

The Design and Development of a Low Power LoRa Based Asset Tracking System

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ABSTRACT

This project has looked at the design and development of a low-power LoRa asset tracking system. It utilised a rapid prototyping development methodology for quick turnaround of versions. A literature review and market research will determine the baseline requirements for a minimum viable product. The project highlights how rapid prototyping is a suitable methodology for developing a final product.

The project consisted of three tracking nodes capable of communicating with a central node/hub running a Python graphical user interface to control and monitor each node. The project looked at specific design features and code that can be implemented to achieve a low-power consumption device. Utilising various modes within the GPS and microcontroller, the device can enter power-saving or sleep modes to reduce idle power consumption. The tracking performance of the device was assessed to see if it met the initial requirements for the project, as the reliability of the GPS data was an essential factor.

The report concludes with a statement on how rapid prototyping is an acceptable approach to this problem, but it has the drawback of being overly time-consuming.

Future recommendations for this system include measures to prevent device misuse, relay capability to link the devices and extend the overall range, a dedicated crypto engine and more power-saving measures.

INTRODUCTION

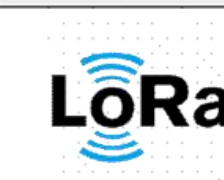
This project focused on designing a LoRa-based low-power communications system and how it can be utilised for asset tracking and management. LoRa is ideal for systems that require low power consumption, long range, and can be deployed anywhere locally without relying on existing infrastructures such as Wi-Fi, cloud services, or cellular connection, which can be expensive and complex to set up.

This will be beneficial for remote areas where Wi-Fi and cellular are not easily accessible or where the system wants to be deployed locally without using cloud services but still maintain a similar level of connectivity.

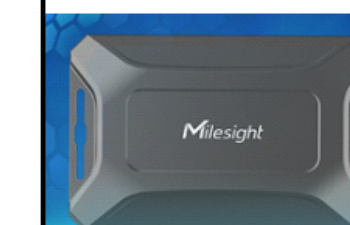
AIMS & OBJECTIVES

- Research current asset tracking solutions and identify limitations and areas of improvement.
- Design and build a low-power PIC microcontroller-based tracking device capable of encrypted communication over the LoRa protocol. This will include a manufactured printed circuit board, circuit design and a suitable case for the nodes to be deployed in.
- Create a user-friendly web-based graphical user interface to interact with and monitor the devices on the system.
- Identify features that can be implemented to prevent the misuse of the device (e.g. audible noise during transmissions, protected encryption keys, protected firmware).
- Test the device's performance in the real world and assess the accuracy of the GPS and battery life of the device.

LITERATURE REVIEW & MARKET RESEARCH

RFID/NFC	Cellular	Wi-Fi	Bluetooth	LoRa
				
Benefits: -Tag are inexpensive -Scanners are capable of detecting multiple tags at once -Management systems available to monitor inventory	Benefits: -Large tracking coverage by utilising existing cellular systems -Server based managements systems	Benefits: -Fast data rates -Great for local area asset tracking -Can rely on existing Wi-Fi infrastructure within the business	Benefits: -Whilst Bluetooth has a limited range on its own, successful application like the apple airtag covers a much larger area	Benefits: -Designed to be utilised with low power IoT devices -Resistant to interference -Can integrate with LoRaWAN to increase coverage
Drawbacks: -RFID tags need to be manually scanned by the user -Only suitable for inventory management with constant physical access to items of interest -Limited range	Drawbacks: -Each tracking tag will need to have cellular connectivity -Expensive -Subscribe to local networks -Not very power efficient	Drawbacks: -Coverage will extend to the range of the access points -Relies on existing Wi-Fi infrastructure/networking -Power efficiency for battery powered devices isn't ideal	Drawbacks: -To achieve a large coverage it must utilise existing infrastructure -Limited range	Drawbacks: -Coverage of 100M LOS -Low data rates -Relies on other systems to have wide coverage range -Compatibility issues between different models

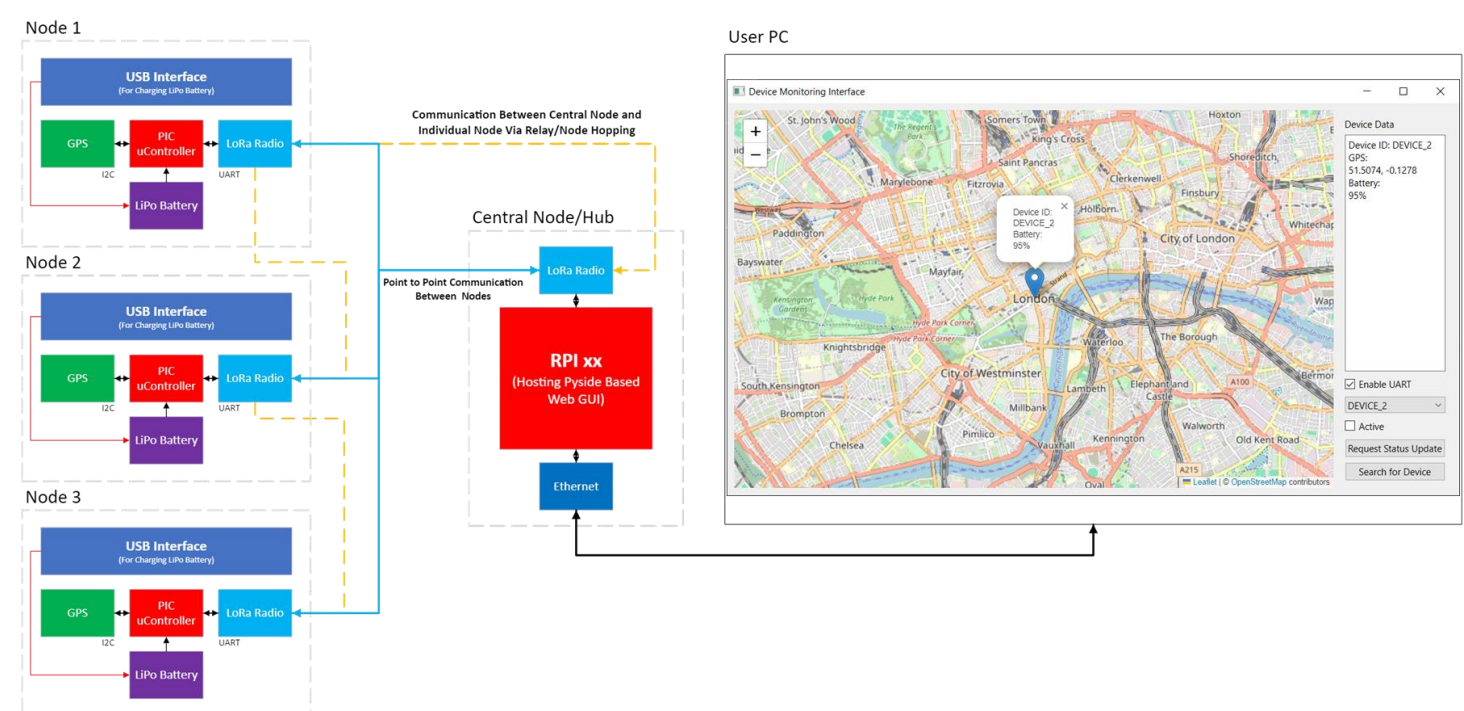
Initial research was carried out on the most appropriate wireless communication protocol that would fit the requirements of this project, with the table above summarising the benefits and drawbacks of each technology and highlighting why LoRa is the most suitable.

SenseCAP Card Tracker T1000-E for Meshtastic	TRACKPAC Mokosmart-LW006	AllIoT - LoRaWAN GPS Tracking PoC Kit	Milesight - LoRaWAN GPS Tracker
			
Benefits: -Small in Size, Long battery life, -LoRaWAN compatible	Benefits: -Small, Long Battery life, -LoRaWAN, Waterproof, SOS button	Benefits: -Small, Long Battery life, -LoRaWAN, WiFi, Bluetooth, GPS	Benefits: -Small, Long Battery life, -LoRaWAN, WiFi, Bluetooth, GPS
Drawbacks: -Designed to work around meshtastic	Drawbacks: -Only Works on LoRaWAN	Drawbacks: -Requires LoRaWAN gateways for operation	Drawbacks: -Requires LoRaWAN gateways

Market research into existing LoRa-based tracking solutions highlighted many benefits towards using the LoRa protocol. These include small, lightweight designs, low power consumption, and compatibility with alternative wireless protocols. However, the main drawback across all these products is that they can only achieve these long-range figures because they rely on LoRaWAN connectivity.

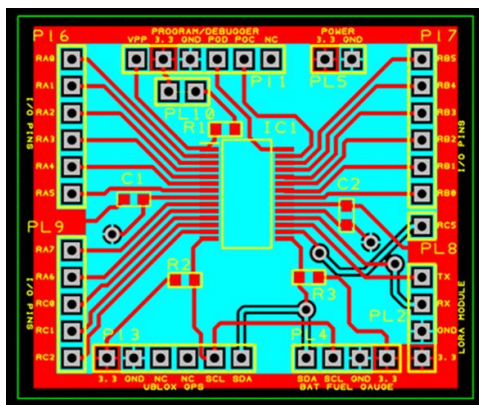
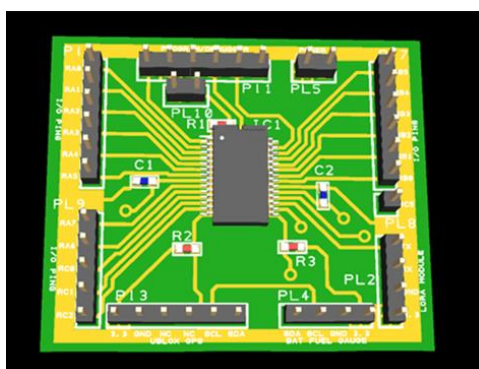
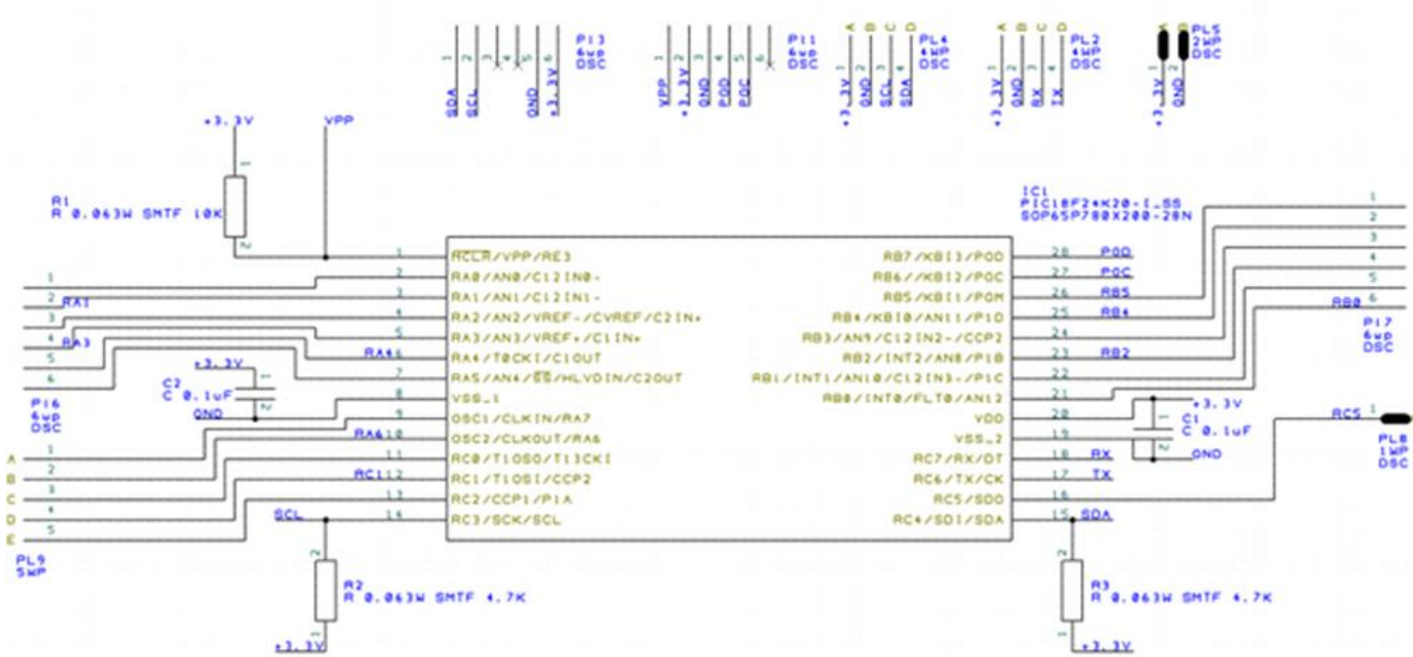
SYSTEM DESIGN

The work achieved on this project will help mitigate the issues observed in the literature review. The key limitations of current asset management systems are that they rely on existing infrastructure for long-range communication and are costly. This project aims to reduce the complexity, cost, and power consumption of the system while providing a product that can be deployed anywhere.



The system design for the asset tracking includes a central node that hosts the Python-based GUI, tracking nodes, and a user PC that interfaces with the whole system over a remote desktop connection.

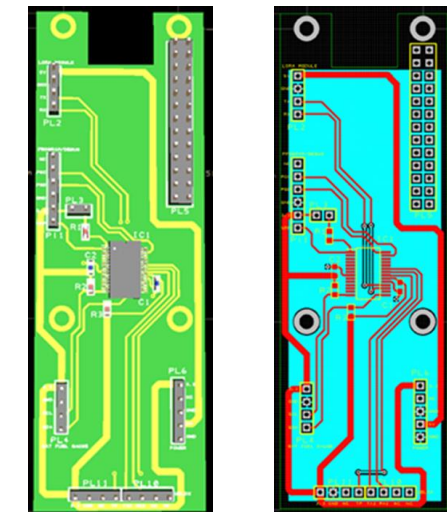
INITIAL & FINAL PROTOTYPE DESIGN



The schematic design for the initial prototype/test PCB was designed specifically for testing the microcontrollers, with the following features:

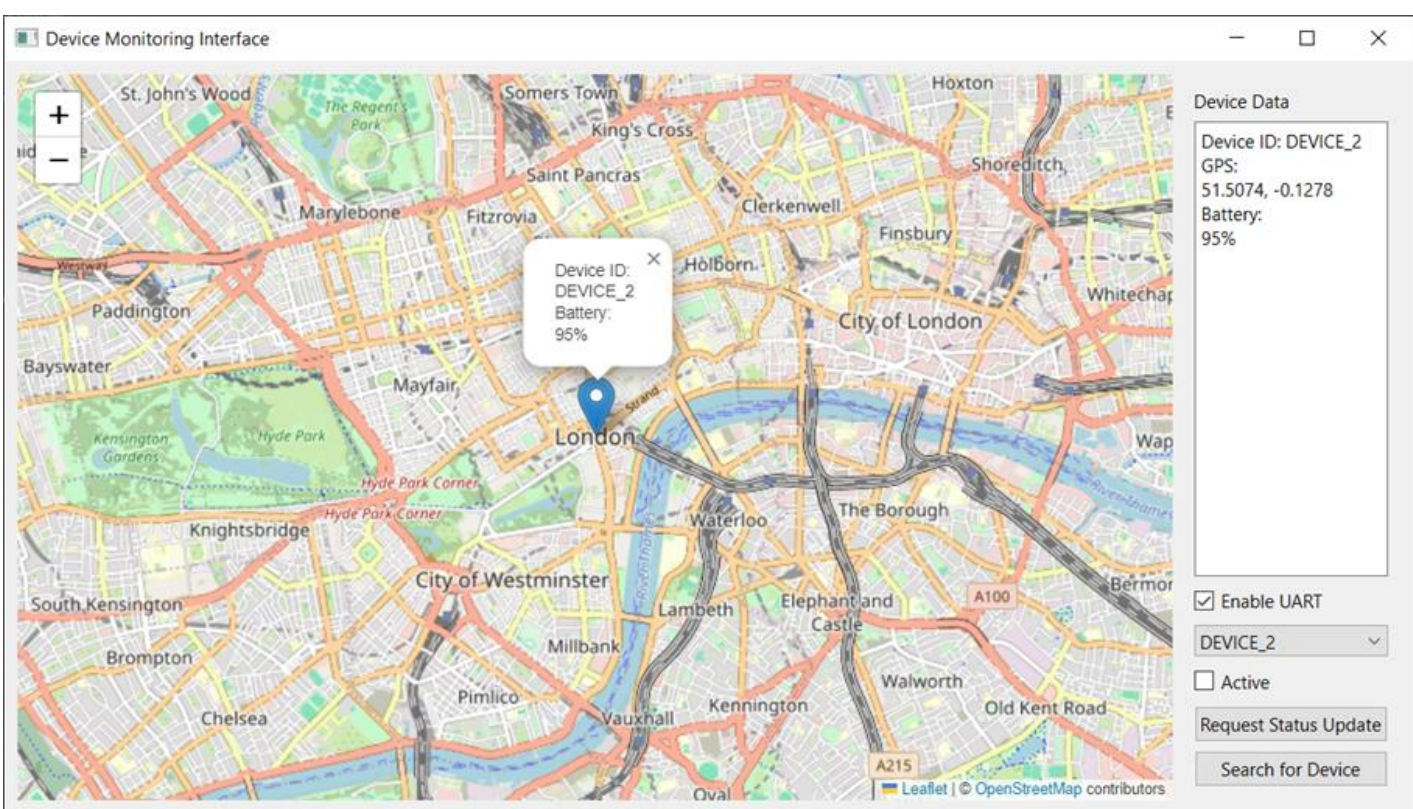
- Power delivery
- Programming
- I2C communication
- UART communication

The PCB design (on the left) was then developed to validate that the microcontroller could be programmed, powered, and communicate with the various modules.



The tracking node was then designed as a fieldable device, including component layout and case design. At this stage, most attention was focused on the layout of the pin headers to fit with the various modules inside the case.

GRAPHICAL USER INTERFACE



Python-based GUI utilising the following libraries:

- PySide6 (GUI)
- Offline Folium (Map)
- IO (Communication via serial ports)

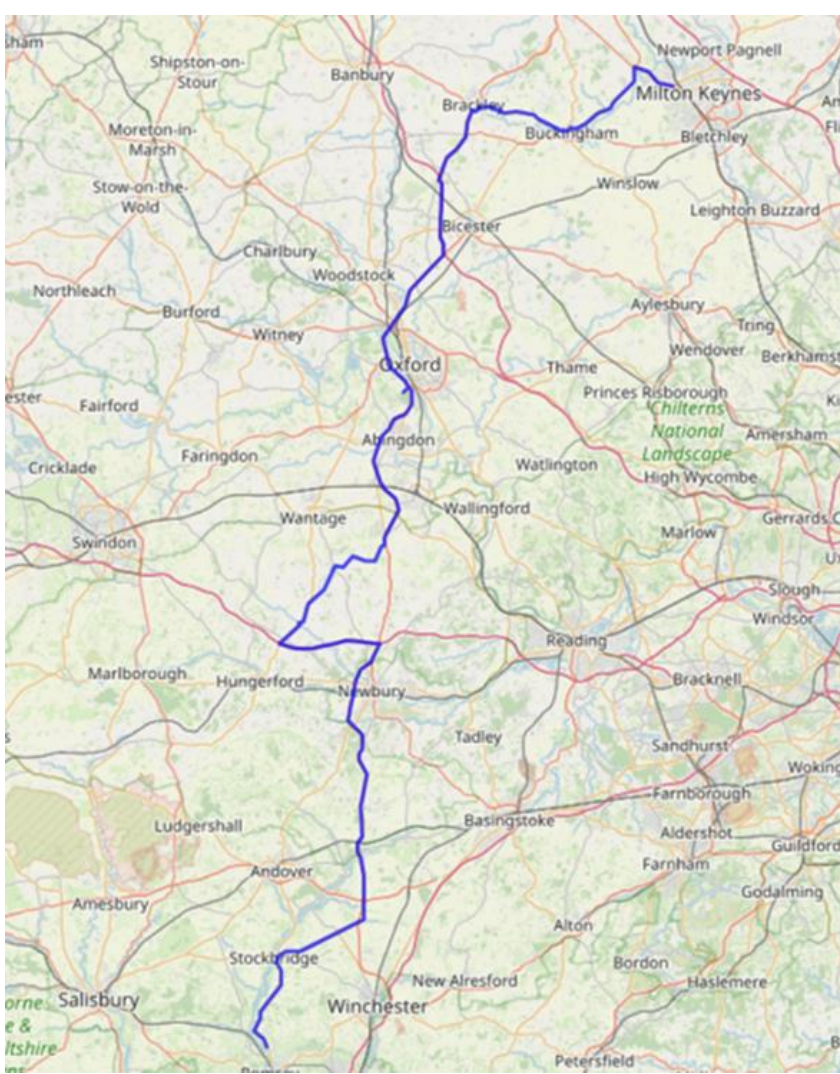
This GUI was developed alongside the initial designs to provide a simple interface to control and monitor the nodes in the system. The interactive map will plot the device's location on a map with the identifier and battery percentage within a pop-up window.

FINAL PROTOTYPE ASSEMBLY



The parts were assembled within the 3d-designed and printed case with the battery and battery monitor in the lower layer. The next layer is the LoRa radio module and power distribution board, and the final PCB is mounted directly on top using the pin headers and screws to secure it. The button is connected between the battery monitor and the power distribution board, enabling the device to turn on and off.

TESTING



The results show that the tracking node is more than sufficient for tracking performance. The map clearly shows the route taken on the trip and proves that the tracking node can reliably track for over three hours.

- Normal operation achieved 33.5 hours.
- GPS power saving achieved 42 hours.
- Power saving & 60-second intervals achieved 81.5 hours.

CONCLUSION & RECOMMENDATIONS

In conclusion, the designed system was successful as it could communicate with all the tracking nodes, had accurate tracking, was power efficient and displayed the data on an easy-to-use GUI. The product meets the requirements stated at the start of the report and is a functioning prototype.

Whilst the design of the system was successful and the tracking nodes operated within the requirements outlined at the start of the report, some recommendations can be made for future iterations:

- Reduce the size of the tracking nodes
- Reduce the size of the data packets being sent
- Implement a crypto engine to handle encryption
- Implement measures to prevent misuse of the device
- Implement more power-saving measures
- Implement relay capability to extend overall range