Clongowes Wood College)	3rd 1908
20.1°C	Kerry (Dooks)	1st 2015
18.1°C	Dublin (Peamount)	2nd 1948

Table 2.1: Highest shader air Met Eireann(13^{th} June 2023)

According to the table, the highest temperature is 33.3 now to look at the other extreme for the Lowest temperature:

Lowest Shaded Air (°C)	Station	Date
-19.1°C	Sligo (Markree)	16th 1881
-17.8°C	Longford (Mostrim)	7th 1895
-17.2°C	Sligo (Markree)	3rd 1947
-7.7°C	Sligo (Markree)	15th 1892
-5.6°C	Donegal (Glenties)	4th 1979
-3.3°C	Offaly (Clonsast)	1st 1962
-0.3°C	Longford (Mostrim)	8th 1889
-2.7°C	Wicklow (Rathdrum)	30th 1964
-3.5°C	Offaly (Clonsast)	8th 1972
-8.3°C	Sligo (Markree)	31st 1926
-11.5°C	Wexford (Clonroche)	29th 2010
-17.5°C	Mayo (Straide)	25th 2010

Table 2.2: Lowest shader air Met Eireann(13^{th} June 2023)

According to the table above the lowest temp is -19.1 In consideration for where the project our condition was a range of -19.1°C to 33.3°C.

I also looked at humdity this referes to the amount of water vaper in the air. from met eirrean ? got this table: The ranges are 68.3% to 88 % So with these conserdations here are

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Mean at 0900UTC	87.0	86.4	84.0	79.5	76.9	76.7	78.5	81.0	83.4	85.5	88.5	88.0	83.0
Mean at 1500UTC	80.6	75.7	71.0	68.3	68.0	68.3	69.0	69.3	71.5	75.1	80.3	83.1	73.3

Table 2.3: Realtive Humidity(%) according to met eirrean

the diffrent components:

Components	Voltage Range	temperature range	Accuracy	Analogue /Digtial outputs	Current in	additional information
DHT22	3-6 volts	-40 to 80^o C	+/-0.5ºC	Digital	1.5mA	sample period 2 seconds
LM35D2	4 -30 Volts	-55 to 150	+/-0.5ºC (at 25ºC)	Analogue	10mA	None
TMP36	2.7 to 5.5 Volts	-40 to 125	+/-1ºC (at 25ºC)	Analogue	250 µA	NONE
LM75	3.0 to 5.5V	-55 to 125ºC	+/-2.0ºC (at -55 to 125ºC range))	Analogue	100 µA	NONE
DHT111	3-5.5V	0-50 °C	±2°C	Digital	1mA	sample period 1 second

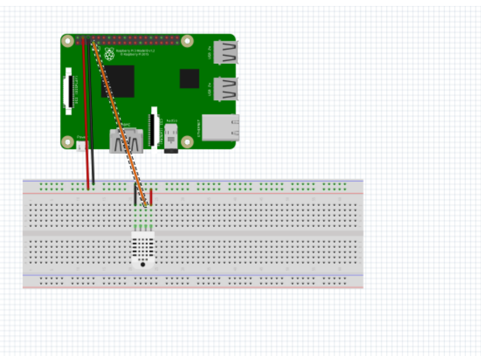
Table 2.4: Comparing of temperature sensors

After this, I limited this down to two sensors DHT22 and DHT11. The following are the advantages and disadvantages of the DHT22 and DHT11: So in conclusion I choose DHT22

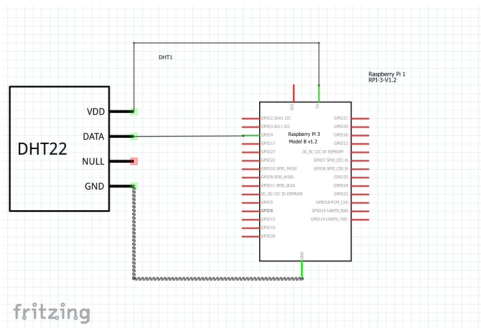
Device	Advantages	Disadvantages
DHT22	good accuracy has temp and humidity, falls in our temp range	sample period 2 seconds
DHT11	OK voltage,better sample period	draws a lot of current , and our of range

Table 2.5: Comparing DHT22 and DHT11

which is a Digital output. See a wiring diagram below This will have an Interface of the following:



(a) Interface for DHT22



(b) Schematic for DHT22

From above we see our schematic, DHT22 connections are the following:

- VDD is connected to 5v of the pi
- the Data pin is connected to GPIO 3

- Gnd pin of the pi is connected to the ground of DHT22

? The following is the link to the datasheet of this module when reading from this componet there is a delay of 2 second due to the sampling period.

Light sensor

In this section, we want to consider the following:

1. What region are we in
2. What light levels do we expect in this country
3. What sensor will accommodate this range

For this sensor we also must consider the outside aspect of the project i found this table on ? This table is the assoicated lux level incate when the vaules are . From above we want

Imminence	Example
0.002 lux	Moonless clear night sky
0.2 lux	Design minimum for emergency lighting (AS2293).
0.27 & 1 lux	Full moon on a clear night
3.4 lux	Dark limit of civil twilight under a clear sky
50 lux	Family living room
80 lux	Hallway/toilet
100 lux	Very dark overcast day
300 to 500 lux	Sunrise or Sunset on a clear day. Well-lit office area.
1,000 lux	Overcast day; typical TV studio lighting
10,000 to 25,000 lux	Full daylight (not direct sun)
32,000 to 130,000 lux	Direct sunlight

Table 2.6: Illuminates values

our sensor to be 0.002 to 25000 lux ideally, with that in mind here are the components I found through research:

Modules	Voltage Range	Analogue /Digital Outputs	illumination range	Current rating
LM393 with GL5528	3.3v to 5v	Analogue	0 lux to 100lux	250nA
DFR0026	3.3v to 5v	Analogue	1 Lux to 6000 Lux	120uA
LM393 with n5ac501085	max 150V	Analogue	10 lux to 100lux	1mW
LM393 with NSL-06S53	max 100v	analogue	1 to 100	50mw

Table 2.7: table of light sensors

After doing research DFR0026 **?** is the option I propose to use as it is the best for our application which will have an analogue output to see the interface see below:

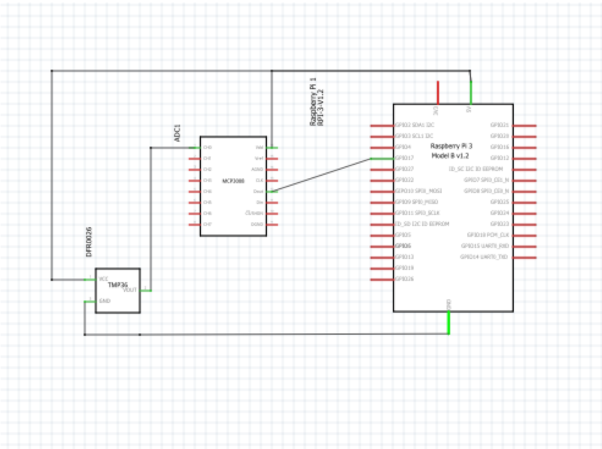


Figure 2.4: Interface for DFR0026

The following are the connections:

1. VCC pin is connected to 5v
2. Gnd of the sensor is connected to Gnd of the Pi
3. The output is connected to ch 0
4. the output ranges from 0 to 5 v

The commpoent relies on the ADC which is on page12

Motion sensor

For this section, we have to consider the following:

1. The range of the sensor
2. The degree of the sensor
3. How long of a delay is the sensor

The following are the components I considered:

Modules	Voltage Range	Distance	Max angle	Analogue /Digital Outputs	Power
HC-SR501	5-20V	3 to 7m	110	Digital	50uA
AM312	4.5-20v	3m	130	Digital	60uA
AS312	-0.3 - 3.6V	12m	130	Digital	100mA

Table 2.8: Motion sensor components

The sensor I'm choosing is AS312**?**(which has a delay time of 2 seconds) which is a Digital interface to see the wiring see below:

the following is the interface for our device

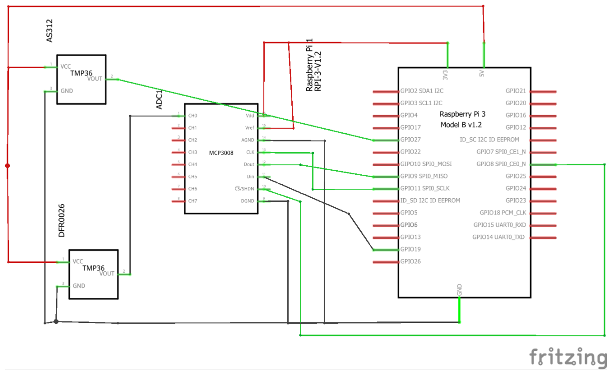


Figure 2.5: Interface for AS312

The connections are the following:

1. VCC is connected to 5v pin of the Pi
2. GND is connected to the GND of the Pi
3. Vout is connected to GPIO 27

This component has the following:

1. Range of 12 meters
2. An angle of 65^o degree

3. A Delay of 15 $\mu Seconds$

Radio Module

For this section, we have the following considerations:

- The devices are in a forest
- Meaning Gigahertz isn't a desirable frequency
- We want a module that low low-power
- a model that will have a high throughput

Through research, I found the following table:

Out of these, I picked the MM2 Series 900 MHz**?**.Note that the seller of this radio module has limited the documentation of this module makes it hard to draw an interface for this module which will be done next semester

Modules	Tx/RX Voltage	Frequency	Range	TX/RX power	Through put	Error detection	Rx sensitivity	Hopping channel
Gravity: 315MHZ RF Receiver Module	3.3v/5v	315Mhz	50 m	-10dbm -95dm	9.6kbps (max)	none	-108 dbi	no
MM2 Series 900 MHz OEM Radio	3.5 5.0	902 928 Mhz	32km	1175 ma tx rx 125ma	80 - 115.2 kbps	32-bit CRC	-108dbm @ 115.2kbps for BER 10^{-4} -103 dm @153.6 for BER 10^{-4}	50 to 112, user-selectable
RF 433MHz Transmitter/Receiver Module	5V 3-12v	433.92 MHz	20-200 meters	10 mW	2kbps	ASK modulation no error check	-105 db	no
Digi XBee-PRO 900HP RF Module	2.1 to 3.6v dc	902 to 928 Mhz	14km - 6.5km	24dm	10kps -200kps	NONE	-101dm	FHSS (Software Selectable Channels)

Table 2.9: Radio modules found in research

2.2.2 ADC Considerations

for the ADC the following considerations:

1. low power
2. high bit resolution
3. low amount of channels
4. high sample rate

the two things we want for this is the high bit Resolution and a high sample rate

Device	Resolution	Sample rate	Input range	Power consumption
ADC pi Zero	17 bits	100KHz	0-5.06v	10mA
MCP3008	10 bits	200 ksps	2.7v- 5.5v	500uA

Above are the components I had to choose from for this project, I picked MCP3008 due to its resolution and sample rate the following is the schematic for the MCP3008**?** the following

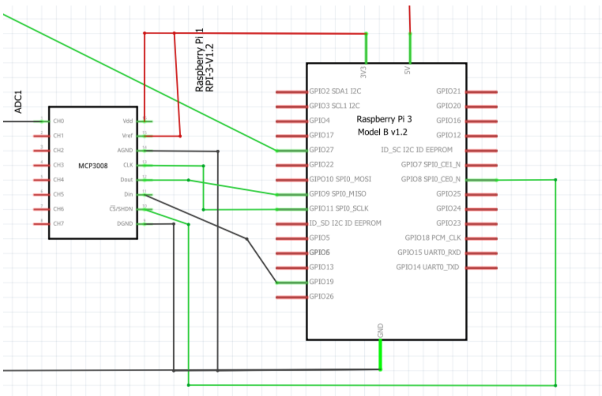


Figure 2.6: Schematic for MCP3008

are connections:

1. VDD is connected to 3v3 pin of the Pi
2. VRef is also connected to 3v3 pin of the Pi
3. AGND is connected to the gnd pin

4. CLK pin is connected to GPIO port 11
5. Dout pin is connected to GPIO port 9
6. Din pin is connected to GPIO port 19
7. CS pin is connected to GPIO port 8
8. DGND ping is connected to the gnd pin

this commponet has the following:

1. A 10 bit resultion
2. seen as the reference will be 3.3v
3. 200ksps meaning the delay to read is 5μ seconds

2.2.3 Camera

For the camera, we have to keep in mind the following:

1. Focal length
2. Resolution
3. Power
4. what lux values it works at

Modules	Voltage range	lens size	Image Resolution	Video Resolution	Frame Rate	Type of Output	Preferred condition	Power
Raspberry Pi VR 220 Camera	3.3V ac	can change with lens	3280 X 2462	1920 x 1080	30 FPS	Need to research	Daytime	38mA
DIGILENT 410-358	3.6v	optical size 1/4 inches	2592 x 1944	?	?	Digital	?	200mA
The Raspberry Pi NoIR	3.3v	1/4 inches	3280 x 2464	1080 or 720	30 60 fps	need to research	house	38mA
OV7670 VGA	2.45 to 3.0v ac	1/6 inches	2.36mm x 3.6um	?	30 fps	analogue	need to research	60mW

Table 2.10: Camera module

The camera I pick is a Raspberry Pi VR 220**?** Camera to see how to connect look at the following link

2.2.4 Memory module

For this section, we consider the following:

1. The file formatting of the sensor data
2. The file formatting of the camera data
3. What are the possible sizes of data
4. what is the size of the raspberry pi OS

in my project, I plan on using the following:

product name	Capacity	Speed class	Read speed	write spe
SAMSUNG EVO Plus Class 10 microSDXC	256 GB	U3	up to 130MB/s	up to 130M
SANDISK Ultra Performance Class 10 microSDXC	128 GB	class 10 u1	up to 80 MB/s	up to 10 M

Table 2.11: mirco SDs in consirdation

1. For the sensor I plan on use storing the data in a CSV file with the following heading: (timestamp, heat, humidity, light level, anything detected) which can be around 25KB
2. For the camera in the plan using 10 MB is the largest file size
3. For the raspbery pi i downloaded the raspberry imager this has loads of options such as the following on 16

after has been we must consider a mircoSD ,here is the following considerations: According to our sensor modules we have the following:

1. DHTT22 has a sample period of 2 seconds
2. AS312 which has a delay time of 15 μ seconds
3. MCP3008 5 μ seconds
4. Turbo 1GB has a read speed of

this depends on the onboard storage but here is what I found through research: The Raspberry

Brand	Product Name	Storage Capacity	USB Version	Data Transfer Sp	Read/Write Spee	Durability	Encryption	Form Factor	Compatibility	Price
SanDisk	Cruzer Glide 1GB USB 3.0 Flash Drive	1 GB	USB 3.0	100 MB/s	80 MB/s	Water and shock resistant	No	Standard	Windows, Mac, Linux	$5.99
PNY	Turbo 1GB USB 2.0 Flash Drive	1 GB	USB 2.0	480 Mbps	300 Mbps	Water and shock resistant	No	Standard	Windows, Mac, Linux	$3.99
Verbatim	Store 'n' Go 1GB USB 2.0 Flash Drive	1 GB	USB 2.0	480 Mbps	300 Mbps	Not specified	No	Standard	Windows, Mac, Linux	$2.99

Table 2.12: Memory usb to consider

Pi 4 supports USB 2 and USB 3. For this, I'll pick the Turbo 1GB USB 2 Flash Drive

2.2.5 Battery

In this section, we want to consider the following:

1. Have enough power for all sensors and radio module
2. Have storage of the battery
3. Discharge rate of the battery (how many operating hours can I get out of the battery)

Here are the following Devices I found :

Modules	Voltage	Interface	Power	Chemistry	Supply time
Li-polymer Battery HAT	5v	Micro USB	1.8A	lithium battery	5 hours

Table 2.13: battery considerations

The battery I'm going for is the li-polymer which has a micro USB how to charge:

- Step 1: Insert the Li-polymer battery into a 2.0mm battery socket
- Step 2: Connect the power adapter to a micro USB or Type-C interface by USB cable.

Aside: this commpoent has the following:

1. A battery that is 3.7v 3000mAh
2. Output voltage of 5 volts
3. an estimated Power supply time of 5 hours

2.2.6 Arduino vs PI Consideration

In this project, we will have to choose between what microprocessor we will use. we can have 3 options

1. PCB (printed circuit board) where we design the circuit in a program like Fusion 360. The major issue is due to the current state of silicon chips which will slow down the progress of the implementation stage
2. Arduino
3. Raspberry Pi

for these will consider the Arduino and the Raspberry Pi the Advantages and disadvantages of these are the following:

Arduino	pi
Advantages	Advantages
1. Arduino has a 10-bit ADC	1. Pi can compile Python (easier to write)
Disadvantages	Disadvantages
1. Arduino has a supper set of C++ 2. Arduino only has 6 Analogue pins	1. Pi is a technically a small CPU 2. The pi needs an ADC circuit to deal with inputs that are analogu

Table 2.14: Advantages /Disadvantages of Arduino vs pi

Although the Arduino would be more efficient than the Raspberry Pi due to Raspberry Pi has an Operating System I am picking the Pi as I'm more familiar with Python and Linux. Linux can be used to handle the networking side of the project I am willing to lose some efficiency in power for an easier time making the code for this project

Picking a Raspberry Pi

Now that we have picked out a device to use we need to define what we need in terms of the following:

1. The amount of GIPO PORTS we need
2. Nature of the output of the sensor

3. Speed of the clock

GPIO(General purpose input/output) is used to select the input/output the pi can only take in digital signals only Seen as we have our components chosen that require A GPIO port (temperature/ humidity, on page 7, Light on page 9, motion on page 10) we need at least 3 GPIO ports to be available to us as the light sensor and the motion will need an adc as looking through the documentation .firstly let's look at the different models

Raspberry Pi Model	Internal Clock Speed	Power (Watts)	GPIO Features	Type of Connectors	SRAM
Raspberry Pi 1 Model B+	700 MHz	5.5	26 GPIO pins	1 HDMI, 1 micro USB, 1 USB 2.0, 1 audio jack	512 MB
Raspberry Pi 2 Model B	900 MHz	7.5	40 GPIO pins	1 HDMI, 1 micro USB, 4 USB 2.0, 1 audio jack	1 GB
Raspberry Pi 3 Model B+	1.4 GHz	8	40 GPIO pins	1 HDMI, 1 micro USB, 4 USB 2.0, 1 audio jack, 1 Gigabit Ethernet, 1 PoE header	1 GB
Raspberry Pi 3 Model A+	1.4 GHz	5	26 GPIO pins	1 HDMI, 1 micro USB, 2 USB 2.0, 1 audio jack	512 MB
Raspberry Pi Zero	1 GHz	1.2	40 GPIO pins	1 mini HDMI, 1 micro USB, 1 micro-USB OTG	512 MB
Raspberry Pi Zero W	1 GHz	1.3	40 GPIO pins	1 mini HDMI, 1 micro USB, 1 micro-USB OTG, 1 Wi-Fi/Bluetooth module	512 MB
Raspberry Pi Zero 2 W	1 GHz	0.8	40 GPIO pins	1 mini HDMI, 1 micro USB, 1 micro-USB OTG, 1 Wi-Fi/Bluetooth module	512 MB
Raspberry Pi 4 Model B	1.5 GHz	7	40 GPIO pins	2 HDMI, 2 USB 3.0, 2 USB 2.0, 1 Gigabit Ethernet, 1 audio jack	1 GB, 2

Table 2.15: Table of Raspberry Pi's

The above table displays the modules seen as our radio modules is 900Mhz we want 1.5GHZ which is the Raspberry Pi 4 which needs USB c charger and an HDMI.

Picking an PI OS

Seen as

2.2.7 Conclusion

In this project the hardware needed is the following: these are from

1. 1 x Raspberry Pi 4 Model B
2. 1 x HDMI cable
3. 1 x USBC cable
4. 1 x USB C charging head
5. 1 x DHT22
6. 1 x DFR0026
7. 1 x AS312
8. 1 x MM2 Series 900 MHz
9. 1 x MCP3008
10. 1 x Raspberry Pi VR 220 Camera
11. 1 x Li-polymer Battery HAT
12. 1 x Turbo 1GB

2.3 Software considerations

now that we have established the essential Hardware needed for our project we must consider the following for the software of the project:

1. How to structure code
2. Linux set up of sever and nodes
3. How will data be sent
4. Is this gonna be an OOP or functional approach
5. How to program each device?

2.3.1 Sensor code

in this section, I will discuss the following :

1. DHT22
2. AS312
3. MCP3008
4. DFR0026
5. Kuman for Raspberry Pi 3B+ TFT LCD Display
6. Raspberry Pi VR 220 Camera

this project code will mainly be object-oriented. so the goal is to first test it with my laptop and Create A bash file full of commands to install the Libraries making the code to be split up into different parts so that all that is needed is the Libraries I make and code that won't all have to compiled in one file

DHT22

in this section we have to consider the following:

1. the GPIO port as on page 7 this is connected to port 3
2. the type of output is digital so no extra hardware/code is needed

the following is a rough guide on how to read from the DHT22 I got this from the following link (**Note: I haven't tested this due to the constraints of this year so I can only go off what others have done.**)Firstly open the terminal in the pi and type the following commands

```
git clone https://github.com/adafruit/Adafruit_Python_DHT.git
cd Adafruit_Python_DHT
sudo apt-get update
sudo apt-get install build-essential python-dev
sudo python setup.py install
```

the following is the sample code for this sensor

Listing 2.1: Example code for DHT2

```
#Libraries
import Adafruit_DHT as dht
from time import sleep
def setup_DHT22(Gpoiport:int):
humidityy,temp=dht.read_retry(dht.DHT22, Gpoiport
    )
        sleep(5)
        return humundity,temp
h,t=setup_DHT22(3)
print('Temp={0:0.1f}*C␣␣Humidity={1:0.1f}%'.
    format(t,h))
```

this code will import the DHT Libraries from Adafruit and the module of time, next a function is called where the port is defined and in the DHT is mainly used DHT Libraries

AS312

for this section i followed this link we also want to keep in mind the following:

1. This has a digital interface and is connected to GPIO 27

Here are the rough steps firstly type the following into the terminal

```
sudo apt-get install python-rpi.gpio
```

Then type this into an IDE of your choosing

Listing 2.2: Example code for AS312

```
import RPi.GPIO as GPIO
import time

pir_sensor = 27
GPIO.setmode(GPIO.BOARD)

GPIO.setup(pir_sensor, GPIO.IN)
current_state = 0

time.sleep(0.1)
current_state = GPIO.input(pir_sensor)
if current_state == 1:
        print("GPIO␣pin␣%s␣is␣%s" % (pir_sensor,
           current_state))
        # trigger camera
# must look up this
GPIO.cleanup()
```

DFR0026

from the last example, nothing has changed from the last component an example code for this can be found on page 20

2.3.2 MCP3008

for this section, we want to consider the following:

1. The MCP3008 data out is GIPO 9

this section follows this link firstly try the following in command in the terminal

```
sudo raspi-config nonint do_spi 0
```

Listing 2.3: ADC code

```
from gpiozero import MCP3008
from time import sleep
DFR0026 = MCP3008(channel=0, device=0,port=9)

print ('raw:␣{:.5f}'.format(DFR0026.value))
sleep(0.1)
```

2.3.3 Kuman for Raspberry Pi 3B+ TFT LCD Display

first in the terminal type the following:

```
sudo pip install Adafruit_ILI9341
sudo pip install Pillow
```

Listing 2.4: example code for LCD display

```
import Adafruit_ILI9341 as ILI9341
from PIL import Image, ImageDraw, ImageFont
# Configure the display driver GPIO pins
disp = ILI9341.ILI9341(dc=25, spi=SPI.SpiDev(0,
    0), rst=24, mosi=19, sclk=18, miso=21)
# Initialize the display
disp.begin()
# Set the font
font = ImageFont.truetype('Arial.ttf', 16)
# Set the text colour
text_color = (255, 255, 255)  # White text color
# Create a blank image
image = Image. new('RGB', (disp.width, disp.
    height), (0, 0, 0))
# Create an ImageDraw object for drawing on the
    image
draw = ImageDraw.Draw(image)

# Draw the text onto the image
draw.text((10, 10), 'Hello,␣World!', font=font,
    fill=text_color)
disp.display(image.convert('RGB'))
```

2.3.4 Raspberry Pi VR 220 Camera

to get started with this simply look at the following link here is an example of the code of this module :

Listing 2.5: example code for camera

```
from picamera import PiCamera
from time import sleep

camera = PiCamera()

camera.start_preview()
```

```
                    sleep(5)
                    camera.stop_preview()
```

2.3.5 MM2 Series 900 MHz

for this section, the seller of this module has no public documentation so it is hard to come with an make a interface for this section

2.3.6 code structure

The code structure for this will be an object-oriented program all the individual sensors and hardware for the pi will be as displayed above the code in this section will be formatted into objects for example I will have an object called proj_sensor and a method of this would be DHT22 while an attribute of this would be the sample rate the following is a rough breakdown of the structure of the code

- Sensor object
  - Temperature and humanity method
  - light method
  - Motion method which triggers the camera
  - Battery method which is a constructor method
  - Memory method which links with the radio
- radio object which reads from Memory and transmits the data

2.3.7 File structure

For the File structure, we want our sensor data to be stored every hour in a CSV file with the following column headings:

1. timestamp
2. Heat
3. Humidity
4. light level
5. motion detected (True/False)

for the writing to Date, we will use Pandas to write to the CSV file for file sorting, I will use the Python Library glob which I can use to look for files the following is an example of how to make a CSV file: firstly let's make a data frame:

Listing 2.6: sample code for turning sensor data into a data

```python
import pandas as pd
import numpy as np
from datetime import datetime
cols_name=["Timestamp","Tempeature","Hummidty","Light_level","Motion_dected"]

#assume that being recorded now
data=[]
timestap=datetime.now()
timestap=timestap.strftime("%d/%m/%Y %H:%M:%S")
Current_state=1
Heat=0.40
Hummidty=1.0
Light_level=0.23
data=np.array([[timestap],[Heat],[Hummidty],[Light_level],[Current_state]])
data=data.T
df= pd.DataFrame(data,columns=cols_name)
```

Next, use the.To_csv method from pandas another Libraries that could be useful is the Tkinter here is a sample of how to store where the file is gonna be:

Listing 2.7: example code for storing directory

```python
import tkinter as tk
from tkinter import filedialog
import json
import os

root = tk.Tk()
root.withdraw()
selected_dir = filedialog.askdirectory()

if not os.path.exists('selected_dir.json'):
        # Write the selected directory to a JSON file
        with open('selected_dir.json', 'w') as f:
                json.dump(selected_dir, f)
                print("Successfully saved selected directory to JSON file.")
else:
        print("File 'selected_dir.json' already 
```

```
                                      exists.␣Not␣saving␣the␣directory.")

                        root.quit()
```

Other useful Libraries allow you to select all .csv, png called glob

2.3.8 Conclusion

2.4 Attenuation

Attenuation refers to a reduction in the strength of a signal. Attenuation occurs with any signal, whether digital or analogue. Seen the aim of making a network the first step is to look into what frequencies can be transmitted and received.
In the environment in which we want our project to take place, we want the following:

1. An antenna that a high so we can affect the data rate of the signal
2. A frequency range at which Attenuation is not present

Through research, I found the following plots:

1. First Plot The first plot I got for Savage e.t al pg. 7 **?**

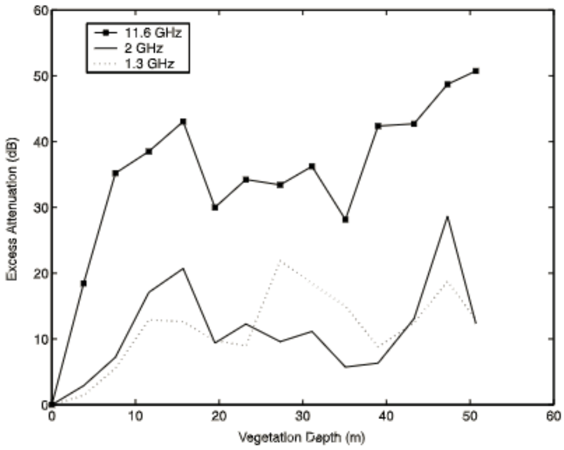


Figure 2.7: Silver Maple in-leaf excess attenuation for the line of trees geometry (receiver antenna height: 3.5 m, SAVAGE ET AL.pg.7

This graph displays as vegetation depth increases Attenuation rises. The problem with this graph is that it doesn't give an in-depth view of which attenuation occurs. This then led me to look up the International Telecommunication Union **?** recommendations for Attenuation in wooded areas

2. Second Plot V is the vertical polarization H is the horizontal polarization

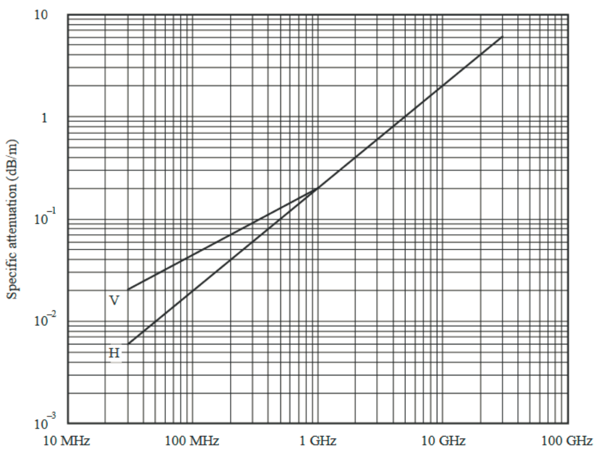


Figure 2.8: Specific attenuation due to woodland (Recommendation ITU-R P.833-7 (02/2012) Attenuation in vegetation pg.5

From this graph we can assume the following:

(a) From a frequency $\geq$15GHz we can assume Attenuation is more components

(b) Around the 1 GHz range we get low values of Attenuation

(c) in the MHz range we get the best response

from this, I selected the range which is $10^6 hz$

so now that we established our range let us consider what happens when it rains **?**

Frequency MHz	Attenuation dB/m
106	0.04
466	0.12
949	0.17
1852	0.3
2118	0.34

Figure 2.9: Predicted attenuation due to rain for the region, which is measured by using the ITU standards,(Source: Hindawi(2014))

Ideally, we want a low MHz but we want speed and this is dictated by what we choose let's further see how radio waves are affected by water/rain

2.4.1 Absorption of water

for this, I found this graph from Lunken Heimer **?**

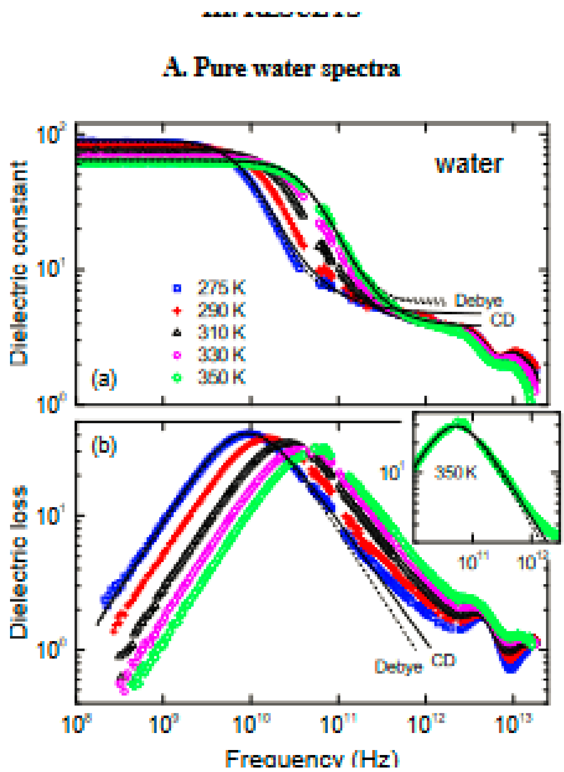


Figure 2.10: absorption of water

According to the graph, Water absorbs MHz frequencies which will affect the transmission in the transmission and in some cases, we might have to consider non-line-of-sight communication when it rains or we might also consider another node to route to receive the node.

2.5 mesh network considerations

For this section, we have to consider the following:

1. How are we setting up the network
2. What framework are we using to set this Up
3. What are the advantages/disadvantages

In my research I found two main frameworks that this project could use to achieve the mesh network these are the following:

1. LORA
2. Zigbee

According to Chen (2023)? "LoRa, as one of Low Power Wide Area Networks (LP-WANs) technologies, aims to enable IoT devices to perform long-range communications with lower power consumption [18]. LoRa makes use of the chirp spread spectrum (CSS) modulation to improve the transmission distance up to kilometres and also be resistant to multi-path effects."

According to Vlad?, "ZigBee is an LP-WPAN (Low-Power-Wireless Personal Area Network) with short range and low power consumption, as mentioned before. The range for ZigBee devices is up to fifty meters and it is characterized by a low data rate, having a maximum value of 250 kbps. The protocol is suitable for sensors and IoT applications because of the low data rate and low power consumption"

the following are the differences between the two: from research, these are very similar but

LoRa		ZigBee	
Advantages	Disadvantages	Advantages	Disadvantag
Long transmission distance	Low transmission rate	Low power consumption	Low data ra
Low power consumption	Slow data transfer rate	Long range	Limited ran
Multi-channel information procession	Small payload	Scalability	Signal interfer
Strong anti-interface ability	Low bandwidth	–	High-sensitivity
High-sensitivity levels	Spectrum interference		

Table 2.16: Advantages and Disadvantages of LoRa and ZigBee

it seems if I plan on adding lots of Zigbee is the best for this challenge

2.6 Review key of research Papers

The following are the research papers I used

1. zhao

   In my research, I found multiple projects that are similar to mine In Zhao(2023)(?, zhao) used LORA to track light sensitivity, air pressure one of the challenges Zhao came across was Attenuation as stated above and also the author came across the problem of not having sufficient solar panels

2. Daniel

   Another paper I found in my research is by Daniel **?** In this, Daniel discusses modeling radio wave propagation in a forest environment which isn't in the scope of the project Daniel's work shows that a better approximation for transmission loss was a key read to under what happens on a more in-depth scale in my project

3. Anna

   ? in Anna's paper she mainly used LORA where she compared line of sight and the non-line line of sight environments in urban and forested areas this paper aims to study the effects of signal propagation in different environments.

4. ITU

   ? in ITU in most research papers I found it referred back to this document this document was very helpful in terms of understanding Attenuation and challenges that face

2.7 Summary

This report highlights the challenges at come from transmitting data in a wooded area these challenges are the following:

1. Attenuation

2. Absorption

In a wooded area, we established that Attenuation occurs due to the reflection, and penetration of radio through any type of medium. We established that our antenna will have to be in the Mhz range but will still have signal loss /errors due to Absorption of the signal received due to rain or water being in the signal path we have yet to consider the non-line of sight environment but this is to be discussed when prototyping, this report mainly focuses on the hardware where the focus is on sensors such as:

- Temperature

- Light

- Motion

- Humidity

The report focuses on how to read this data from a Software perspective the code will be an object-oriented program where the code will be separated into different blocks of code so the file size is minimized and leads to a faster compile time.

]

Chapter 3

Methodology

3.1 Methodology

3.1.1 Introduction

In this Section i will discuss the proposed methodology of this project this will cover the following:

1. The Research Philosophy
2. The Research Approach
3. The Research Design
4. The Data Collection Methods
5. The Model Development
6. The Data Analysis Methods
7. The Ethical Considerations
8. The validity and reliability
9. The Limitations and Delimitation
10. The timeline

3.1.2 Research Philosophy

This research adopts a pragmatic philosophy, which emphasizes the practical application of knowledge and the need for researchers to be flexible and adaptable in their approaches. This aligns well with the computational nature of the research, as it allows for the exploration of different methods and techniques to achieve the research goals.

3.1.3 Research Approach

This study employs a computational research approach, which involves the development and utilization of software tools and algorithms to address research questions. Computational methods are well-suited for handling large datasets, complex systems, and experimental simulations.

3.1.4 Research Design

3.1.5 Data Collection Methods

In this section i dicuss the following:

1. the intall unit test this is for what we expect our sensor to output this will be updated
2. How the data from sensor will be stored
3. the code assoicated with the above points

Unit testing

Fristly i want to made some unit tests the aim of this is the following:

- To make test that will be there for the codeing section of the project

this section will discuss the following for testing:

1. 1 x DHT22
2. 1 x DFR0026
3. 1 x AS312
4. 1 x MM2 Series 900 MHz
5. 1 x MCP3008
6. 1 x Raspberry Pi VR 220 Camera
7. 1 x Li-polymer Battery HAT
8. 1 x Turbo 1GB

DHT22

According to the data sheet **?** seen as the data is 8 bits and the range at which this operates at -40 to 80^{o}c for tempeature meaning we have at least 7 bit in the exponent to represent the measured value. to represent the high end of this sensor i used the following calculation:

$$2^6 + 2^4 = 80$$

which mean we have a 2 bits dedicated to decimal place so the high temperature to be 80.3^{o}c for the lowest temp we have 6 bits to represent - 40 due to 2s complement so lowest will be -40.3^oC so with that that stablish we must make a unit that will do the following:

1. Test if the output is a float
2. Test the high end of the temp sensor so it reads 80.3 as the highest
3. Test for the lowest temp around

be sure to follow steps for folder setup follow instructions on page **??**. we get the following sample code:

Listing 3.1: sample test intial code

```
import unittest
from protest import Read_DHT22
class test_project_code(unittest.TestCase):
    def test_DHT_22_temp_output_type(self):
        self.assertIsInstance(Read_DHT22, float)
    def test_DHT22_temp_range(self):
        self.assertGreaterEqual(Read_DHT22,-30.3)
        self.assertLessEqual(Read_DHT22,80.3)
```

for humidity the Datasheet which ranges from 0 to 100 % we want to test for the following:

1. Test if the output is a float
2. Test if the output ranges 0 to 100

this lead to the following code

Listing 3.2: sample test for DHT22

```
import unittest
from protest import Read_DHT22
class test_project_code(unittest.TestCase):
    hum,temp=Read_DHT22(2)
    def test_DHT22_output_type(self):
        self.assertIsInstance(Read_DHT22,tuple)
    #....

    def test_DHT22_hum_output_type(self):
        self.assertIsInstance(hum,float)

    def test_DHT22_hum_range(self):
        self.assertGreaterEqual(hum,0.0)
        self.assertLessEqual(hum,100.0)
```

DFR0026 & MCP3008

According to the datasheet **?** we must keep in mind that this componet is connected to an ADC this will give me the following test conditions:

1. Test if the output is a float
2. Test the range of this with the upper limit being 5v
3. test the lover limit being 0

Listing 3.3: unit test for DFR0026 and MCP3008

```
    import unittest
    from protest import Read_DHT22,Read_MCP3008
    class test_project_code(unittest.TestCase):
    def test_DFR0026_MCP3008_out_type(self):
        self.assertIsInstance(Read_MCP3008,float)
    def test_DFR0026_MCP3008_out_range(self):
        self.assertLessEqual(5.0000000)
        self.assertGreaterEqual(0.0000000)
```

AS312

for this section we want our tests to be the following:

1. test for type is boolean

we can now add to the snipppet :

```
def test_AS312_out_type(self):
    self.assertIsInstance(Read_AS312,bool)
```

Note : Don't forget to import read$_a s12 function from test file$

Raspberry Pi VR 220 Camera

according to the data sheet ? we the resoultion to it uses is 1080p50 which is 1920x1080p so our tests will have to in copoarte the followoing:

1. **Test the output shape if open cv is gonna be used**
    (a) **test the amout of elelecelm in the 3 dimesional array**
2. **test the file type is png**

this would lead me to the following code snippet.

```
def test_Raspberry_Pi_VR220_out_shape(self):
self.assertEqual(Read_Raspberry_PiVR220.shape,(1920,1080,3))
```

Li-polymer Battery HAT

Turbo 1GB

MM2 Series 900 MHz

conculsion

The intiall draft code for the test devlopemnt si the following

Listing 3.4: Final draft test template

```
    # waiting for other sections
```

3.1.6 Model Development

High-performance computing (HPC) resources are utilized to develop and train computational models. The models are designed to capture the essential features of the research problem and generate meaningful outputs.

3.1.7 Data Analysis Methods

Statistical and machine learning techniques are employed to analyze the data collected from both computational models and real-world sources. These techniques are used to identify patterns, trends, and relationships within the data.

3.1.8 Ethical Considerations

The use of computational methods raises ethical concerns regarding data privacy and security. To address these concerns, data anonymization and encryption techniques are employed to protect sensitive information. Additionally, informed consent is obtained from participants when applicable.

3.1.9 Validity and Reliability

Validation of computational models is achieved through rigorous testing and evaluation. This involves comparing model predictions with real-world data and examining the sensitivity of the models to different parameters. Reliability is ensured through the use of standardized methods and procedures for data collection, analysis, and interpretation.

3.1.10 Limitations and Delimitations

The computational nature of the research introduces limitations due to the complexity of the systems being modeled and the potential for errors in modeling and data analysis. Moreover, the generalizability of the findings may be limited to the specific contexts and conditions considered in the research.

3.1.11 Timeline

The model development phase of the research is scheduled to take place from [start date] to [end date]. The data collection and analysis phases are scheduled to take place from [start date] to [end date]. The final write-up of the research is scheduled to be completed by [deadline date].

Chapter 4

Results

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Chapter 5

Discussion

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Chapter 6

Conclusion & Future Work

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Appendix A

Appendix A

Appendix B

Python Scripts

Appendix C

Bash scripts