INTEGRATED GAS ANALYSER

Course Project for Embedded Systems Workshops- M24

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ABSTRACT

- Toxic gas exposure in industrial environments, such as manufacturing and chemical processing, poses serious risks to worker safety.
- Existing gas detection systems are often bulky and lack real-time monitoring, limiting timely responses to hazards; or might be unaffordable for a majority of industrial sites.
- This project aims to develop a low-cost, portable gas analyser that enhances safety by providing real-time, continuous detection of harmful gases.

INTRODUCTION

- Air quality monitoring is crucial to mitigate health and safety risks from environmental pollution, industrial emissions, and household gas leaks.
- Harmful gases like carbon monoxide (CO), liquefied petroleum gas (LPG), and smoke can cause life-threatening incidents if undetected.
- The proposed Gas Analyzer System uses the MQ-2 sensor to detect these gases and transmits data wirelessly using LoRaWAN technology.
- The system leverages IoT platforms for remote monitoring and cloud-based data storage, ensuring functionality even in areas with low network coverage.

PROBLEM STATEMENT

- Current solutions often fall short due to their bulkiness, lack of portability,insufficient real-time monitoring, and high costs.
- To address these challenges, we have developed a low-cost portable gas analyser.

First Problem

Develop a compact, low-cost solution.

Second Problem

Solution must be scalable; provide real-time, reliable data.

Third Problem

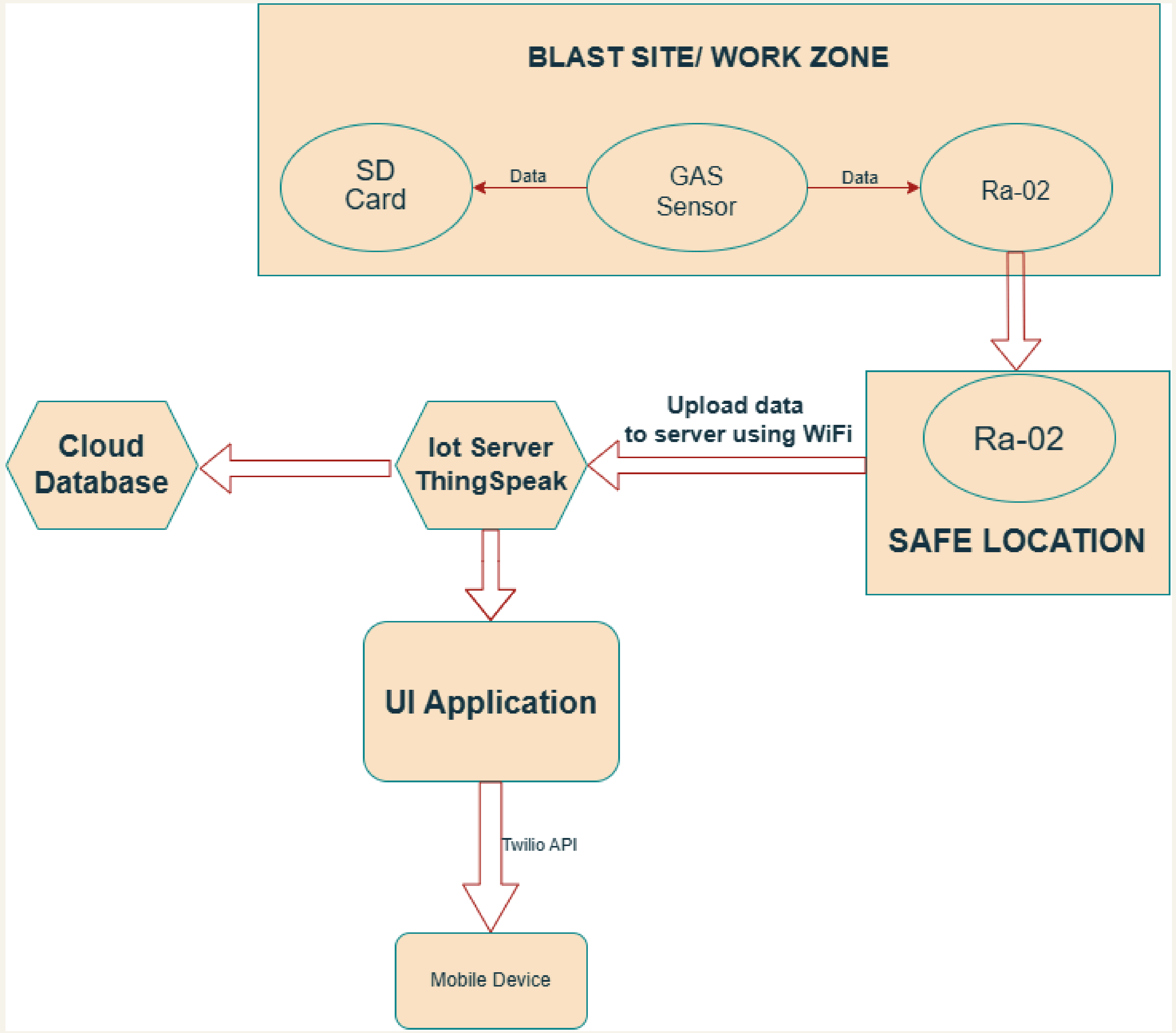
Long-range data transfer in regions of limited network connectivity.

OBJECTIVES

1. Real-time detection.
2. Long-range wireless communication.
3. Cloud based data storage and visualization.
4. Automated Threat Notification
5. On-site monitoring.
6. Data redundancy and offline access.
7. User-friendly web application.
8. Scalability for multiple locations.

PROPOSED SOLUTION

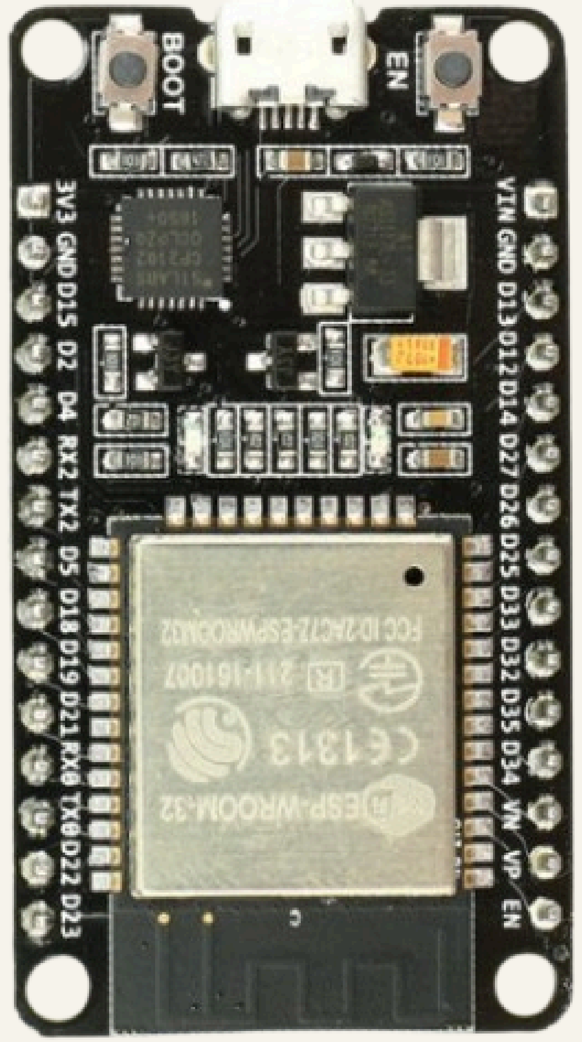
System Architecture



MQ-2 SENSOR

- System uses MQ-2 Sensor for detecting levels of CO, LPG and Smoke.
- Provides reasonably accurate readings, suitable for practical applications.
- Low-cost.

ESP32 MICROCONTROLLER



- Ideal choice due to its low power consumption, built-in Wi-Fi, and SPI communication capabilities.
- Collects data from the MQ-2 sensor and prepares it for transmission.
- Serves as central unit of our system.

Ra-02 LoRa Module

- Chosen for its ability to transmit data over distances of up to few hundred meters with minimal power consumption.
- Allows for transmission of data in areas with limited to no internet connectivity.
- Range can be increased easily by using repeater modules.

ThingSpeak

- Real-time data visualization in user-friendly manner.
- Allows user to observe historical data and observe trends.
- Critical for detecting patterns or identifying potential hazards.

CockroachDB

- Distributed, scalable and resilient.
- Handling of concurrent requests make it suitable for use in an IoT application such as ours.

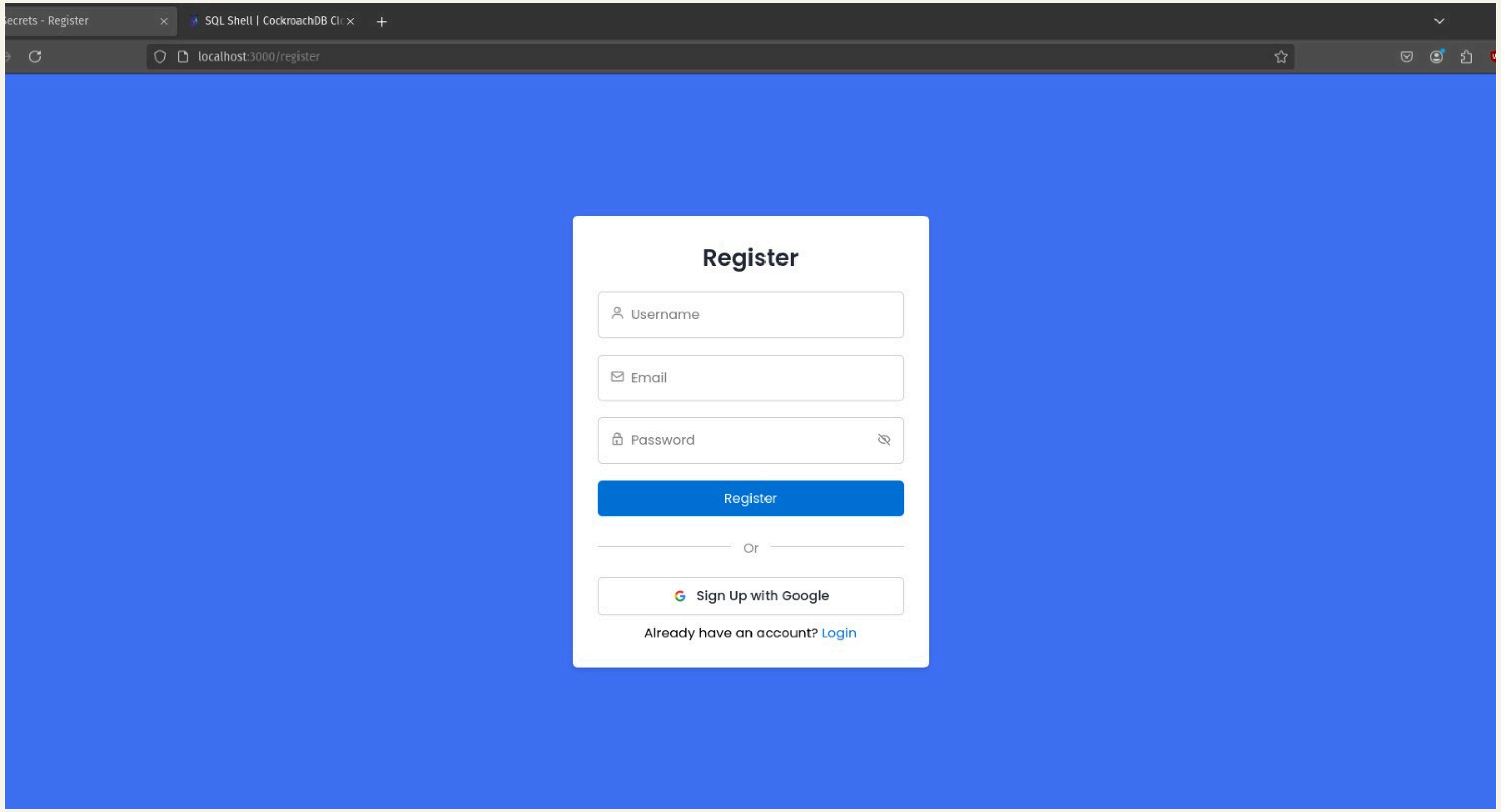
Twilio API

- Real-time notifications on Whatsapp upon crossing of safety thresholds.
- Enables prompt action to prevent potential health and safety risks.

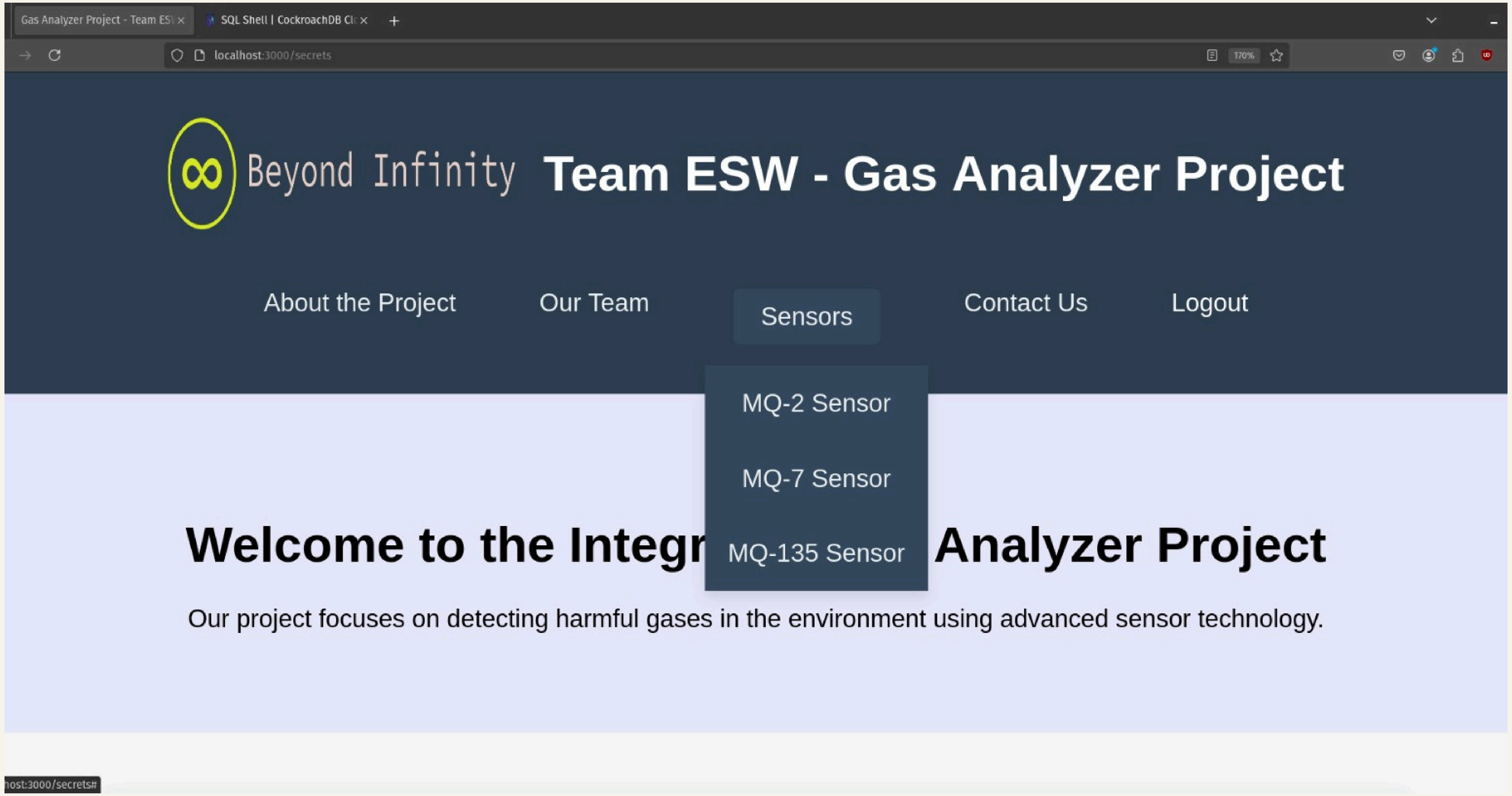
LCD Display

- Used to show current gas levels and whether the conditions are safe or not.
- Fastest access to data at the site.

User Interface

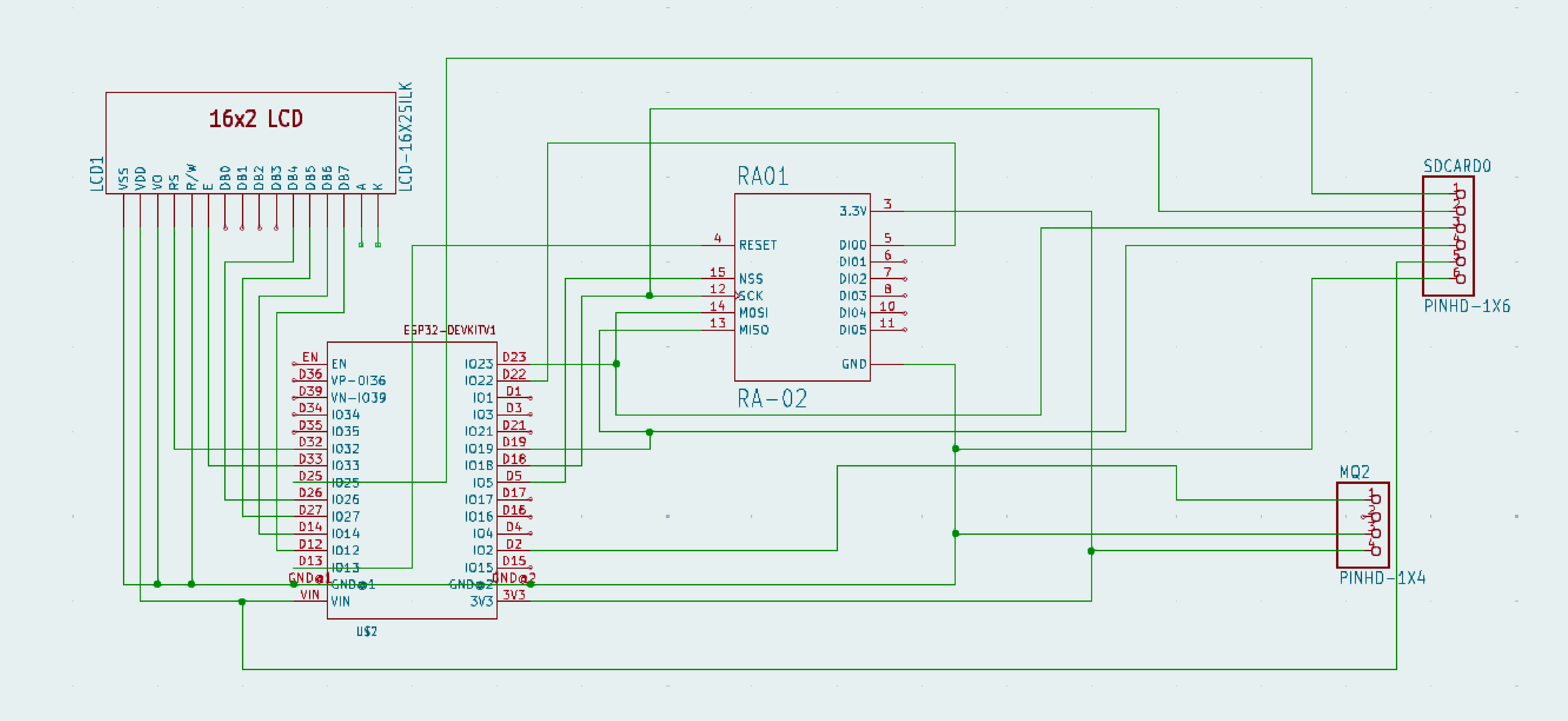


User Interface

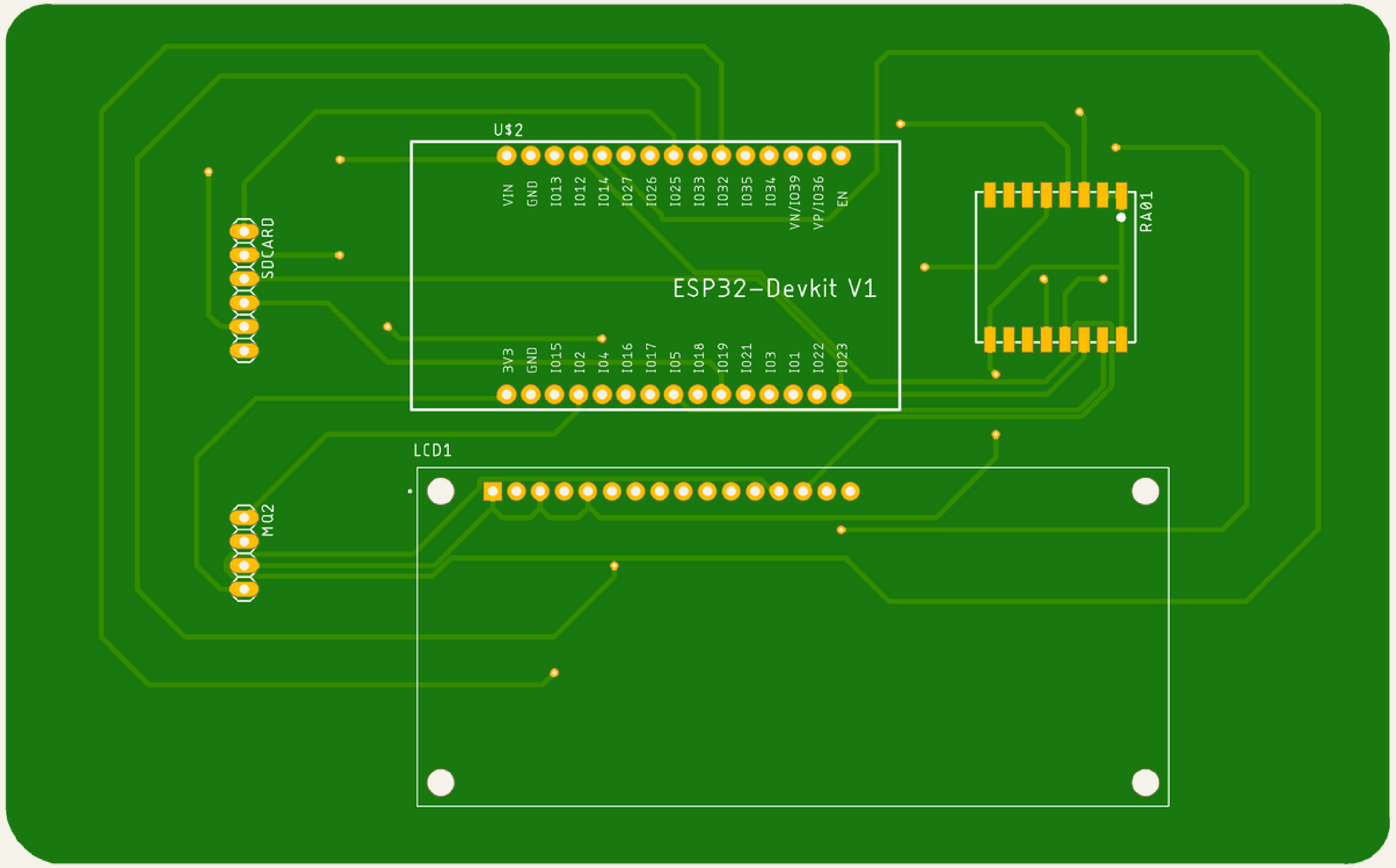


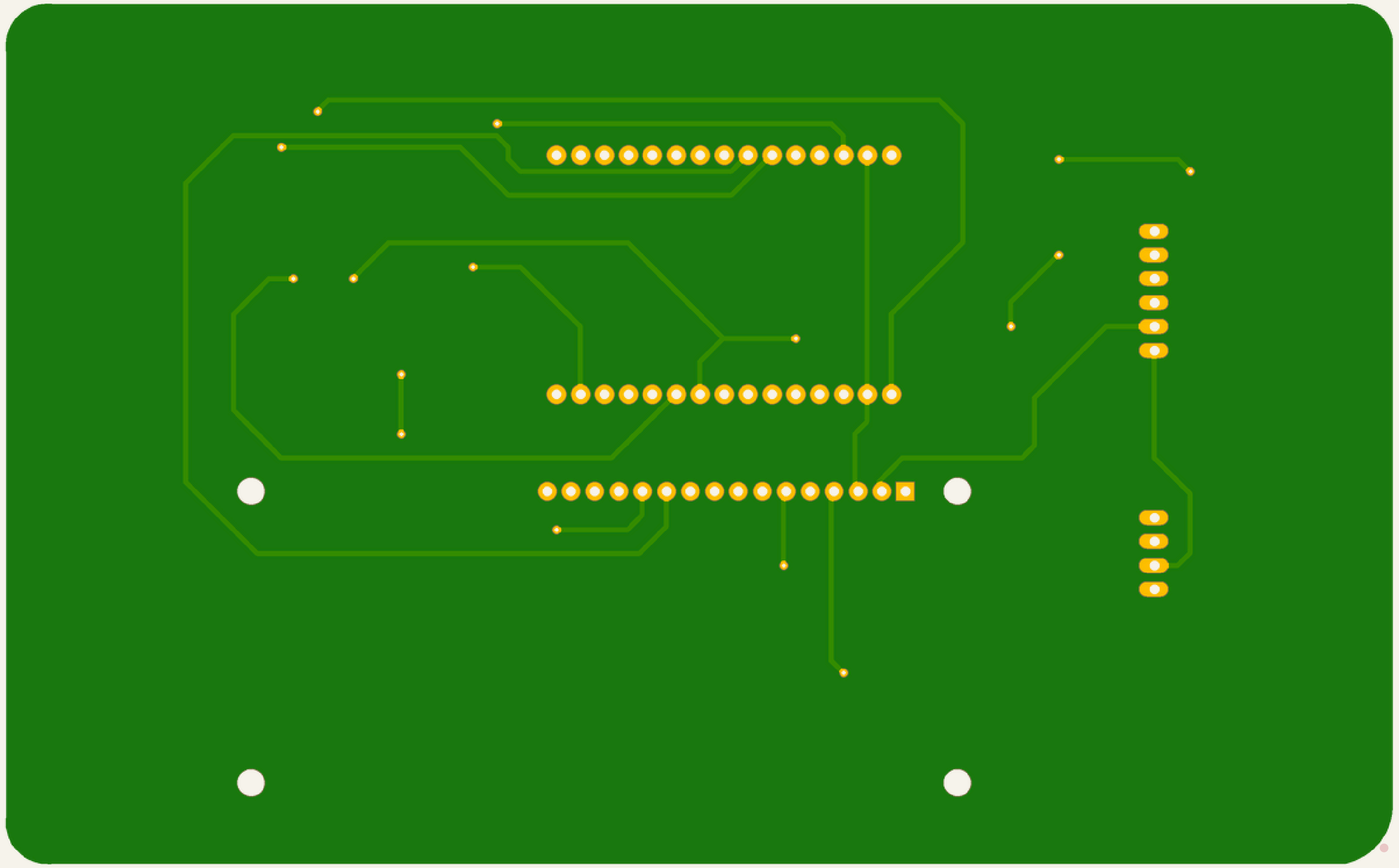
PCB DESIGN

Sender Schematic

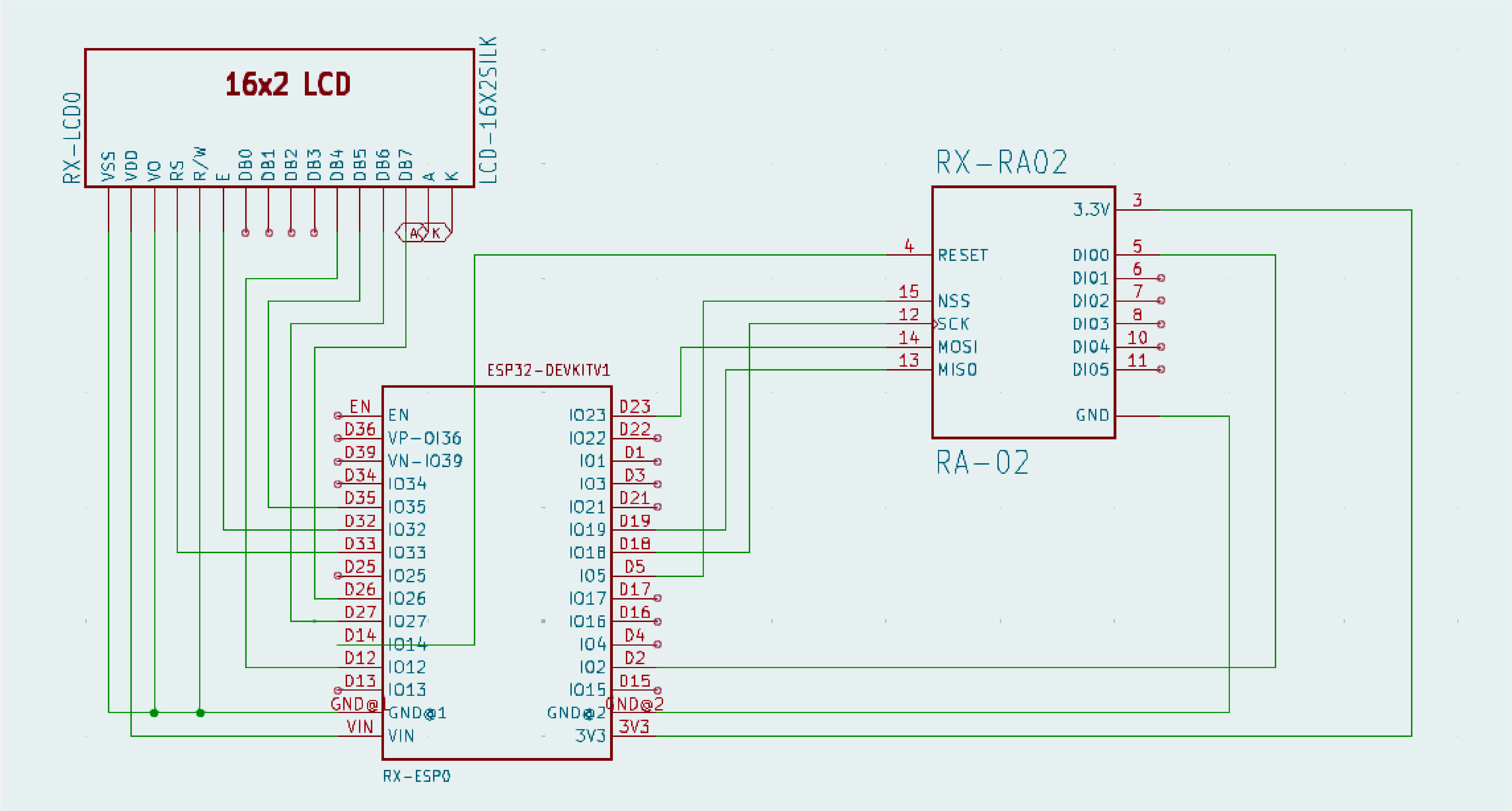


Sender Board

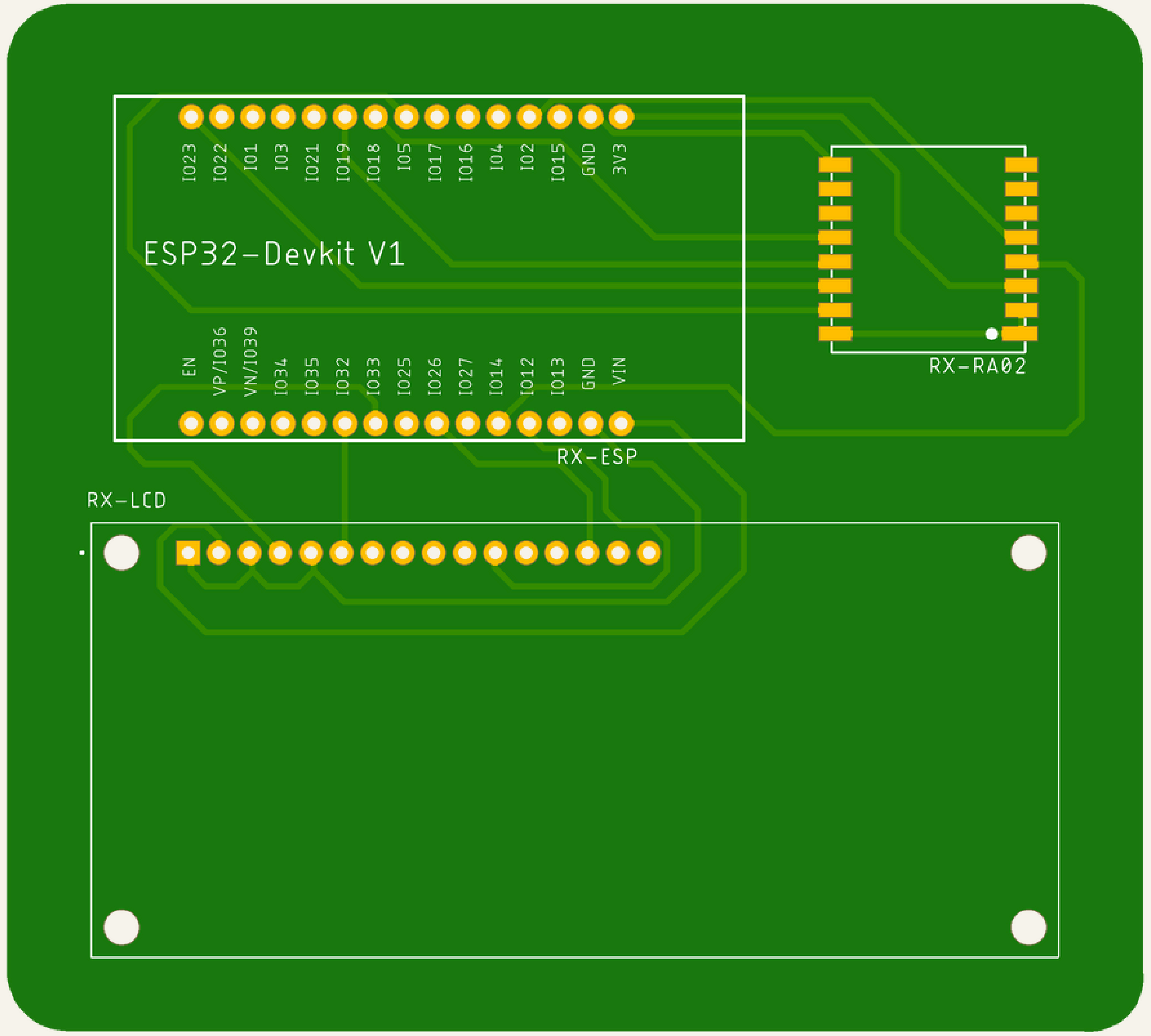


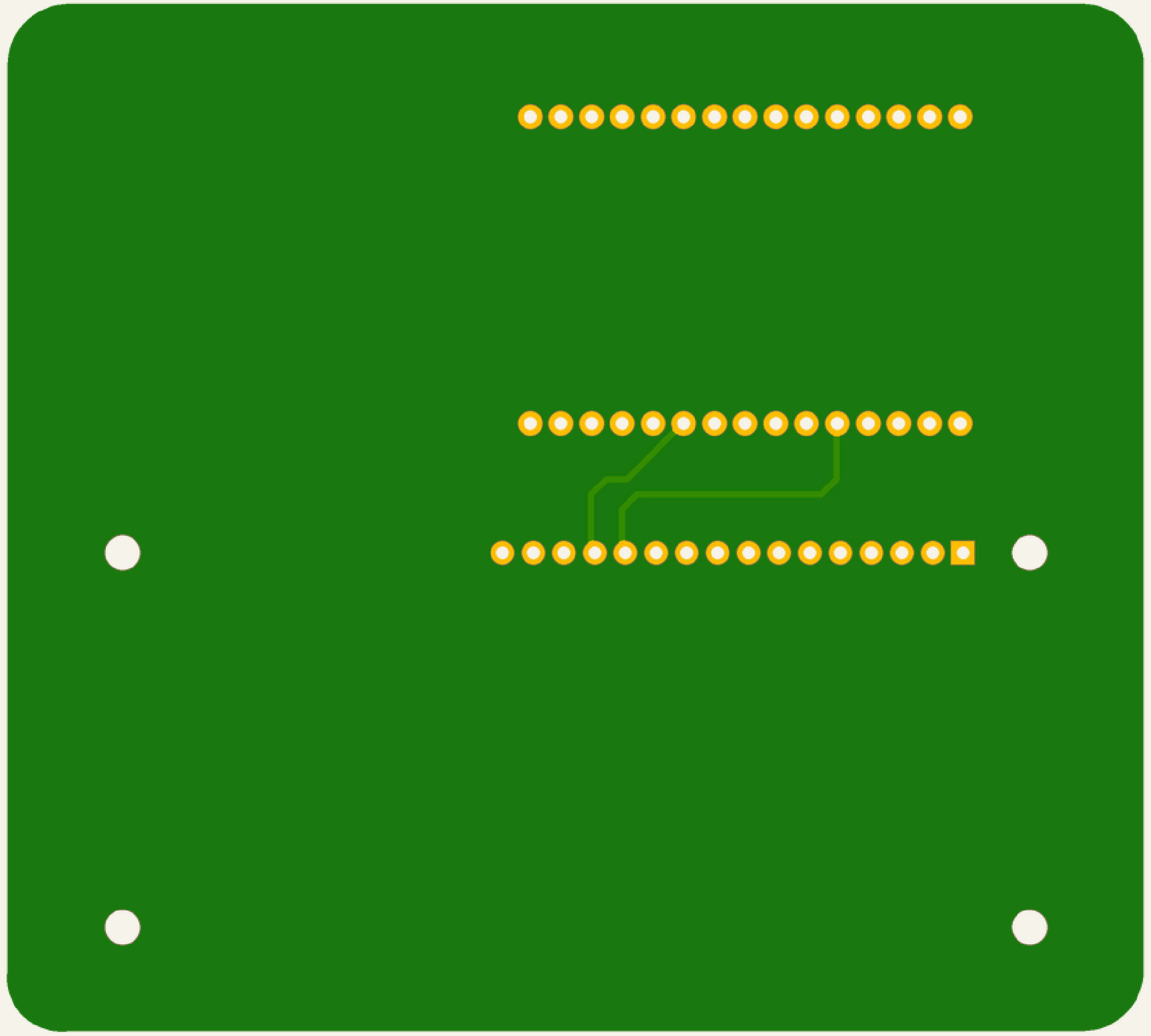


Receiver Schematic

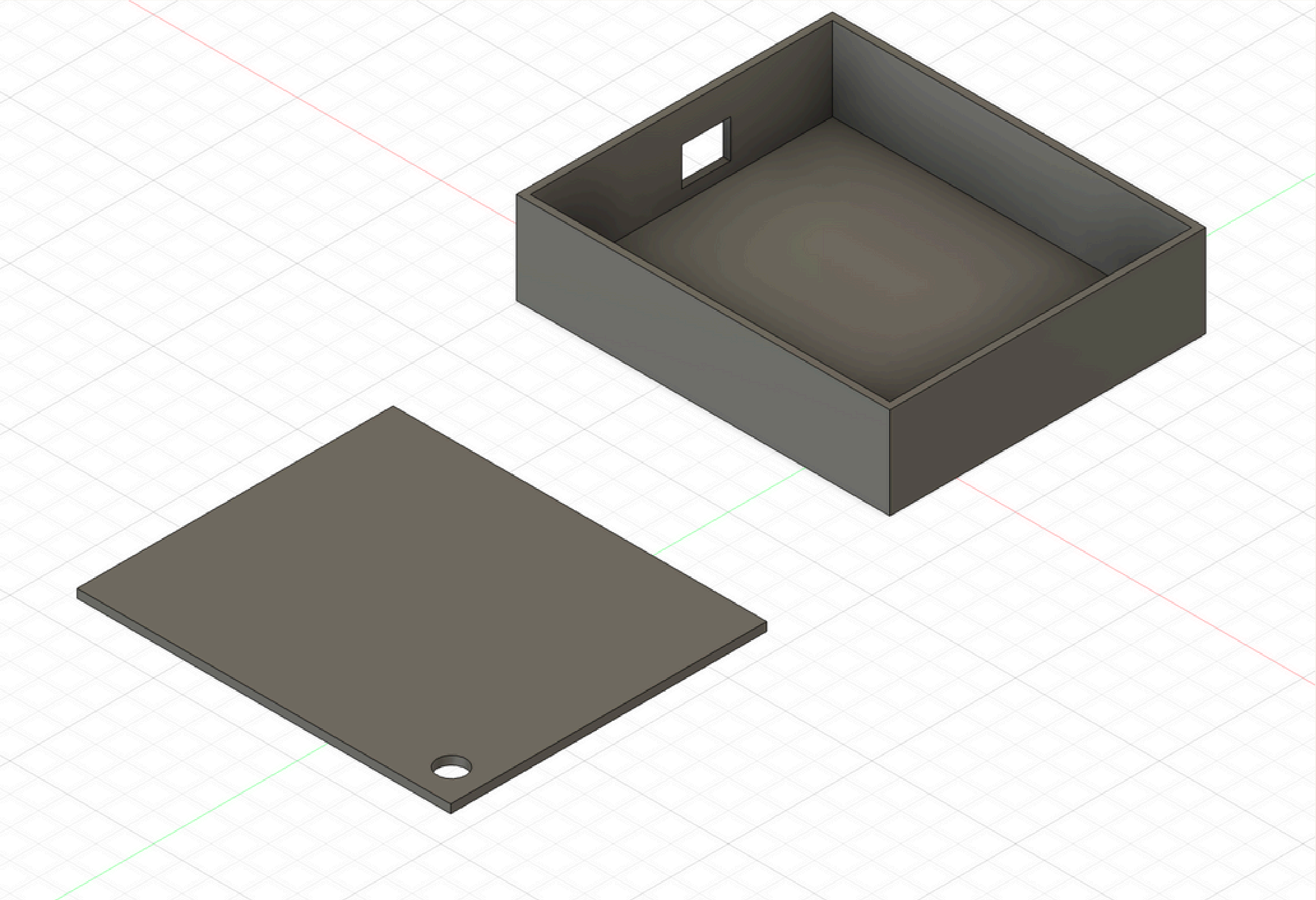


Receiver Board

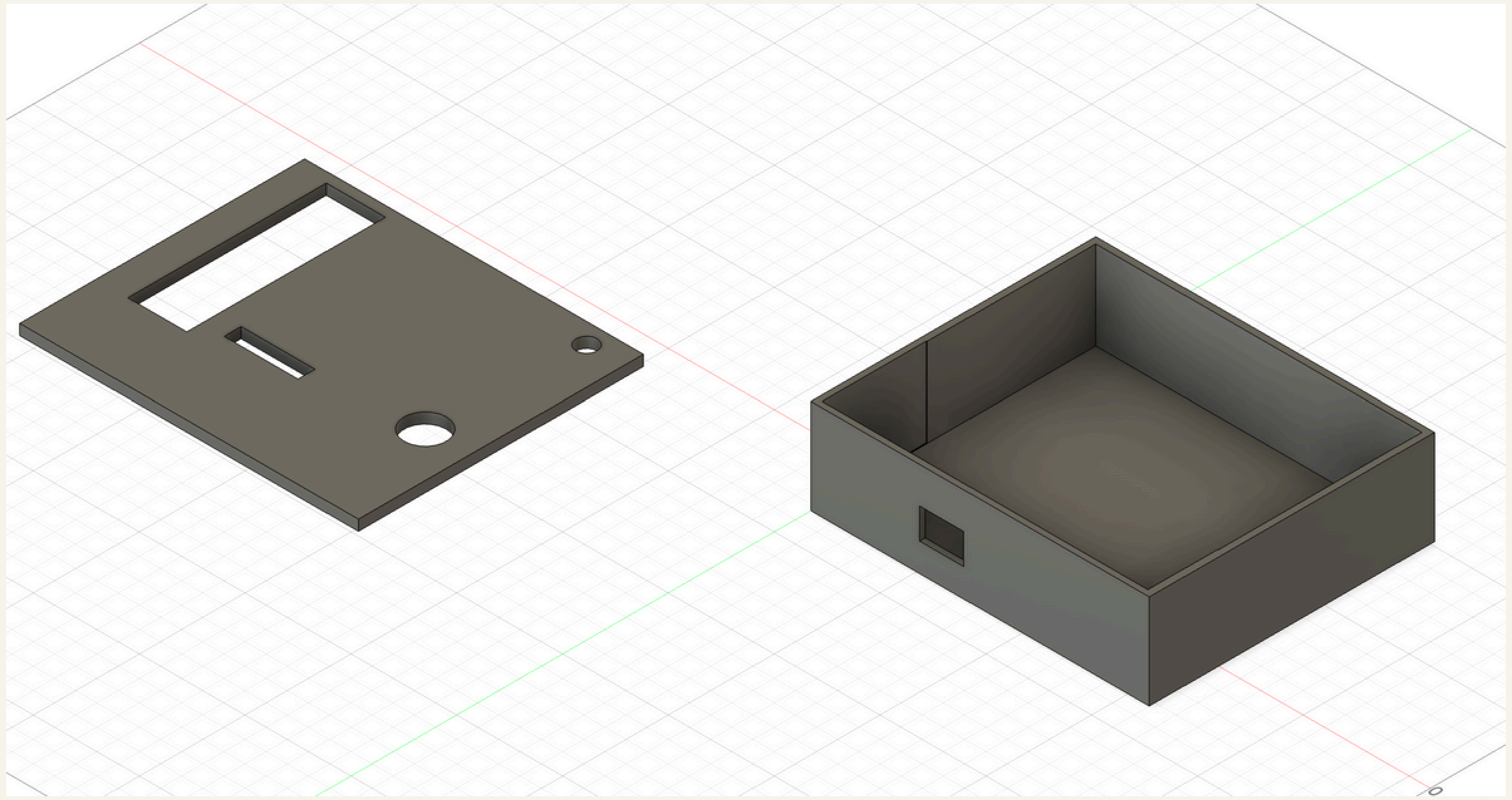




3D Design



Receiver



Sender

LoRa Analysis

Testing LoRa Values Over a Distance of 1-5 Meters

- Setup- Sender and receiver at different ends of the room.
- Parameters measured. (Signal-to-Noise Ratio (SNR), Received Signal Strength Indicator (RSSI), and packet delivery success.)
- Results-
  - Optimal signal strength, with RSSI values remaining between -30 dBm and -40 dBm.
  - Packet transmission success rate ~ 100%.
  - High SNR values ranging from 8 to 10 dB.

Testing LoRa Values Over a Distance of 5-30 Meters

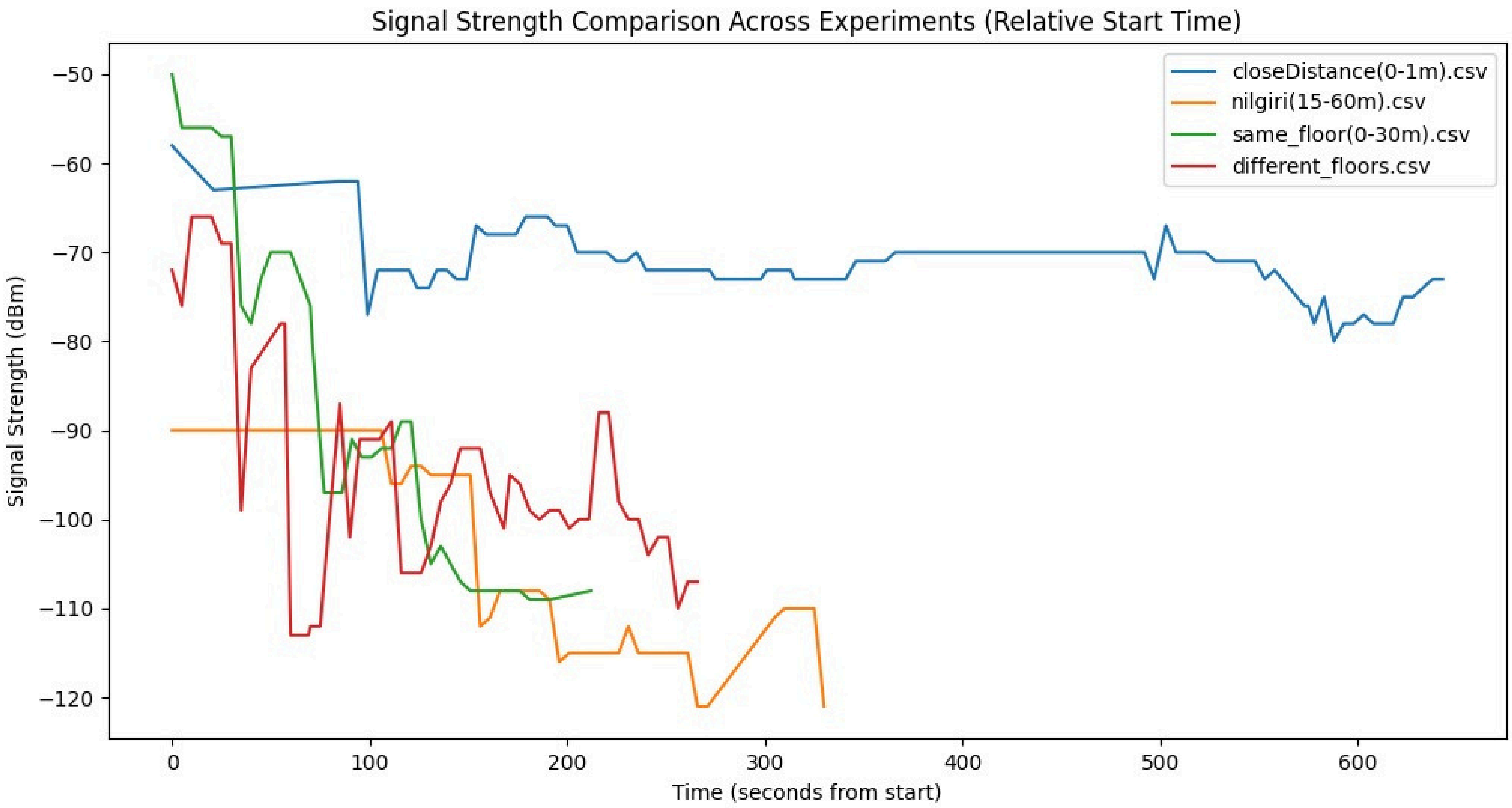
- Setup- Modules on the same floor, to test performance in confined indoor environments. Potential interference due to furniture and walls.
- Parameters measured. (Signal-to-Noise Ratio (SNR), Received Signal Strength Indicator (RSSI), and packet delivery success.)
- Results-
  - RSSI values dropped slightly, ranging from -45 dBm to -60 dBm as the distance increased.
  - Packet transmission success rate ~ 100%.
  - SNR decreased down to -2dB on average due to rooms in between and due to the increasing distance, and packet loss began to occur, especially at the 30 meter mark.

Testing LoRa Values across floors

- Setup- Sender module placed on 3rd floor. Receiver module was taken to 1st, 2nd and 4th floors.
- Parameters measured. (Signal-to-Noise Ratio (SNR), Received Signal Strength Indicator (RSSI), and packet delivery success.)
- Results-
  - RSSI values dropping to -70 dBm on the first floor and -80 dBm on the second floor.
  - SNR Values observe pattern-like behavior.
  - When the distance was increased till the stairs the SNR value decreased and when the receiver was just a floor below then it increased due to less obstacles between them.
  - Significant packet loss observed.

Testing LoRa Values Across Long Distances

- Setup-Sender module placed in one building. Receiver module taken to other building at a distance of 30-75 meters. Done to evaluate signal penetration through obstacles like trees, people and across open spaces between the buildings.
- Parameters measured. (Signal-to-Noise Ratio (SNR), Received Signal Strength Indicator (RSSI), and packet delivery success.)
- Results-
    - RSSI values dropped significantly, falling to -90 dBm at 30 meters and -100 dBm at 30 meters.
    - SNR dropped significantly from 5 to -8 dB
    - Packet success rates fell as well. Signal strength reduced significantly as the distance was increased.


Signal Strength Comparison Across Experiments (Relative Start Time)
closeDistance(0-1m).csv
nilgiri(15-60m).csv
same_floor(0-30m).csv
different_floors.csv
Signal Strength (dBm)
−50
−60
−70
−80
−90
−100
−110
−120
0
100
200
300
400
500
600
Time (seconds from start)

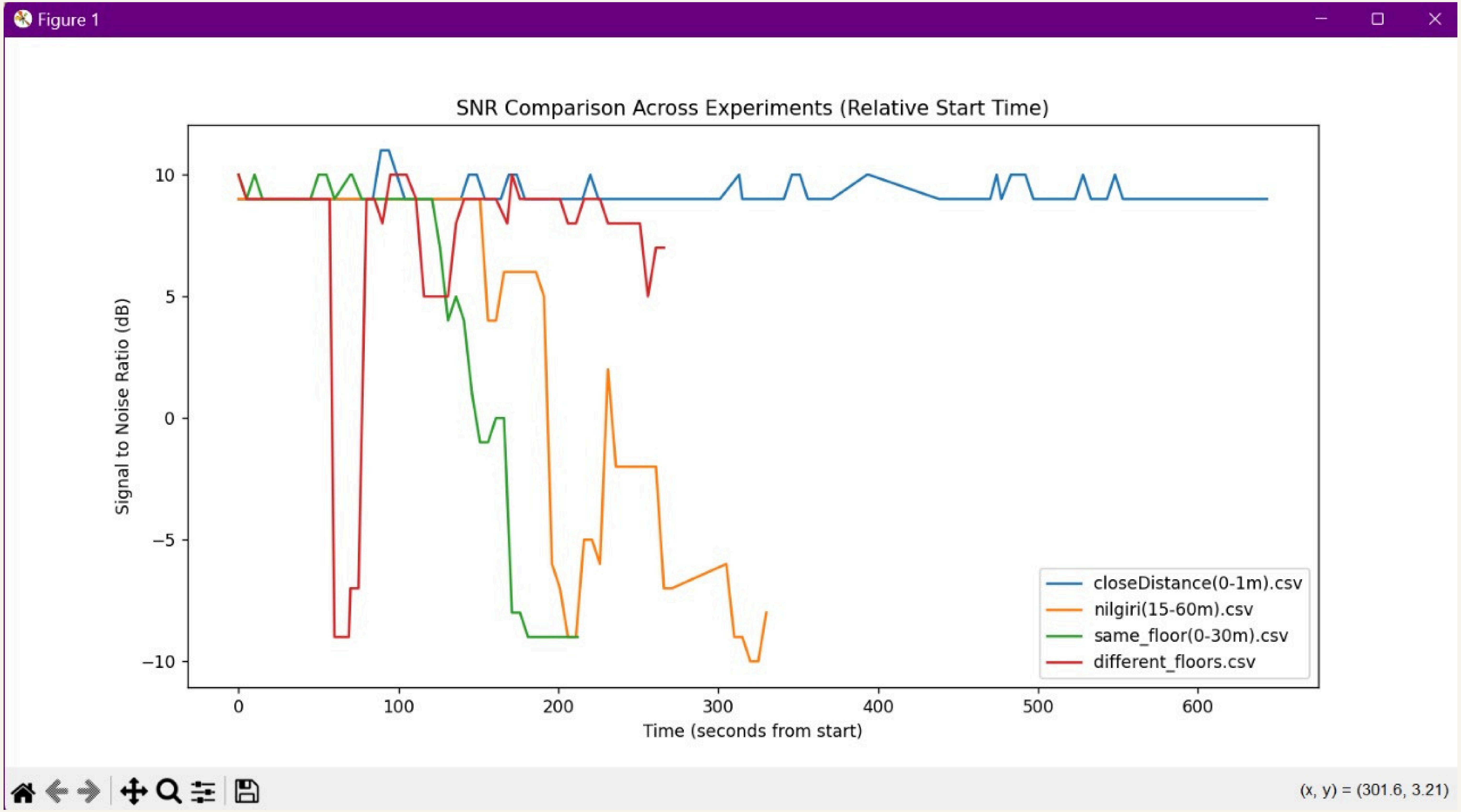
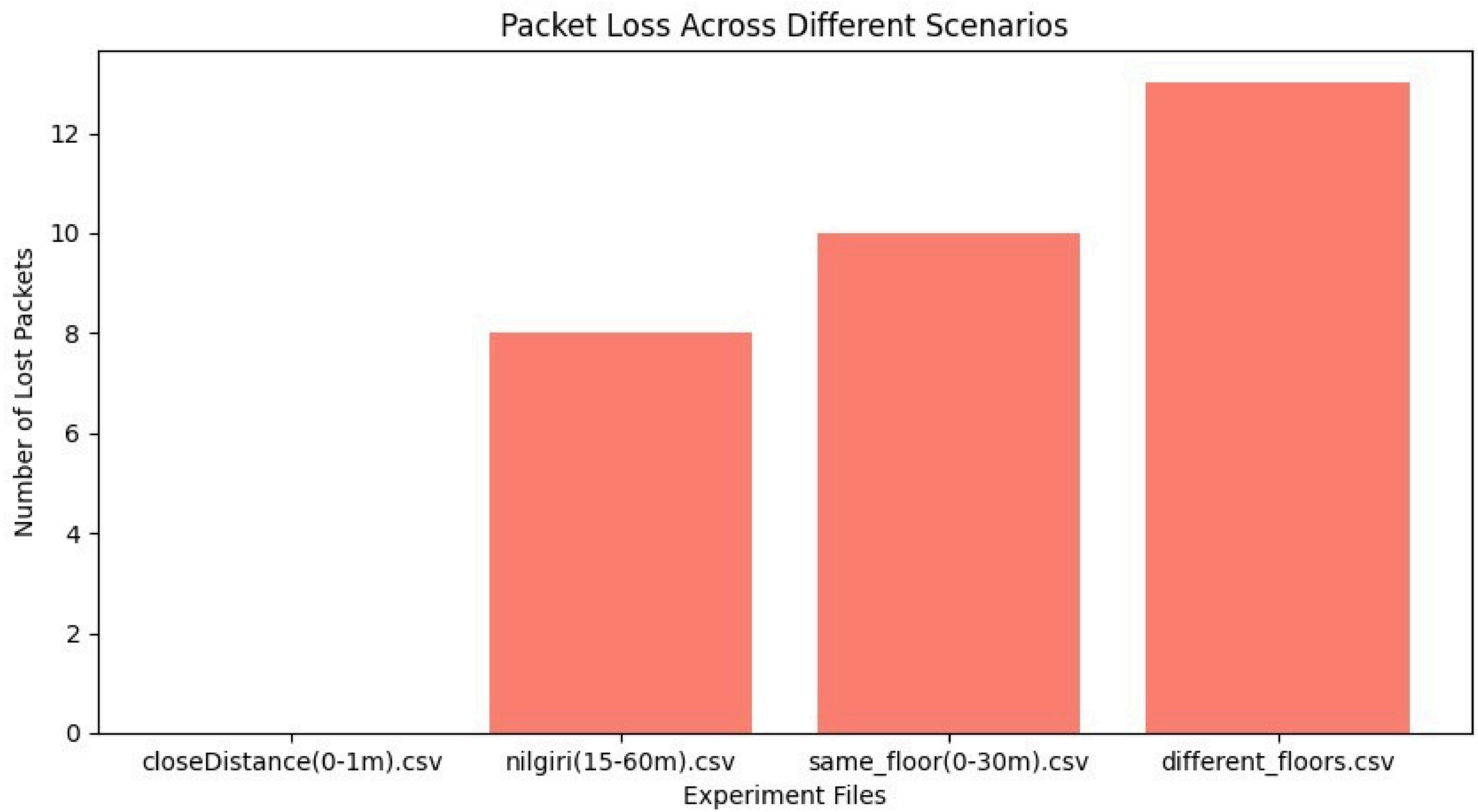


Figure 1
SNR Comparison Across Experiments (Relative Start Time)
Signal to Noise Ratio (dB)
10
5
0
−5
−10
0
100
200
300
400
500
600
Time (seconds from start)
closeDistance(0-1m).csv
nilgiri(15-60m).csv
same_floor(0-30m).csv
different_floors.csv
(x, y) = (301.6, 3.21)




```
PS C:\Users\navee\Downloads\ESW> python packet.py
File: closeDistance(0-1m).csv | Total Packets: 102 | Lost Packets: 0 | Loss Percentage: 0.00%
File: nilgiri(15-60m).csv | Total Packets: 61 | Lost Packets: 8 | Loss Percentage: 40.00%
File: same_floor(0-30m).csv | Total Packets: 40 | Lost Packets: 10 | Loss Percentage: 50.00%
File: different_floors.csv | Total Packets: 53 | Lost Packets: 13 | Loss Percentage: 65.00%
```

Analysis Summary

- LoRa performs exceptionally well in short-range, open environments with minimal interference.
- As obstacles such as walls, floors, and the distance between buildings increase, signal strength and reliability diminish significantly.
- LoRa is effective for long-range communication in rural and less obstructed areas.
- Use in dense urban environments or multi-story buildings may require the use of repeaters or stronger signal antennas to ensure reliable communication.

Cost Analysis

Hardware Costs

Component	Quantity	Unit Cost (INR)	Total Cost (INR)
ESP-32 Module	2	500	1,000
MQ-2 Gas Sensor	1	150	150
Ra-02 LoRa Module	2	500	1,000
SD Card Module	1	100	100
16 GB SD Card	1	400	400
LCD Display	1	200	200
Other Connectors	-	100	100

- PCB Fabrication Cost- INR 3500
- Software Costs- Depends on which service used for cloud databases.

- Total Estimated Project Cost- INR 6500

Modular Hardware Design

Flexible Sensor Integration

- Supports variety of gas sensors- MQ7, MQ135 due to uniform pin configurations.
- Allows for seamless integration of new sensors without the need for significant hardware modifications..

Minimal Code Changes

- Modular Code.
- Only minor adjustments to the sensor calibration parameters and data reading logic are required when switching sensors.

FUTURE EXPANSIONS

1. Sensor callibration.
2. Usage of better sensors.
3. Interfacing with additional sensors.
4. Power optimizations.
5. Integration with advanced IoT platforms.
6. Multi-Node LoRa Network.

Personal Contributions

Team Member	Contrubutions
Hardik Chadha	1) Integrated the SD card module with the Sender module. 2) Integrated the LCD display with the Sender Module. 3) Wrote the code for integrating SD card and LoRa module on the same SPI pins of the sender module, ESP and debugging the issues faced in these parts. 4) Helped in the inititial testing of MQ-2 Sensor. 5) Helped in the testing of LoRa Modules. 6) Helped in the data collection for different experiments for LoRa. 7) Assisted in the Soldering of the PCB connections
Arnav Sharma	1) Integrated HTML with ThingSpeak, to enable live retrieval of data from ThingSpeak to be displayed on the web-page. 2) Used NodeJS and PostgreSQL to connect server, ThingSpeak and CockroachDB. 3) Created database/backend on CockroachDB Cloud for storing data. 4) Made the circuit schematic to be used in the PCB Design. 5) Designed the PCB using Autodesk Eagle. 6) Helped in collection of data for LoRa analysis. 7) Made the PPT's for progress of each week, as well as for the final presentation.

Team Member	Contrubutions
Hiten Garg	1) Analyzed the codes along with Kushal. 2) Implementation of messaging system using TWILIO API with whatsapp integration. 3) Made the HTML page for the website to showcase the overview of our project. 4) Implemented the hardware like connections for both the sender and receiver modules. 5) Worked on data collection for different experiments. 6) Analysed the data using python scripts and made graphs. 7) Made the 3D design for both the sender and receiver modules.
Kushal Mangla	1) Wrote the codes for Lora Modules. 2) Coding and implementation of TWILIO API with Node and Express JS. 3) Made the backend for the the user interface of our website, implementing nodejs, expressjs, postgress. 4) Intergrating the EJS files with our backend server. 5) Helped in hardware integration with Hiten. 6) Helped in data collection for the lora analysis. 7) Analysed the data using python scripts and made graphs. 8) Made the 3D design for both the sender and receiver modules.

THANK YOU