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Weather Balloon Payload

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ABSTRACT :

The Weather Balloon Payload project uses LoRaWAN technology to transmit real-time data from various atmospheric sensors, such as temperature, humidity, GPS, and gas detectors. Powered by an efficient battery system, the payload provides a scalable and reliable platform for monitoring weather and environmental conditions. With its real-time data transmission capabilities, it enhances weather forecasting and climate research. The system is cost-effective, serving as a practical alternative to satellite-based solutions, and is easy to deploy for accurate atmospheric data collection.

Designed for versatility, the system functions as both a weather balloon payload and a standalone weather monitoring platform, making it adaptable to various research needs. AI-driven analysis of the collected data offers real-time insights into weather patterns and atmospheric conditions, improving prediction accuracy. This AI integration equips researchers and meteorologists with advanced tools for monitoring climate changes and making more informed decisions.

Keywords— Weather Balloon Payload, LoRaWAN, Real-time Data Transmission, Atmospheric Sensors, AI-driven Analysis, Weather Forecasting

INTRODUCTION :

The Weather Balloon Payload project is designed to enhance the accuracy and efficiency of weather data collection, particularly at high altitudes where conventional methods struggle. By deploying a balloon equipped with sensors to monitor key atmospheric conditions such as temperature, humidity, and pressure, the system can collect real-time data that is critical for both weather forecasting and climate research. This innovative approach addresses the growing need for precise, timely information to better understand environmental changes and predict weather patterns more accurately. Furthermore, its scalable design makes it adaptable for various applications, from small-scale studies to large meteorological projects, while offering a cost-effective alternative to satellite technology. This introduction sets the stage for a project that not only improves current methodologies but also supports vital climate and environmental research.

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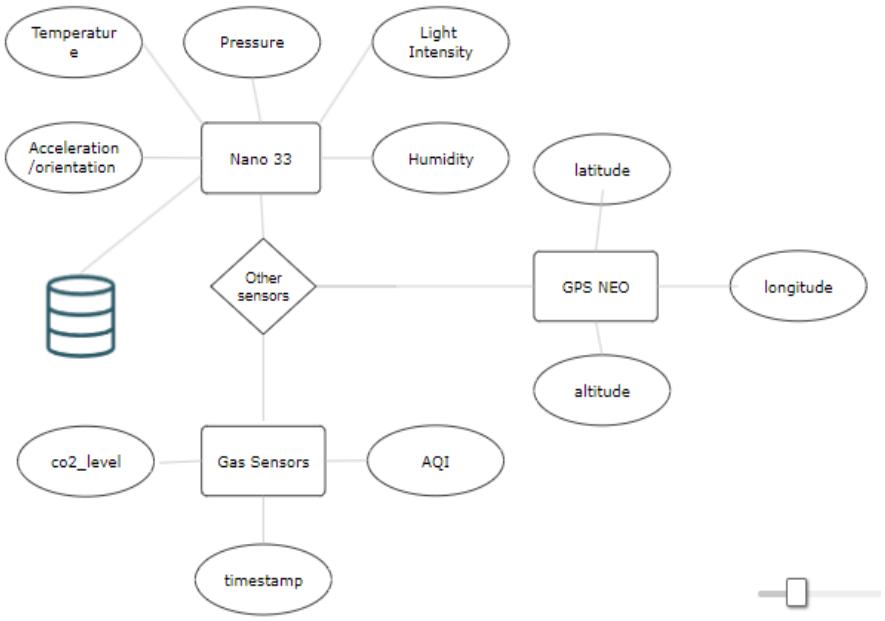
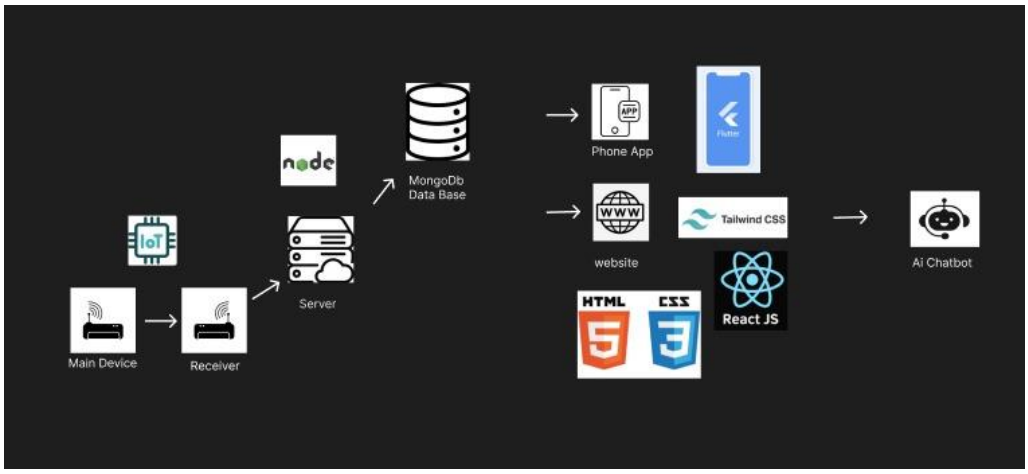
A Weather Balloon Payload addresses a critical need for more accurate and comprehensive weather data collection, especially at high altitudes where traditional ground-based methods are insufficient. The system is equipped with sensors to monitor temperature, humidity, and atmospheric pressure, providing real-time data to ground stations. This ensures more precise weather forecasting and enhances climate research by capturing atmospheric conditions that are crucial for studying climate change.

Compared to existing technologies like satellites, the weather balloon offers several advantages. It collects data from altitudes that satellites cannot, ensuring higher accuracy in predictions. Additionally, it provides real-time transmission of data, which is vital for immediate analysis, and it does so at a much lower cost, making it a cost-effective alternative to expensive high-end equipment.

This project benefits meteorologists, climate researchers, and even smaller-scale weather monitoring stations. It offers a scalable solution that can be adapted for both large and small-scale meteorological studies, ensuring a user-friendly and efficient way to gather critical atmospheric data.



ER Diagram.



Flowchart

HARDWARE SETUP FOR WEATHER BALLOON :

Transmitter (Weather Balloon Payload)

The transmitter module is attached to the weather balloon and is responsible for collecting and transmitting environmental data.

1. **Components**

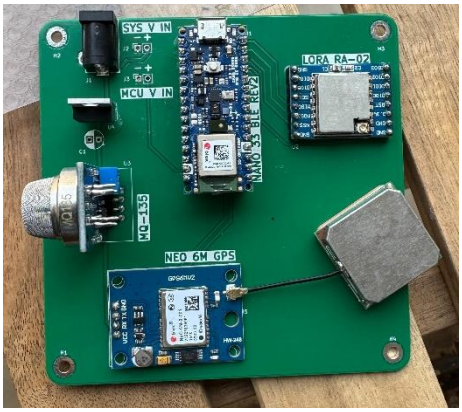
- Microcontroller: Arduino Nano 33 BLE (controls sensors and transmits data)
- LoRa Module: RA-02 AI Thinker (433 MHz) (sends data to the receiver)
- GPS Module: NEO-6M GPS (provides latitude, longitude, altitude, and speed)
- Air Quality Sensor: MQ-135 (measures air pollutants like CO, NH3, NOx, benzene, etc.)
- Temperature and Pressure Sensor: BMP180 or BMP280 (measures temperature and atmospheric pressure)
- Power Supply: 18560 2500mah-5000mah
- Voltage Regulator: LM1117t 3.3V
- Enclosure: 3D printed

2. **Wiring Connections**

- The LoRa RA-02 module is connected to the Arduino Nano 33 BLE via SPI pins.
- The GPS module is connected to the UART pins of the Arduino.
- The MQ-135 air quality sensor outputs an analog signal to the Arduino.
- The BMP180 sensor communicates using I2C.

3. Working

- The GPS module collects location data, including latitude, longitude, altitude, and speed.
- The MQ-135 sensor measures air quality parameters.
- The BMP180 sensor records temperature and atmospheric pressure.
- The Arduino Nano 33 BLE processes data from all sensors.
- The LoRa RA-02 module transmits the processed data at 433 MHz to the ground station.



Transmitter

Receiver (Ground Station)

The receiver module is placed on the ground and is responsible for receiving and processing data from the weather balloon.

1. Components

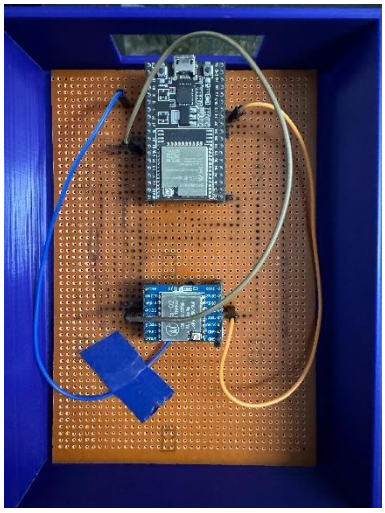
- Microcontroller: ESP8266 or ESP32 (receives and processes data)
- LoRa Module: RA-02 AI Thinker (433 MHz) (receives data from the balloon)
- Antenna: Yagi or Helical Antenna (433 MHz) (improves signal reception)
- Wi-Fi Module: Built-in ESP8266/ESP32 (sends data to a server for online

2. Wiring Connections

- The LoRa RA-02 module is connected to the ESP8266/ESP32 via SPI pins.
- The display (if used) is connected via I2C.
- The power bank supplies stable 5V power to the ESP8266/ESP32.

3. Working

- The LoRa RA-02 module in the receiver picks up signals from the balloon.
- ESP8266 or ESP32 processes the received data.
- ESP8266/ESP32 sends the data to a VPS server via Wi-Fi.
- The real-time data can be accessed on a webpage for tracking purposes.



Reciever

WEBSITE FOR WEATHER BALLOON :

The weather balloon website has 2 pages, a landing page and an analytics page.

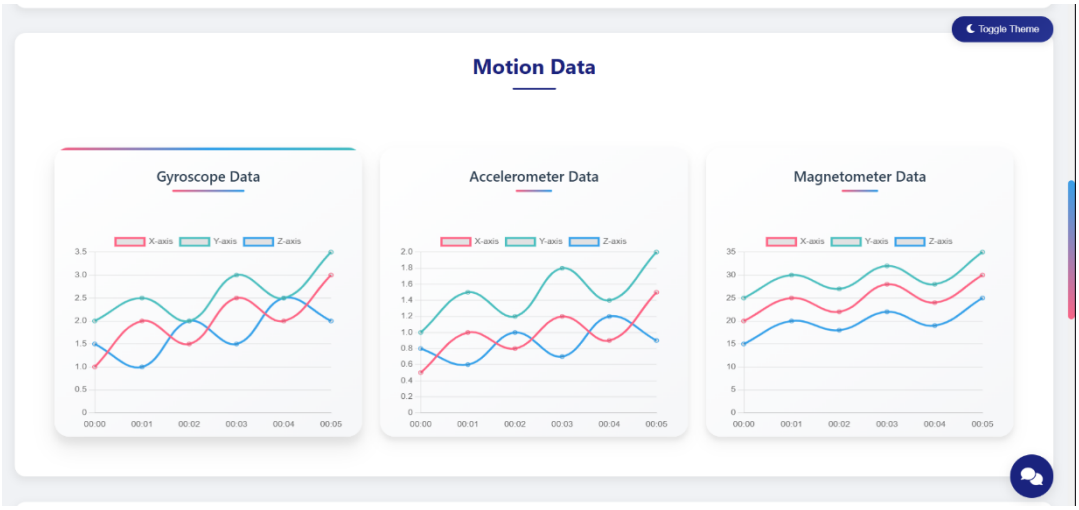
The weather balloon payload dashboard consists of the following key components:

- **Telemetry Data Visualization**: Displays real-time data on temperature, humidity, pressure, sound levels, and air quality index (AQI).
- **Motion Data Analysis**: Visualizes gyroscope, accelerometer, and magnetometer data to track the balloon's movement and orientation.
- **GPS Tracking**: Provides real-time location tracking of the weather balloon using GPS data, displayed on an interactive map.
- **Chatbot Assistant**: A conversational AI assistant that helps users understand the data and provides insights.
- **Landing Page:** Provides an overview of the weather balloon mission, objectives, and key features.

Frontend Development

The frontend of the dashboard is built using **HTML5**, **CSS3**, and **JavaScript**. Key libraries and frameworks used include:

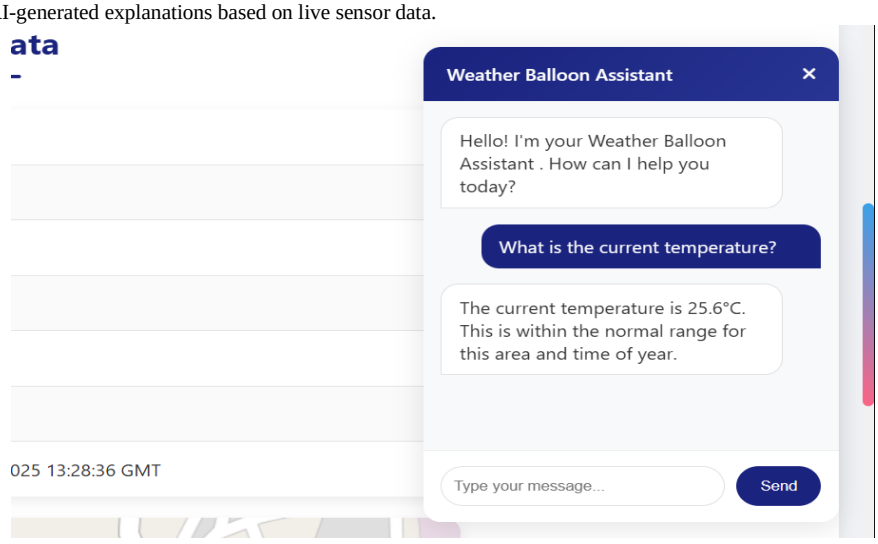
- **Chart.js**: For creating interactive graphs and charts to visualize telemetry and motion data.
- **Leaflet.js**: For displaying the weather balloon's location on an interactive map.
- **Particles.js**: For creating an animated background effect that enhances the user experience.
- **AOS (Animate on Scroll) Library**: For adding smooth animations to the dashboard element



Website UI

Chatbot Integration

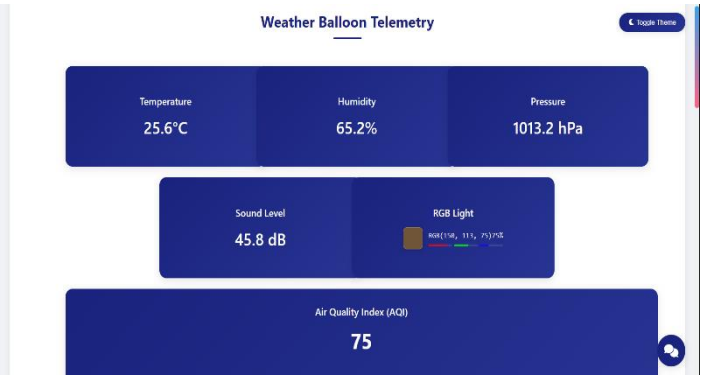
The **Weather Balloon Payload Dashboard** features an intelligent chatbot powered by Google **Gemini API**, designed to help users interpret real-time sensor data effectively. This chatbot acts as a virtual assistant, providing insights into telemetry, motion, and GPS tracking data fetched from the backend API. Users can ask questions about current environmental conditions, altitude, pressure variations, and predicted landing locations, and the chatbot responds with AI-generated explanations based on live sensor data.



Chatbot

Real-time Data Fetching

The Weather Balloon Payload Dashboard fetches real-time sensor data from a server using JSON (JavaScript Object Notation). JSON is a lightweight format commonly used for data exchange between the frontend and backend. The dashboard continuously retrieves telemetry, motion, and GPS tracking data by making API requests, ensuring live updates.



Realtime Data

MOBILE APPLICATION FOR WEATHER BALLOON :

The **Weather Balloon Payload Mobile Application** provides real-time telemetry, motion analysis, and GPS tracking, enhancing data accessibility and visualization. It integrates an AI-powered chatbot to assist users in interpreting environmental parameters. This app serves as a comprehensive tool for researchers, educators, and enthusiasts to monitor weather balloon missions effectively.

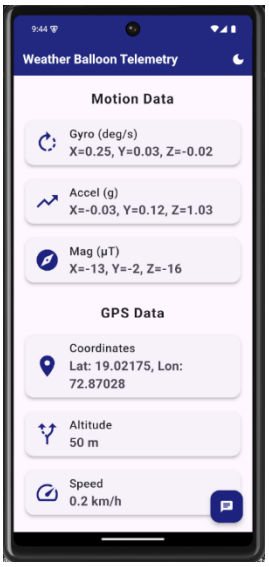
The weather balloon payload dashboard consists of the following key components:

- **Telemetry Data Visualization**: Displays live sensor data, including temperature, humidity, pressure, sound levels, and air quality index (AQI).
- **Motion Data Analysis**: Tracks balloon orientation using gyroscope, accelerometer, and magnetometer data.
- **GPS Tracking:** Provides real-time location monitoring, displaying altitude, speed, and precise coordinates.
- **Chatbot Assistant:** A conversational AI chatbot, powered by Google Gemini API, helps users interpret sensor readings and gain insights.
- **Dark & Light Mode**: Users can toggle between dark and light themes for an improved UI experience.

Frontend Development

The app is developed using **Flutter**, ensuring cross-platform compatibility on Android and iOS. Key UI features include:

- **Material Design Components**: Ensures a clean and responsive user interface.
- **Dynamic Theme Switching**: Allows users to toggle between light and dark modes.
- **Real-time Data Display**: Utilizes **FutureBuilder** in Flutter to update sensor data dynamically.



UI in Ligh tmode

UI in Dark mode

Chatbot Integration

The app features an AI-powered chatbot, leveraging the **Google Gemini API**. It allows users to:

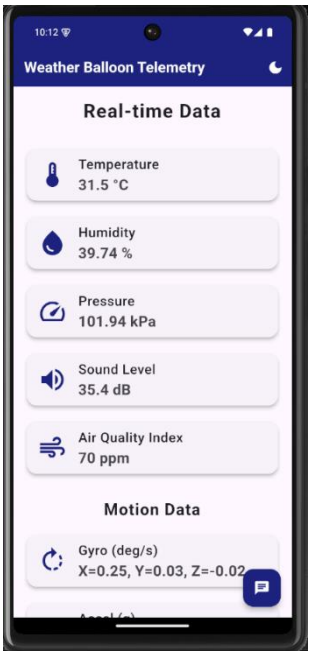
- Ask questions about environmental conditions, altitude, pressure variations, and predicted landing locations.
- Receive AI-generated explanations based on live sensor readings.

Chatbot Interface

Real-time Data Fetching

The application retrieves real-time weather balloon sensor data from a remote server using **RESTful APIs**. It processes JSON responses efficiently, ensuring:

- **Seamless Telemetry Updates**: Live updates of sensor parameters.
- **GPS Tracking Synchronization**: Continuous retrieval of latitude, longitude, and altitude data.
- **Efficient Error Handling**: Detects and notifies users of connectivity issues.



Real-time Data

CONCLUSION

The Weather Balloon Payload project demonstrates a scalable, cost-effective, and highly adaptable approach to atmospheric data collection. By leveraging LoRaWAN technology for real-time data transmission, the system ensures continuous monitoring of critical weather parameters, including temperature, humidity, pressure, air quality, and GPS location. The integration of AI-powered analytics enhances data interpretation, enabling researchers and meteorologists to derive meaningful insights for weather forecasting and climate studies.

The **mobile application and website dashboard** provide an intuitive interface for users to access and analyze telemetry data efficiently. Features such as **real-time visualization, GPS tracking, chatbot assistance, and dynamic UI themes** contribute to a seamless user experience. Compared to traditional satellite-based weather monitoring solutions, this project **offers a low-cost, high-accuracy alternative**, making it suitable for small-scale and large-scale meteorological applications alike.

Future enhancements may include **machine learning-based predictive analytics**, improved **sensor calibration for higher precision**, and **extended communication range for global data accessibility**. The project lays the foundation for further advancements in real-time atmospheric monitoring and environmental research.

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