LoRa Mesh Network for Efficient Data Acquisition in Remote Research Locations

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1 The Problem

In the current data-driven era, the demand for high-quality, reliable data is at an all-time high. This demand, however, comes with increased expenditure [1]. The cost of data collection and retrieval can be a significant barrier for researchers, particularly those conducting studies in remote or hard-to-reach locations [2]. These locations often require specialised equipment and logistics, further increasing the costs [3].

Marine research is a prime example of such a scenario. The vastness and inaccessibility of the oceans make data collection a challenging and expensive endeavor [4]. Traditional methods involve deploying research vessels or larger buoys equipped with expensive equipment. However, these methods are not only costly but also limited in their reach and frequency of data collection [5]. Furthermore, they are susceptible to damage from harsh marine conditions, leading to potential data loss and additional repair or replacement costs [6].

Similarly, research in other remote locations such as deserts, mountains, or polar regions presents its own set of challenges. The harsh environmental conditions, coupled with the lack of infrastructure, make data collection in these regions a costly and logistically challenging task [7].

2 Proposed Solution

2.1 LoRa (Long Range) Communications

LoRa, short for "long range", is a proprietary physical radio communication technique based on spread spectrum modulation techniques derived from chirp spread spectrum (CSS) technology. It was developed by Cycleo, a company of Grenoble, France, and later acquired by Semtech [8].

LoRa is known for its long-range, low-power communication capabilities, making it an ideal choice for applications that transmit small chunks of data with low bit rates [9]. Data can be transmitted at a longer range compared to technologies like WiFi, Bluetooth or ZigBee [9]. **These features make LoRa well suited for sensors and actuators that operate in low power mode** [9].

2.2 The proposal

This project proposes the design and implementation of a distributed mesh network, with each node comprising a LoRa device connected to a microcontroller. These microcontrollers will be equipped with various sensors for gathering data from the surrounding environment. The nodes will be strategically deployed on land or sea buoys, enabling the collection of terrestrial and marine data respectively.

The mesh network's topology will extend the theoretical reach of each node, ensuring a more resilient and extensive network coverage [10]. Additionally, to allow for efficient data retrieval, a drone, outfitted with a LoRa module, will be utilized. Ideally the drone would only have to be in the range of one node to collect all the data, without the need for manual intervention.

The project's implications extend to various fields, including climate studies, marine biology, and agriculture, marking a significant contribution to remote sensing and environmental science.

Similar work has been conducted by Hazwan Mohd Ghazali et al. which outlined a theoretical framework for researchers using LoRa, and also defined key metrics for measuring the use of these systems [11]. It provides recommendations for researchers on what research perspectives should be explored when implementing UAVs for IoT LoRa networks.

2.3 Practice-Based Research

To develop this system to be robust and fault-tolerant, a series of methods will be employed to test the system. A/B Testing will be used to test different configurations under different scenarios:

- **Real-world Field Testing**: This would help determine the range and coverage of the system, and highlight any potential data transmission issues.
- **Resilience Testing**: Intentionally disabling nodes or introducing interference could help better understand fault tolerant and data redundancy.
- **Data Analysis**: Analysing both existing and gathered environmental datasets would help better understand the conditions the network will operate under.

Finally, a t-test would be conducted to test if the performance difference in varying configurations are statistically significant or not.

3 Diagrams

3.1 Systems/Component Diagram

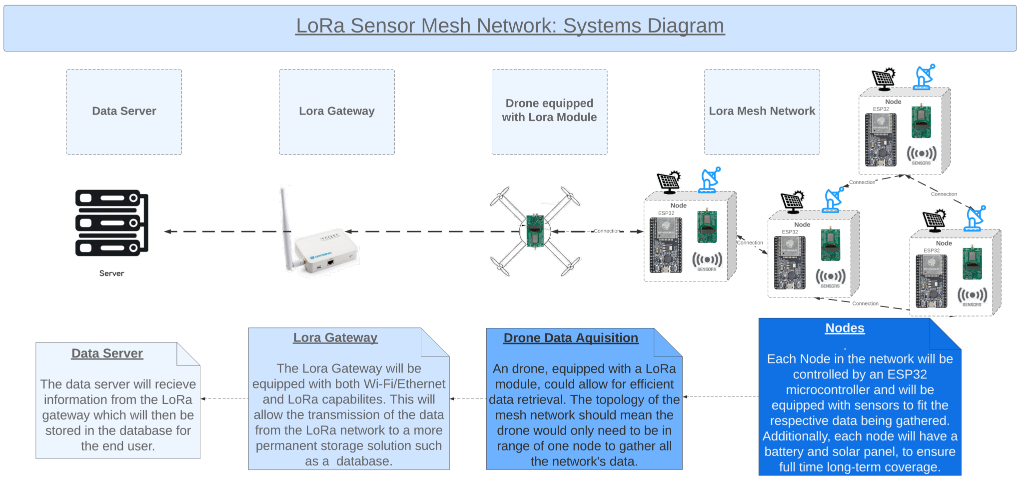

Figure 1: Systems Diagram

Key Features:

- Mesh Network of Sensor Nodes for gathering and routing data.
- Data Aquisition drone for efficient data retrieval.
- LoRa Gateway, for transferring the data from the Lora Network to more traditional servers.
- Data server, for long-term storage of the data.

3.2 Node Class Diagram

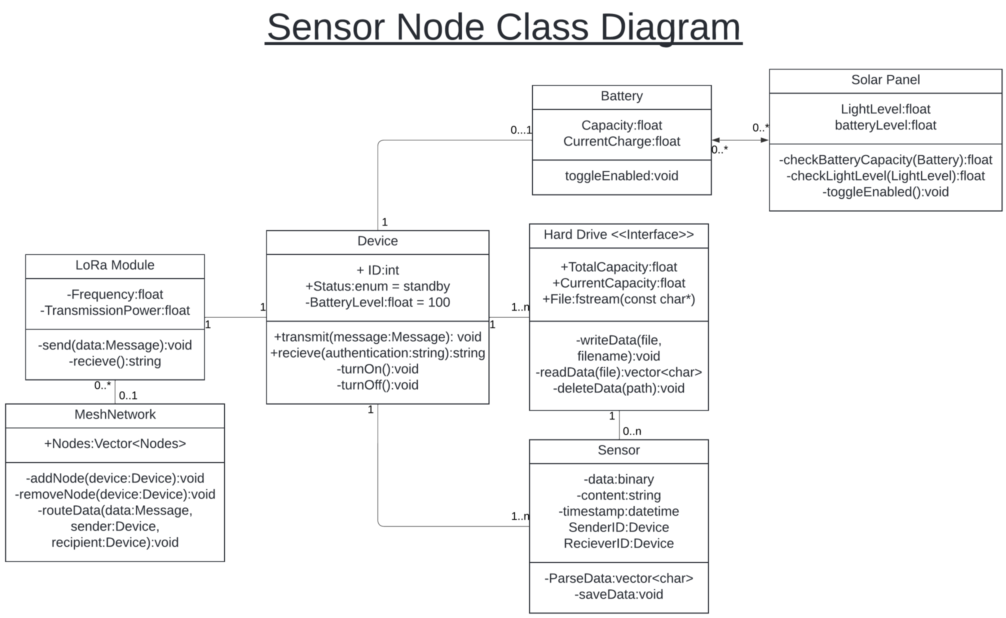

Figure 2: Class Diagram for a Sensor Node

Key Features:

- Self-Organising Mesh Network.
- External Sensor to Hard-Drive interface for data storage.
- Solar Panel and Battery combination for reliable power.
- ESP32 in each node to handle the controlling and logic of the system.

3.3 UML Use Sequence Diagram

Diagram.png

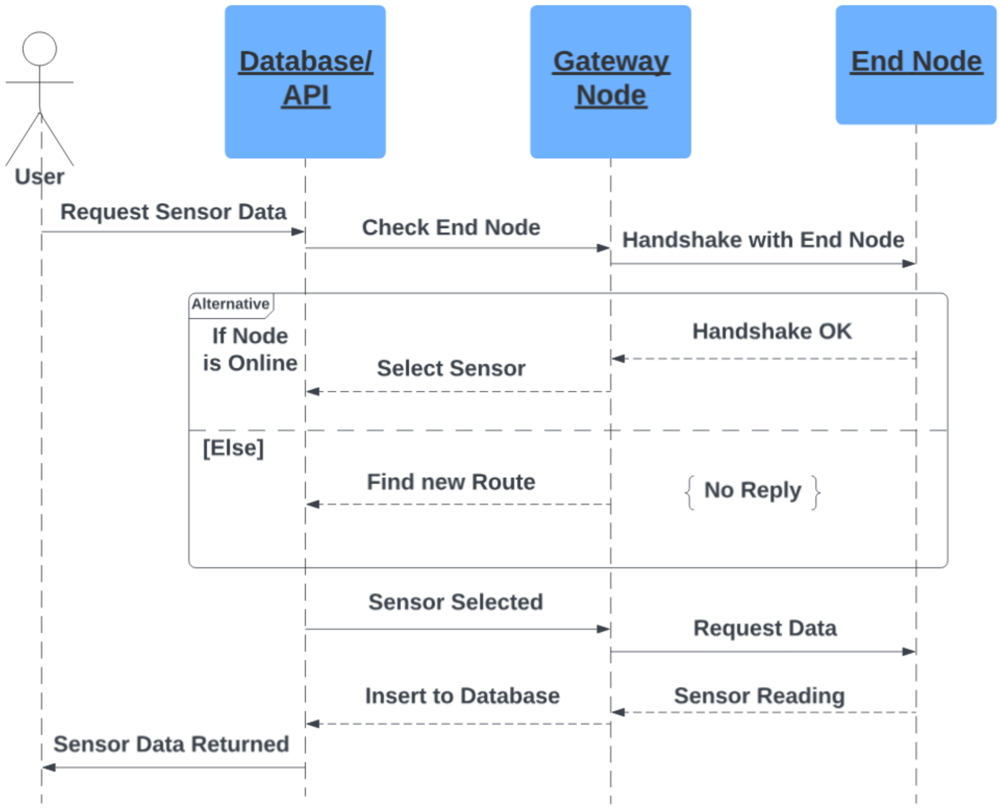

Figure 3: Sequence Diagram of user requesting new sensor data

4 Development Plan

4.1 Methodology

For this project, Agile methodology would most suit the requirements and time constraints. An iterative approach would allow for testing and validation of new features incrementally, and would reduce the risk of cost management.

Agile would also allow the project to remain flexible to any unforeseen issues or changes that need to be addressed after the initial sprints.

An adaptable development life-cycle would allow different team members with varying skills to focus on separate branches of the project. For example, one developer could work on the drone system while the other focuses on the mesh topology. Futhermore, all software and APIs created will be containerised using Docker, to allow for seamless deployment and scaling across differing environments and hardware, This will help with collaboration and reduce potential conflicts between development environments.

These methods and frameworks help the project to align with its goal of creating a robust, scalable and secure system for data collection.

4.2 Gantt Chart Development Road-map

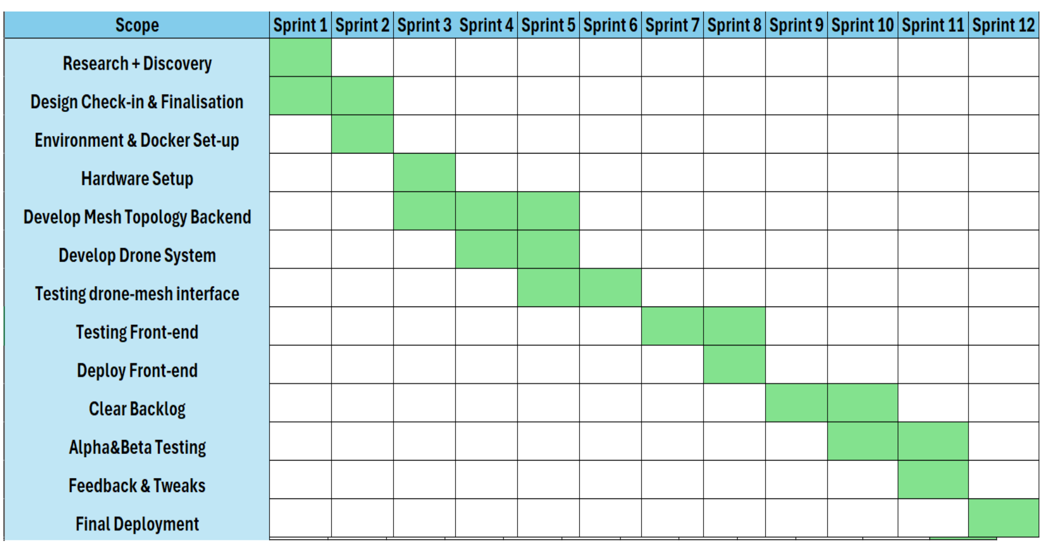

Figure 4: Development Gantt Chart

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