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Development of underground mine monitoring and communication system based on Wireless Sensor Networks (WSN)

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Avani Victoria Falls Resort, Livingstone, Zambia

PRESENTATION LAYOUT

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- Purpose of the Study
- Study Objectives
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- Underground WSN Studies
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Introduction

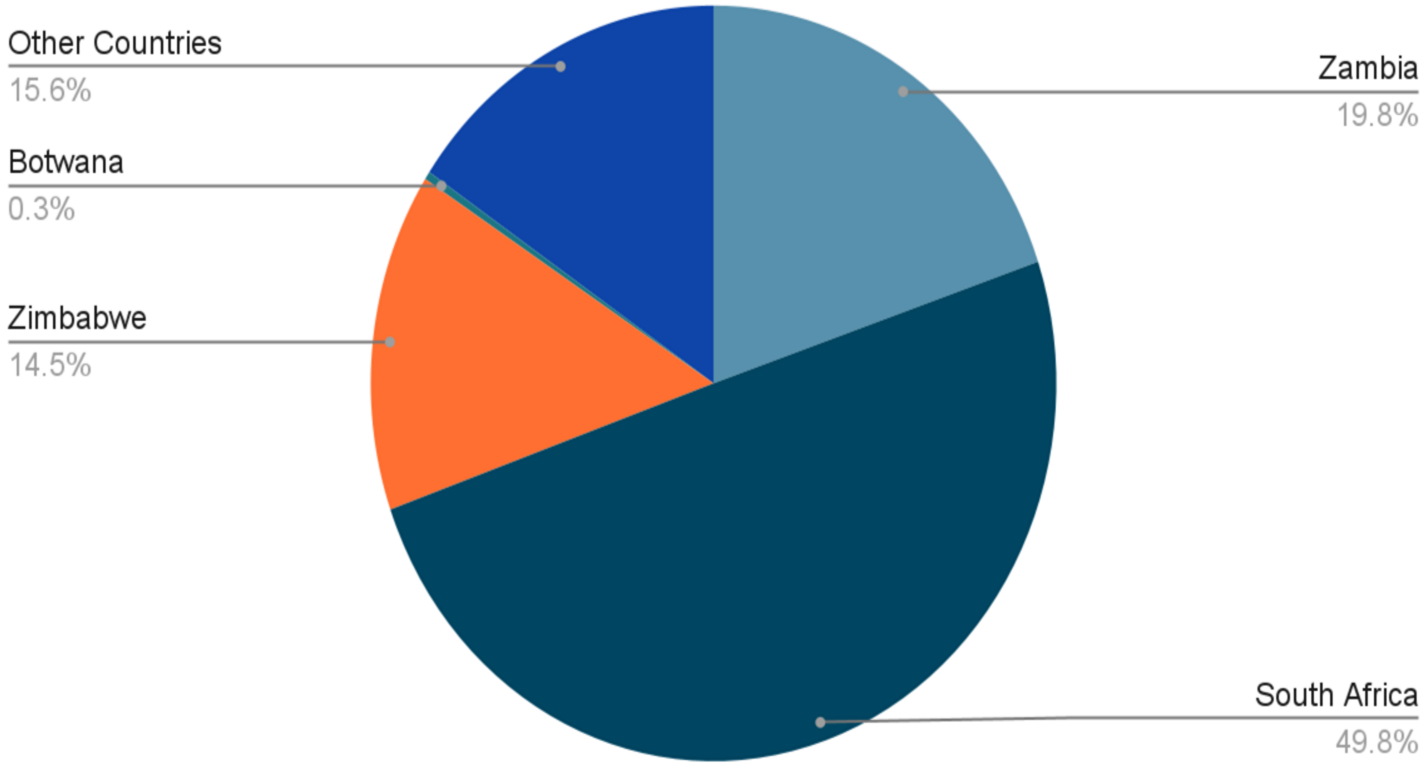
- The mining environment can be a hazardous place to work - both for the labour force and the equipment used.
- The nature of the operational environment dictates that several measures be put in place to make the place as ideal as possible for both the human workforce and the machinery that operates there.
- This research focuses on developing a system for monitoring and reporting critical environmental parameters in underground mine by employing a wireless sensor network (WSN).

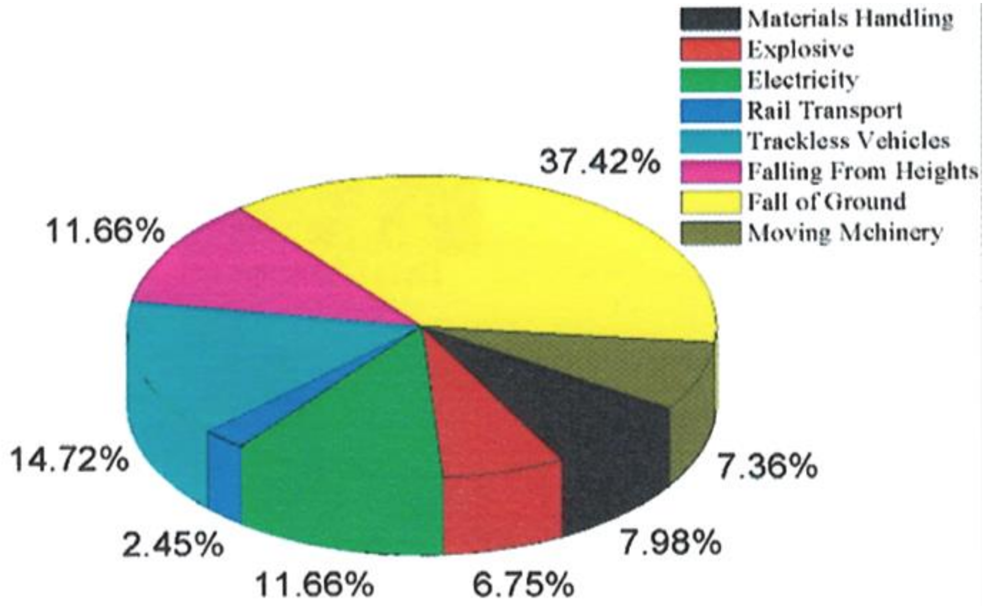
Statement of the Problem

- The majority of mining accidents that occur tend to occur underground.
- Over the period from 1990 to 2020, there were 3,458 underground mining incidents in the region, according to the SADC.
- About 10,302 people died in these accidents, while 11,246 people were hurt.

https://www.cdc.gov/niosh/mining/topics/rockfalls.html

Fatal Underground Mining Accidents in SADC between 1990 and 2020





Statement of the Problem

- Several technologies have been developed and designed to help monitor and communicate the potential risks that arise from underground mining operations.
- Cabled monitoring systems
  - Optical Fibre sensor systems
  - Hardened phone cable systems (Like the ones used in Zambia)
- Multielectromechanical Systems
  - Photogrammetry
  - Wireless Sensor Networks

Purpose of the Study

- To design and develop a WNS that can monitor and communicate environmental parameters (Temperatures and Humidity) in underground mines.
- The system will combine cutting-edge sensor networks, real-time data processing and effective communication protocols to reduce the risk of mine accidents.

Study Objectives

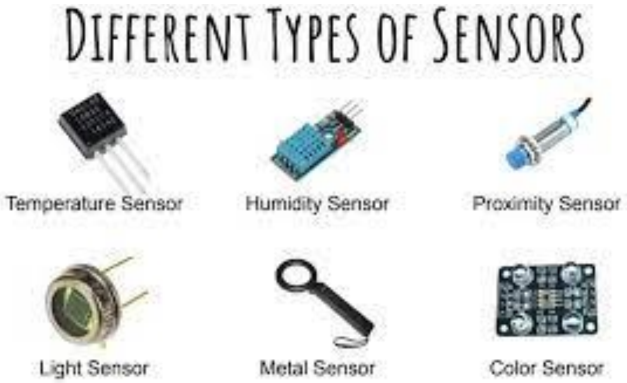
1. To create a WNS that will be used to monitor environmental temperatures and humidity in underground mines
2. To test limitations of transmitting the collected data and sending it to the surface in near-real time
3. To determine an ideal network topology for reliable data transmission by the system;
4. To develop a monitoring and data interpretation interface;

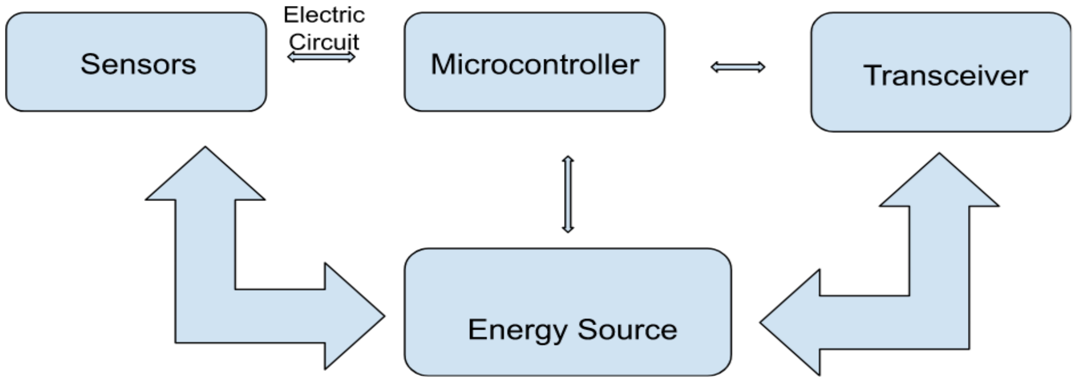
Significance of the Study

- The significance of this work is as follows:
  - Real-time monitoring of critical variables can aid in evacuating an unsafe zone;
  - The prototype created in the study can further be expanded upon to monitor additional parameters like gas pockets, roof falls, subsidence to mention a few
  - Identifying cost-effective communication protocols that can be used and deployed underground for more rigorous WSNs
  - Improvement of communication methods between the miners underground and the control room on the surface.

Wireless Sensor Networks (WNS)

- WNS is a network of sensors that form a meshed node for data collection in different environments.





Existing WSN Systems

- Habitat/Environmental monitoring
- Human health monitoring
- Underground WSNs

Underground WSN Studies

- Chanda et.al (2014) designed and conducted an investigation on radio wave attenuation using ZigBee at the Angas Zinc Mine in Australia.
- Moridi M.A et al. (2015) designed an underground mine monitoring and communication system that integrated ZigBee and GIS.
- Pan Tao and Liu Xiaoyang(2011), designed a system which combines ZigBee technology and WiFi to monitor gas, provide wireless communication, personnel management, video surveillance and a disaster prevention system.
- Byung Wan Jo and Khan R. M. A., (2018), developed an air quality pollution prediction system that was using the Azure machine Learning Studio. The system comprised of sensor modules, communication protocol and a base station for data analysis and prediction modelling.

Methodology | Research Design

- Desk work for coding (using C++)
- Build a prototype network
- Field testing of prototype
- Linkage of prototype with management software

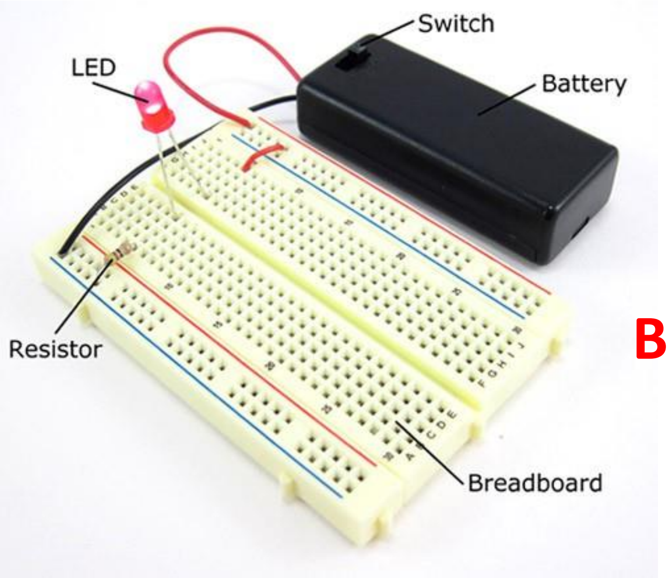
Methodology | Study Areas

- The target study areas were Lubambe Mine and Nampundwe Mine;
- However, this was not possible due to several challenges with getting permissions;
- Test of the developed prototype were conducted in three areas around Lusaka, Zambia;
    - Kabulonga;
    - Kalingalinga; and
    - The University of Zambia grounds

Methodology | Instruments used

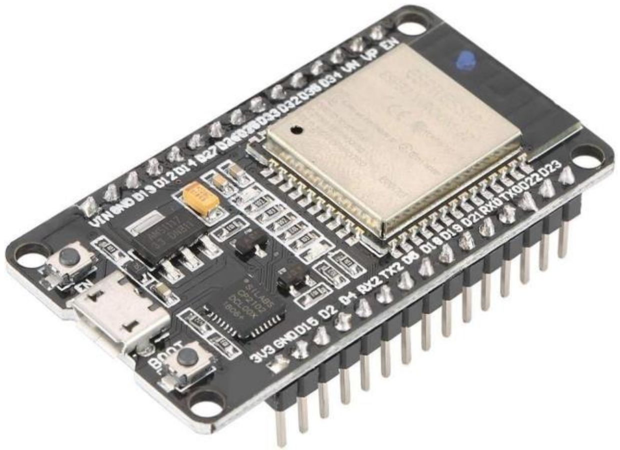
- Computer for Coding
- Breadboard for circuit development
- Multimeter to measure desired voltage output
- DHT11 Temperature and Humidity sensor
- ESP32 microcontroller board
- Internet Router
- Power banks as a power source

Methodology | Instruments used

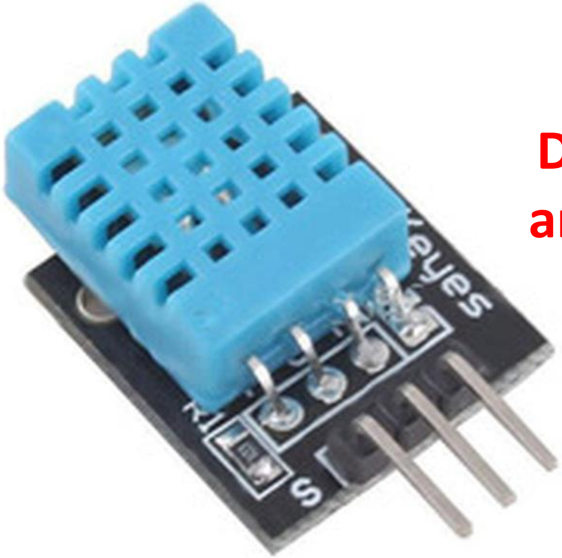


Breadboard for circuit

Multimeter



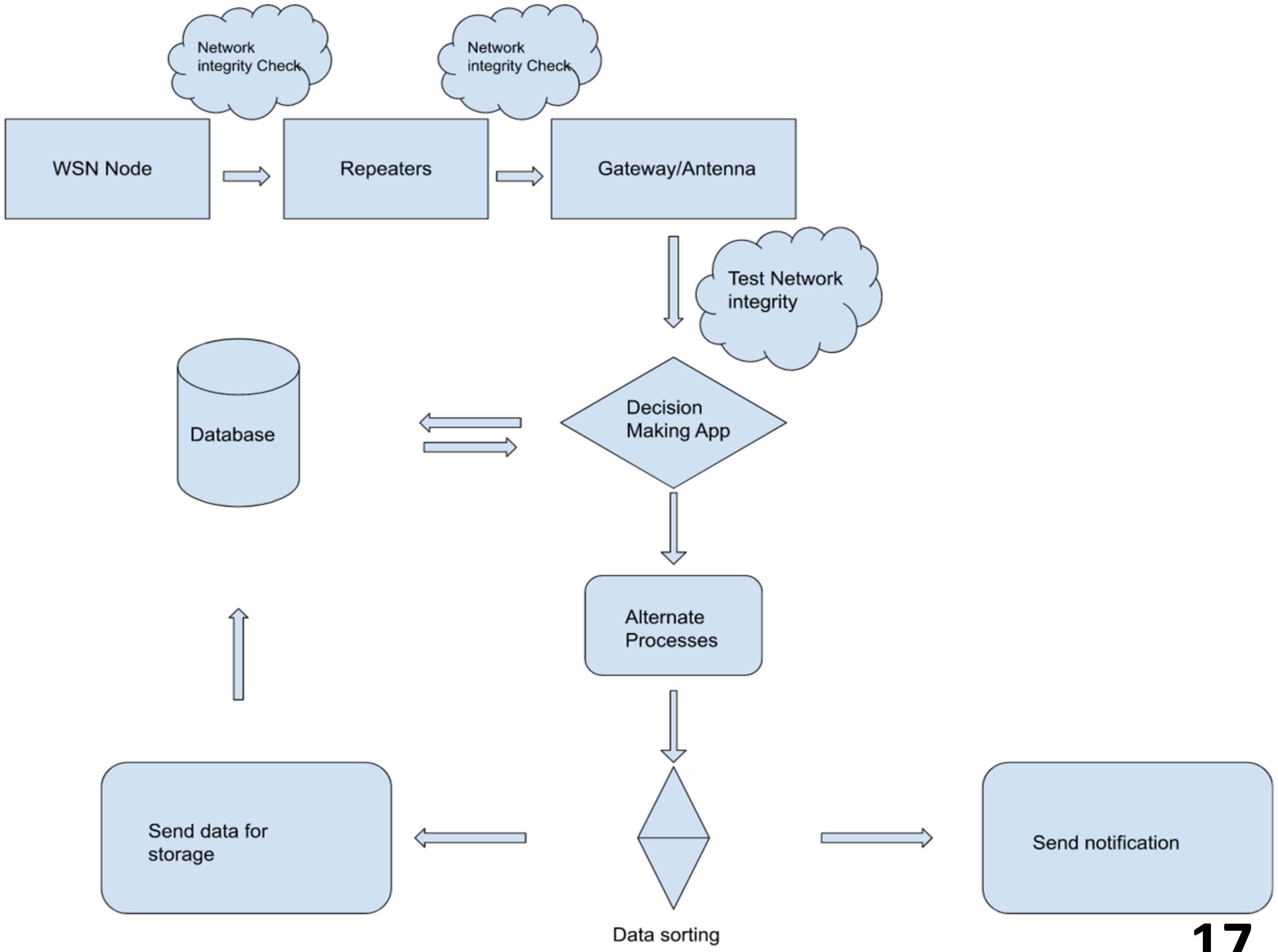
ESP32 Microcontroller board



DHT11 Temperature and Humidity sensor

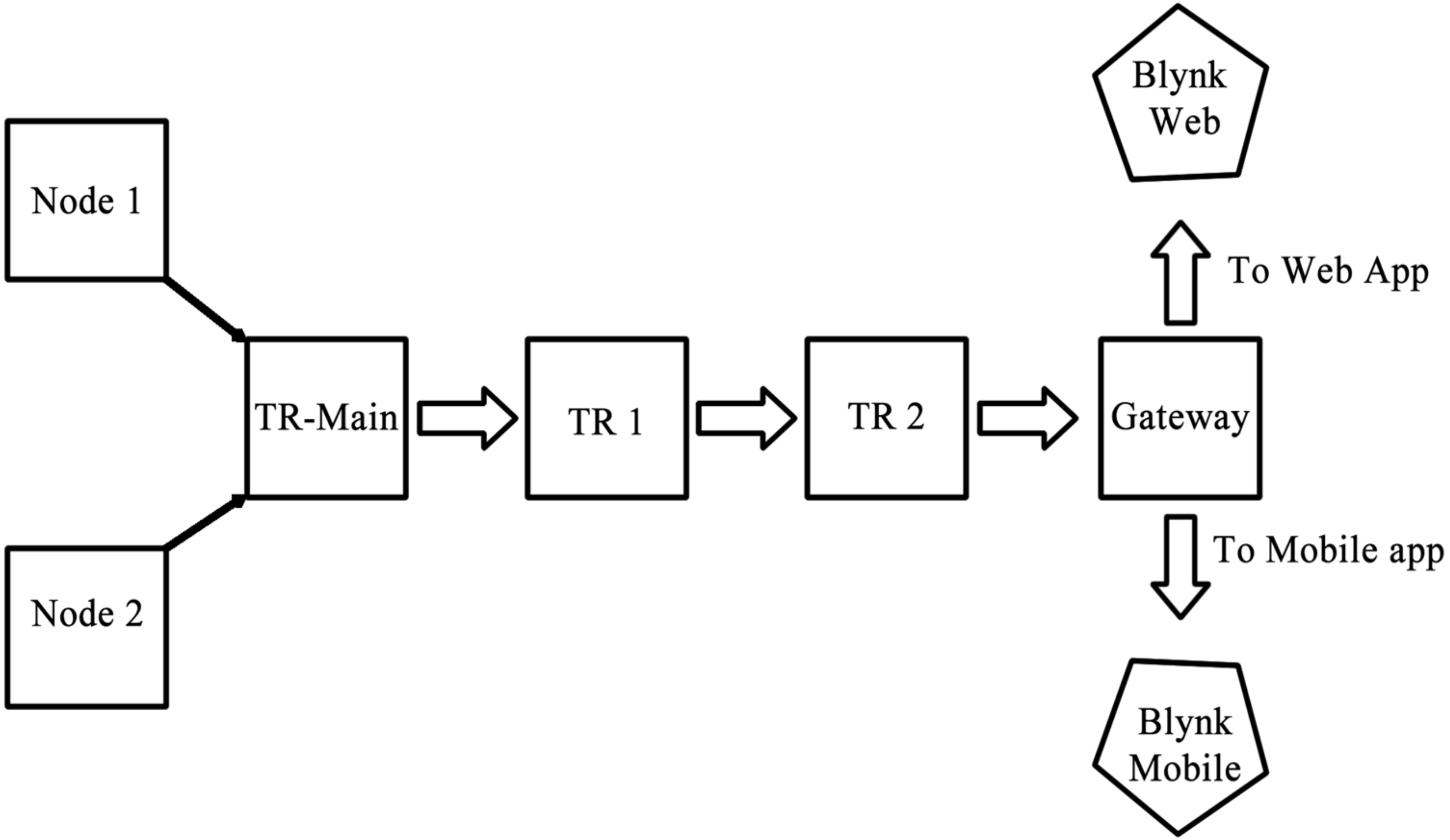
Methodology | WSN Design

- The system iteration algorithm that was developed for the WSN used in the study is shown in the Figure:



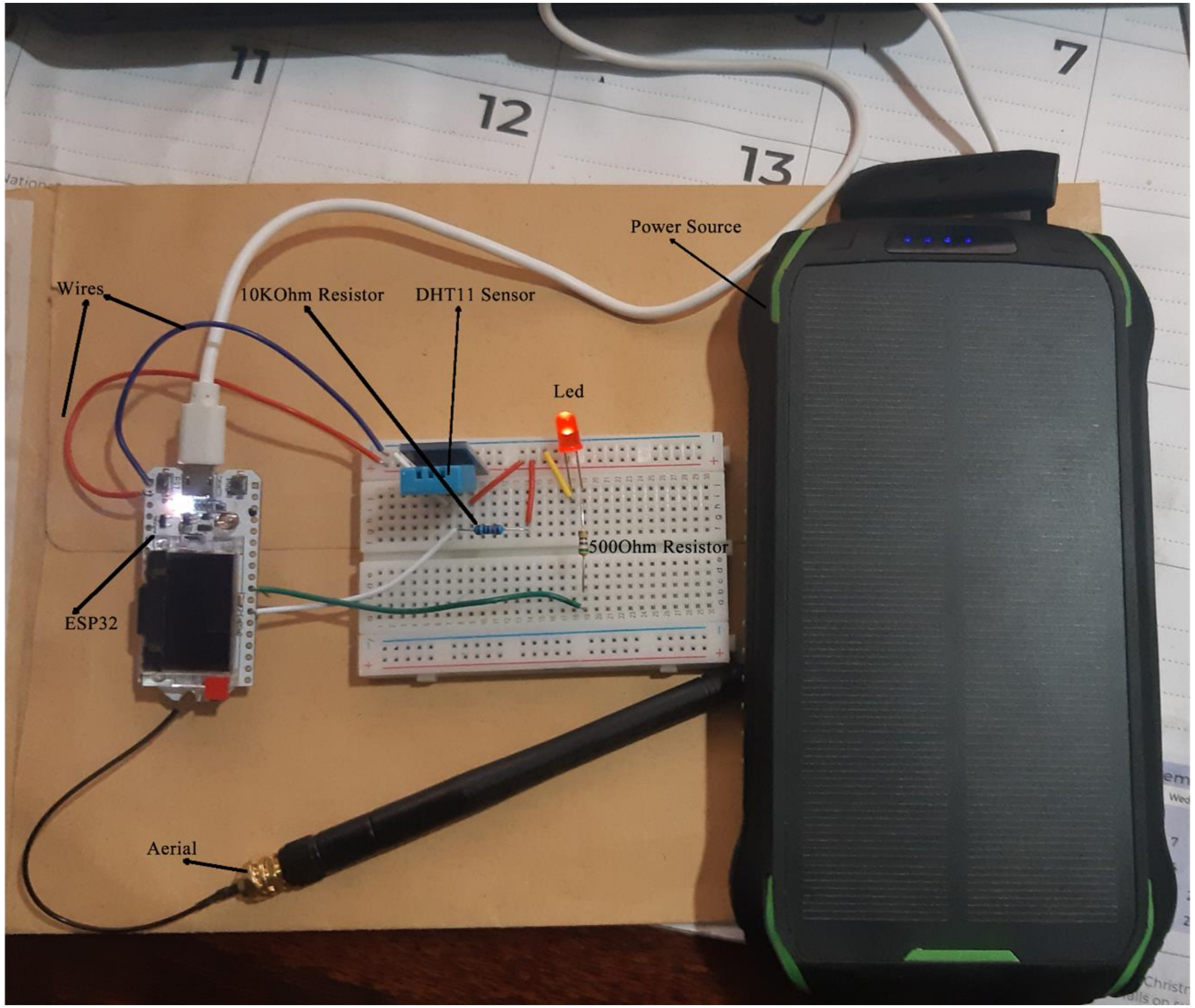
Methodology | WSN Design

- The WSN that was designed for use in the study comprises of the following:
  - 2 sensor nodes
  - 3 Repeater transceivers
  - 1 gateway
  - 1 web platform



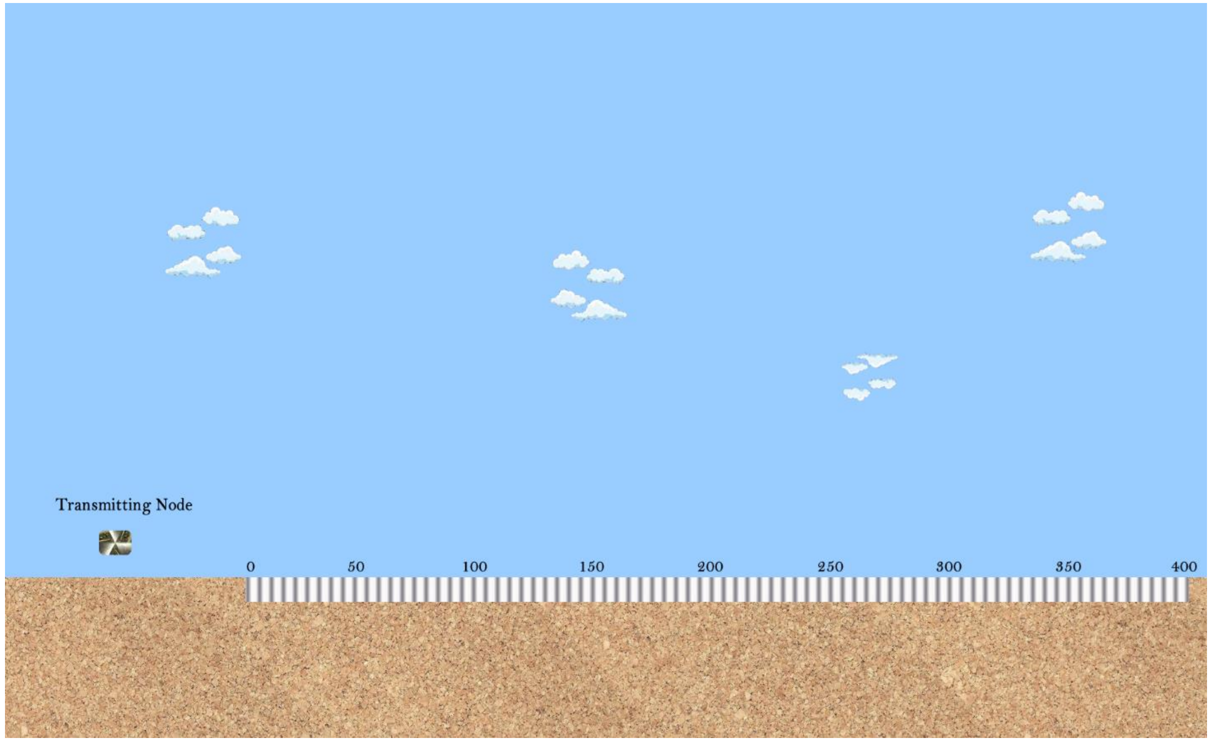
Methodology | WSN Design

- The figure below shows a single node of the WSN that was developed

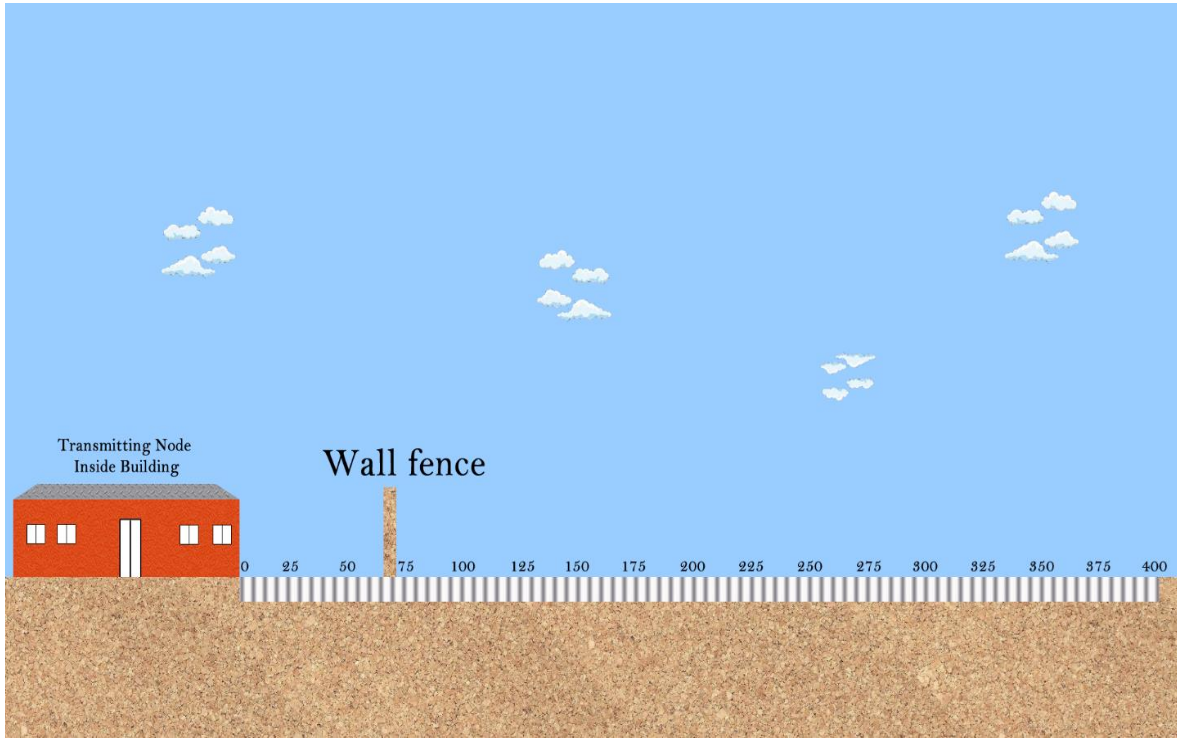


Methodology | Data Collection

- Two on-surface tests were conducted to determine the best placements of the nodes for tests underground. The tests were:
  - Open Air Tests
  - Obstructed-Node Placement tests



Open Air Test



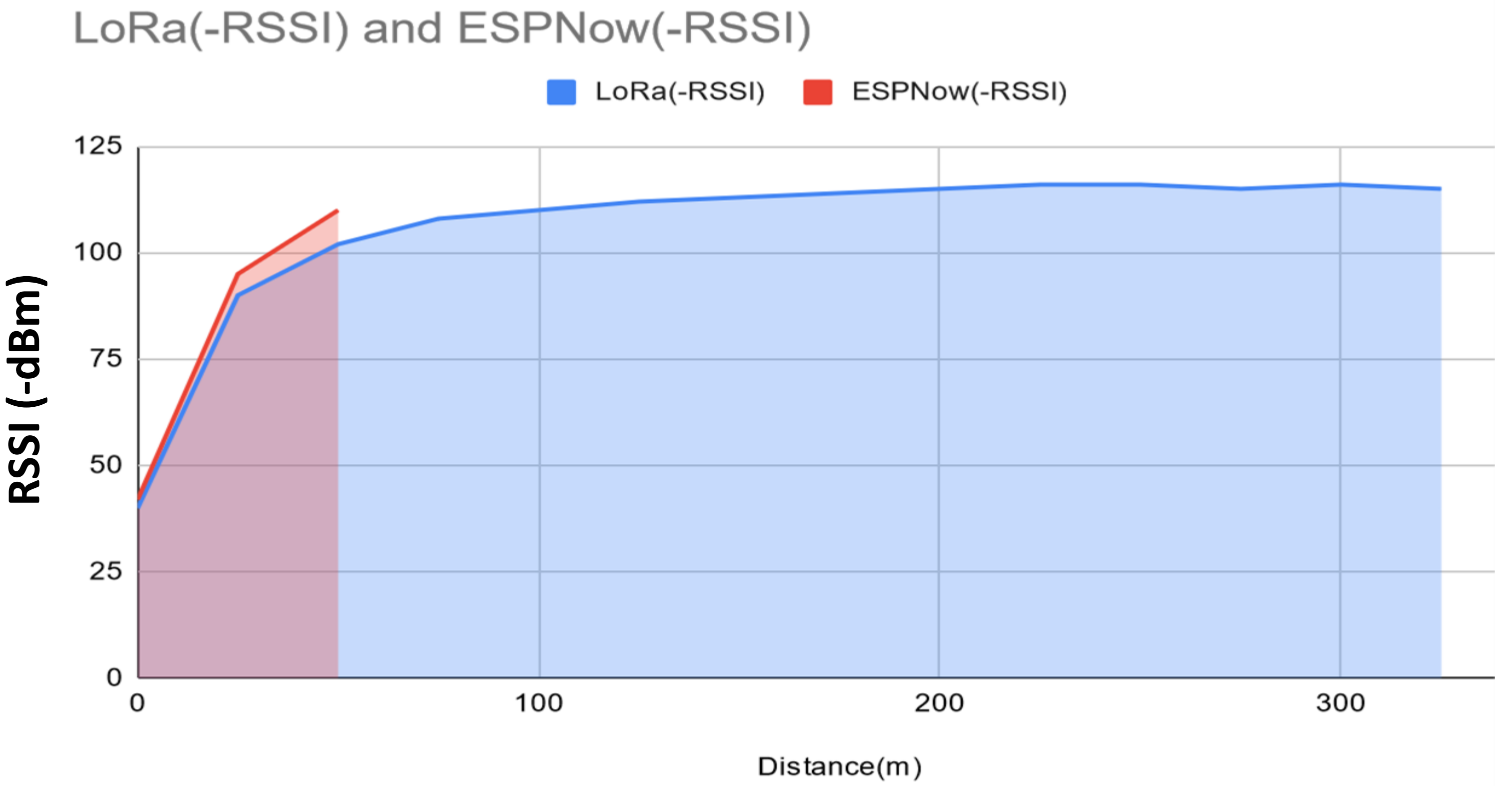
Obstructed-Node Test

Results| Data Collection

- Two protocols were picked and tested in both open air and Obstructed-Node Placement.
- The protocols were LoRa and ESPNow.
- The key parameter which was tested was the *Received Signal Strength Indicator (RSSI)* that the node was sending to the gateway over a predetermined interval of 10 seconds.
- The results are shown in tables and graphs below.

Results| Data Analysis

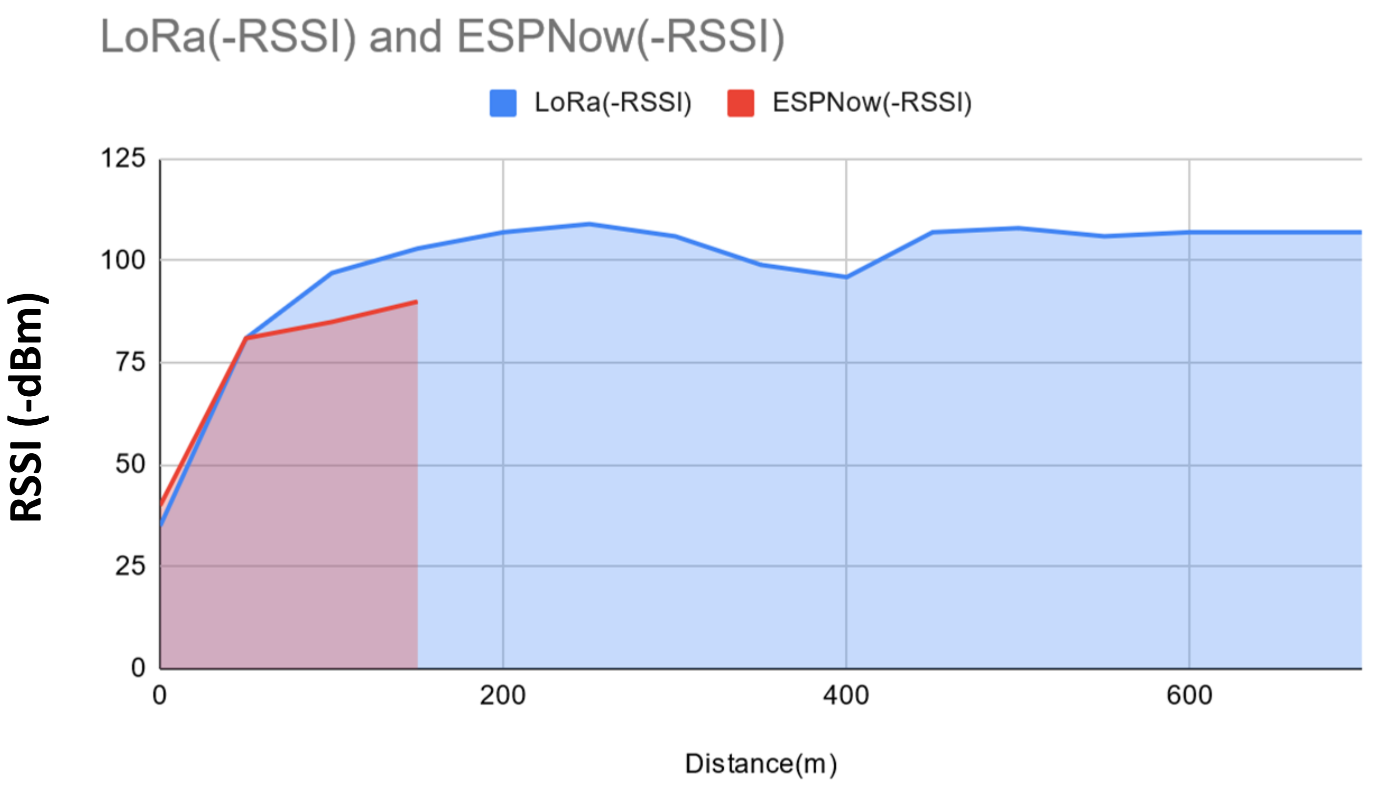
- Open Air Distance determination test Results



Distance (m)	LoRa- RSSI (dBm)	ESPNow- RSSI (dBm)	Comment
0	-40	-42	
25	-90	-95	
50	-102	-110	
75	-108		Signal for ESP Now lost at 55m
350	-115		Signal for LoRa lost at 330m

Results| Data Analysis

- Obstructed Node Distance determination test Results



Distance (m)	LoRa RSSI (-dBm)	ESPNow RSSI (-dBm)	Comment
0	-35	-40	
50	-81	-81	
100	-97	-85	
150	-103	-90	
200	-107		Signal for ESP Now lost at 160m
700	-107		No Signal loss for LoRa until 1km

Discussion and Conclusion

- A simple WSN was built which combined two different communication protocols, LoRa and ESPNow.
- The combination was done to take advantage of the ESPNow's capability to provide immediate and real-time updates in localized areas, which resulted in having a very responsive system, and
- LoRa's capability to transmit data over a wide area, which ensured efficient coverage and connectivity to the central node that was processing the data and sending it to the Blynk server for further analysis and interpretation.

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THANK YOU FOR YOUR ATTENTION.