LoRa Sensor Network: A Mesh-based approach to data aquisition

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Introduction

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].

The problem

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].

Therefore the main focus of this proposal aims to address the following issues:

- Difficult to scale: Gathering sensor data can be an extensive task, especially with larger scale projects.
- Expensive Data Retrieval: Manned missions and Satellite communications are too costly for smaller budget research.
- Data Loss: The loss of data in remote locations can result in wasted resources.

The Solution

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 [8]. 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.

- Data Gathering: A scalable solution for gathering sensor data, for large or small projects.
- Cost affordant Data Aquisition: Cheaper alternatives to costly manned missions.
- Data redundancy: A reliable fault-resistant network with reduced data redundancy.

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 [9].
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 [10]. Data can be transmitted at a longer range compared to technologies like WiFi, Bluetooth or ZigBee [10]. These features make LoRa well suited for sensors and actuators. that operate in low power mode [10].

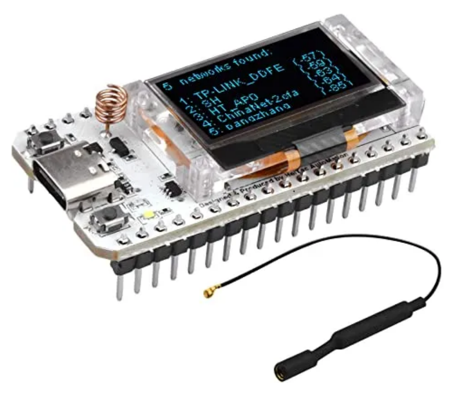

Figure 1. Heltec ESP32 LoRa v3

Researchers have provided empirical evidence of the use of LoRa devices in IoT applications for the industry [11]. However, to our knowledge, hardly any information is available on configuring the LoRa enabled End-nodes for every-day users. This indicates that while LoRa has been utilized in IoT applications, there is still a lot of potential for further research, especially in terms of optimizing network performance for efficient IoT applications[12]. LoRa's unique features make it an ideal choice for Internet of Things (IoT) applications, especially in the field of wireless sensor networks (WSNs) focused on IoT concepts. The evolution of LoRa for WSNs has been significant as it has the potential to resolve the requisites and difficulties of diverse sensor network applications [11, 12].

Systems Diagram

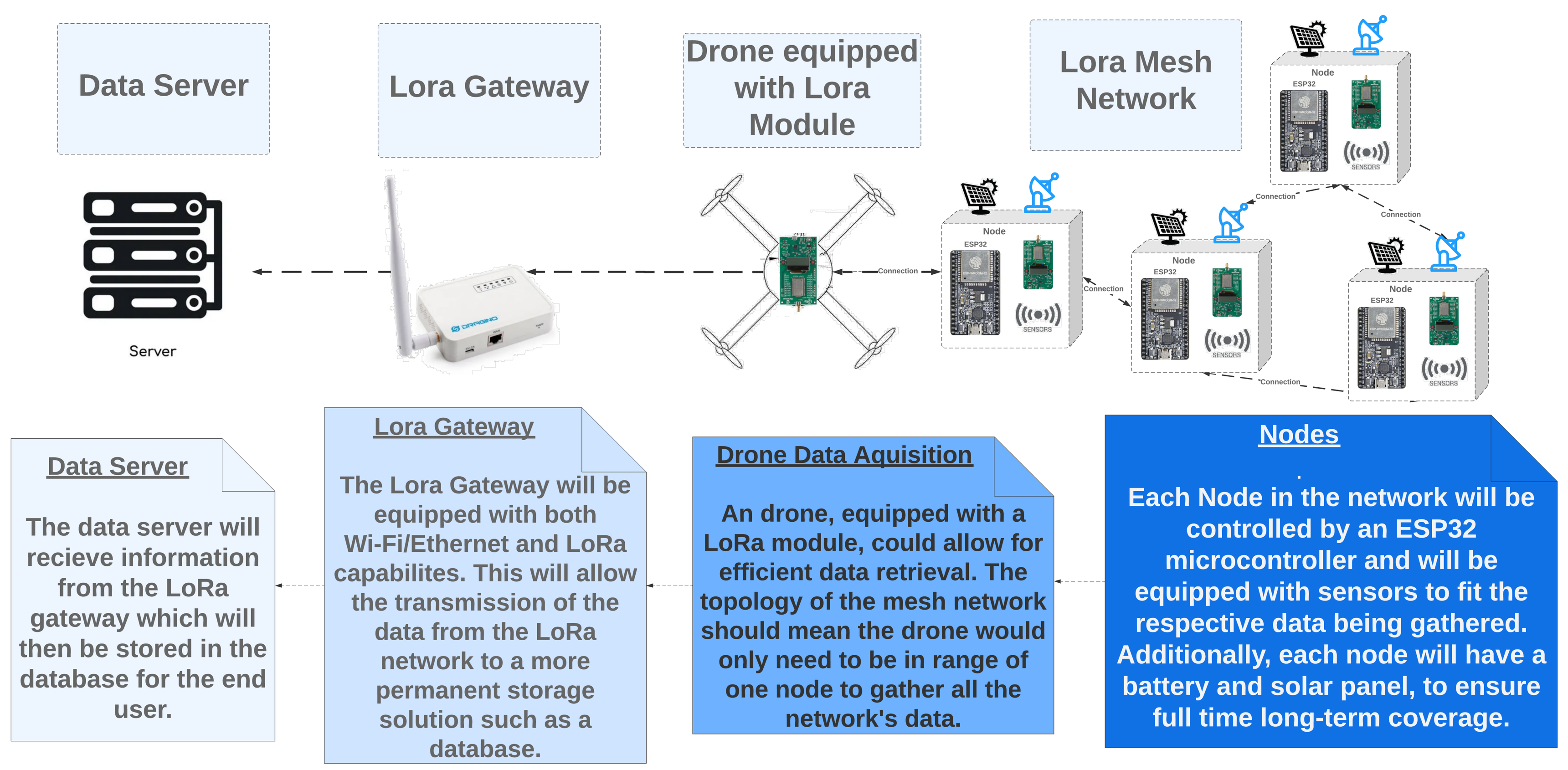

Figure 2. A System Overview of the network

Key Features:

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

Node Diagram

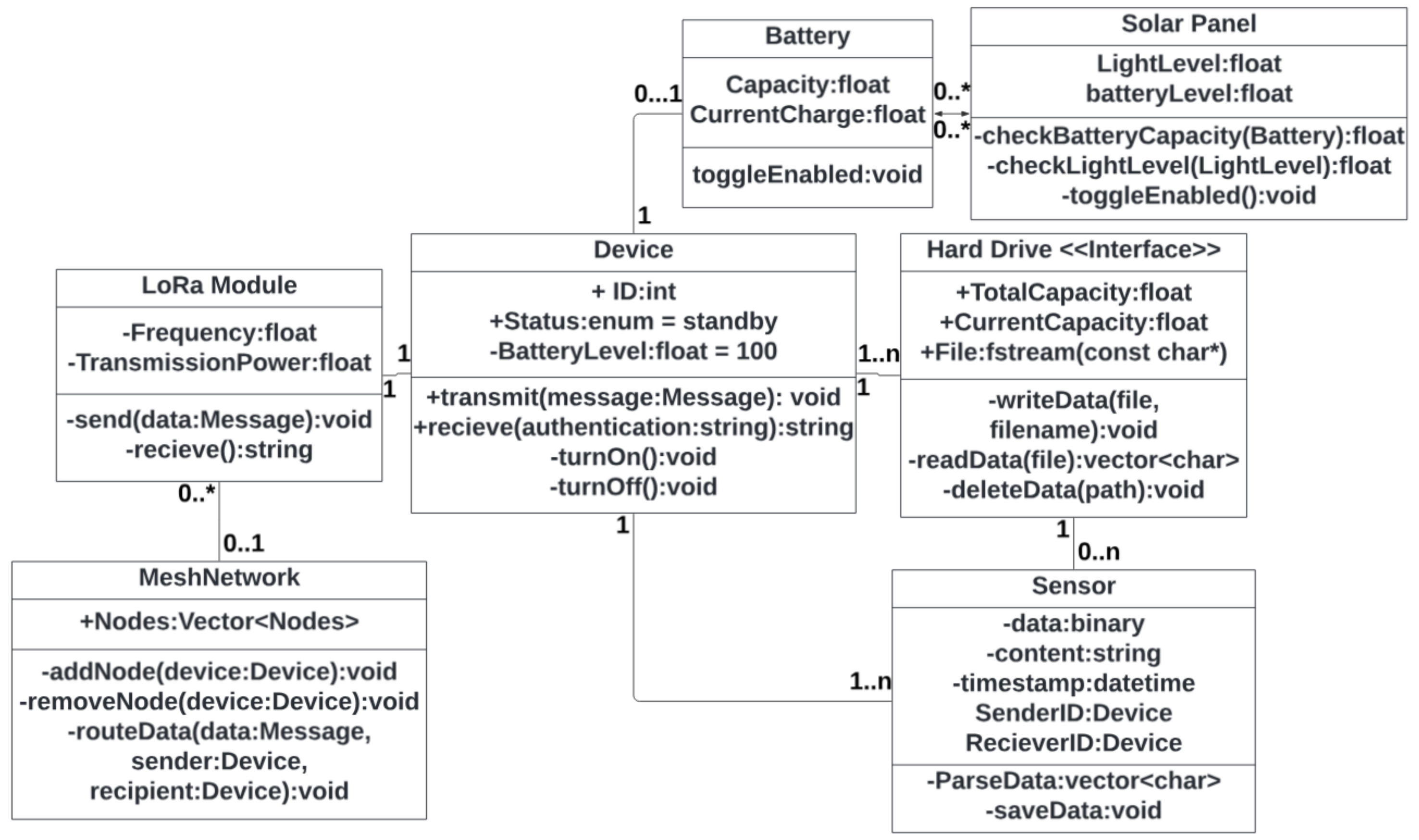

Figure 3. An overview of an example node

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.

Mesh Topology

Each node in the network will periodically broadcast its existence. This will allow other nodes to build up a map of the network and route the data accordingly. This allows the network to extend its range far beyond the reach of a single node.

Mesh network topology

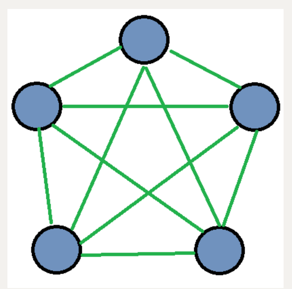

Figure 4. An diagram of mesh topology

In the event of a node failure or obstruction, the mesh topology allows data to be rerouted through other nodes, ensuring continuous data collection and transmission. This makes the network highly resilient, particularly important for deployments in remote or harsh environments that this system is built for [13].

Future work and Development Lifecycle

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.

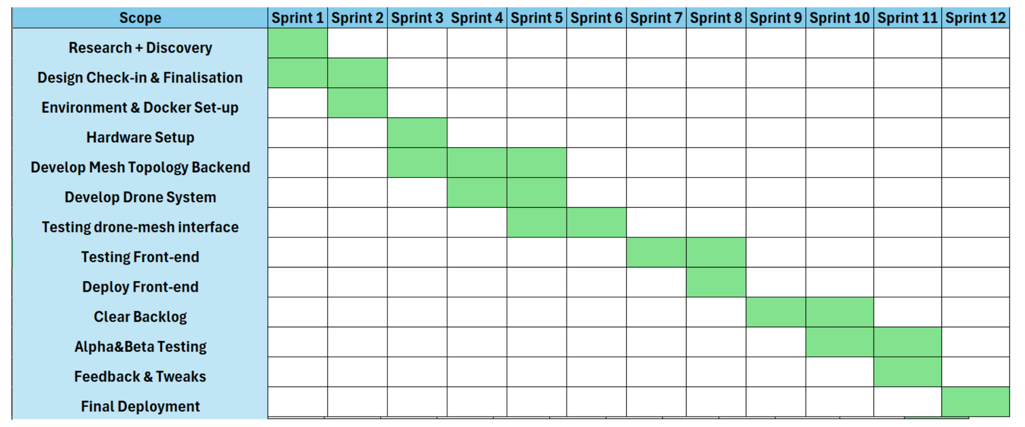

Figure 5. An overview of an example node

References

[1] M. Jahanbakht, W. Xiang, L. Hanzo, and M. Rahimi Azghadi, "Internet of underwater things and big marine data analytics—a comprehensive survey," IEEE Communications Surveys Tutorials, vol. 23, no. 2, pp. 904–956, 2021.

[2] S. S. Furlaneto, A. L. dos Santos, and C. S. Hara, "An efficient data acquisition model for urban sensor networks," in 2012 IEEE Network Operations and Management Symposium, pp. 113–120, 2012.

[3] D. Ebrahimi, S. Sharafeddine, P.-H. Ho, and C. Assi, "Uav-aided projection-based compressive data gathering in wireless sensor networks," IEEE Internet of Things Journal, vol. 6, no. 2, pp. 1893–1905, 2019.

[4] W. Turrell, "Improving the implementation of marine monitoring in the northeast atlantic," Marine pollution bulletin, vol. 128, pp. 527–538, 2018.

[5] M. L. Muradian, T. A. Branch, and A. E. Punt, "A framework for assessing which sampling programmes provide the best trade-off between accuracy and cost of data in stock assessments," ICES Journal of Marine Science, vol. 76, pp. 2102–2113, 09 2019.

[6] M. Emory, "Noaa fisheries seeks volunteers for research study to modernize shrimp data collection in the gulf of mexico," NOAA Fisheries, 12 2023.

[7] P. Baker, D. Hegney, C. Rogers-Clark, P. Fahey, D. Gorman, and G. Mitchell, "Planning research in rural and remote areas," Rural and Remote Health, vol. 4, no. 2, pp. 1–11, 2004.

[8] I. Akyildiz and X. Wang, "A survey on wireless mesh networks," IEEE Communications Magazine, vol. 43, no. 9, pp. S23–S30, 2005.

[9] Semtech, "What is lora?," 2024.

[10] R. Wenner, "What are lora and lorawan?," 3 2024.

[11] R. Mistry, M. Neves, and B. Goswami, "A systematic study on lora communication in iot: Implementation challenges and research solutions," in International Conference on Information, Communication and Computing Technology, pp. 16–29, Springer, 2022.

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