The Talking Mailbox

2907 Sensors and Actuator Networks

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1 Introduction

1.1 Problem Statement

All Professors and Lecturers have a lot to do and may not always have time to check their mailbox. Imagine how long some letters are left in the mailbox for days just because a professor is busy. On the other hand, checking your mailbox only to find nothing is quite frustrating. What if there was a way that your mailbox could tell you when there is mail? What if you had a talking mailbox?
To solve this problem, we introduce **The Talking Mailbox**. The aim of The Talking Mailbox project is to design and assemble a system that can detect the presence of mail within a mailbox in Building 06 and notify the owner of the mailbox.

1.2 Literature Review

1.3 Project Plan

1.4 System Concept

1.4.1 Functional Requirements

For The Talking Door to be a satisfiable product, the following functional requirements must be implemented:

- It can detect if the mailbox is opened.
- It can detect light as a redundancy for confirming the opening status of the mailbox.
- It can detect whether or not mail is present within the mailbox.
- It can communicate if mail is in the box to a website / dashboard (based on LoRaWAN).
- It alerts the responsible person via email or dashboard upon mail detection.
- It can check the battery status.
- It sends battery status updates to a website at regular intervals.
- It sends a low battery warning to a website when the battery falls below a defined threshold.

1.4.2 Technical Requirements

For The Talking Door to operate and perform its functions, the following technical requirements must be implemented:

- The weight sensor can detect a change in weight of approximately 20 g. This indicates when a piece of mail has been placed within the box.
- The tilt sensor can detect the rotation of the post box lid. This indicates when the lid is opened.
- The LDR can detect the change in light intensity by a defined threshold. This indicates when the lid is opened.
- The transmitter can reliably connect and communicate via the LoRaWAN Gateway.
- The server with which the LoRaWAN communicates can send emails to relevant personnel about the mail.
- The power supply is a battery with a working voltage of 3.1 V to 5.5 V.
- The enclosure can protect the system within a typical indoor environment (IP 31).
- The system should function at temperatures ranging 0–40°C and humidity 10–90%.

1.4.3 Project Requirements

For The Talking Mailbox project to produce a functional product upon close out, the following project requirements must be met:

- The budget is 100€.
- The project workload is estimated at 100 h.
- The project schedule adheres to the following deadlines:

Pitch:	2025-10-21
Bill of Materials:	2025-10-23
Schematic Design:	2025-11-23
Project Implementation:	2025-12-19
Project Report:	2026-01-05
Project Presentation and Demo:	2026-01-17

2 Theoretical Background

Before starting with actual project, some theoretical framework is required.

2.1 Communication

As for the communication, this project used LoRa as the communication encoding and LoRaWAN as the MAC Protocol.

2.1.1 LoRa

LoRa (**Lo**ng **Ra**nge) is the physical layer and is a modulation technique which allows for wireless communication. It is able to send information long ranges, with relatively less energy. It is derived from Chirp Spread Spectrum (CSS). It encodes information similar to how bats/dolphins communicate. LoRa is used extensively with sensors and actuator projects for the following reasons:

- Low power consumption
  - Transmitting: 10 mA
  - Sleep: 100 nA
- Long range → upto 15 km
- Robust against interferences

There are many more reasons as well, but these are the primary which were kept in mind for selecting it for this project.
LoRa works on a license free frequency range, in Europe this is EU868 (863–870/873 MHz). This will be used in this project (Precisely: 868.1 MHz).

2.1.2 LoRaWAN

LoRaWAN (**LoRa W**ide **A**rea **N**etwork) on the other hand is the data link layer on top of LoRa. It defines the communication protocols and architecture. After the initial release in January 2015, many versions have been released, with latest being 1.0.4 (Series 1.0) and 1.1 (Series 1.1) being released in October 2020 and October 2017 respectively. (Yes, 1.0.4 is newer than 1.1). The version used in this project is 1.0.4, for reasons which will be explained later in Section 4.1.2.
Figure 1, shows how LoRa and LoRaWAN differ and work together.

2.2 Sensors

This project used 3 sensors, their functioning has been briefly described below. This framework is essential to understand the design choices made in this project in Section 3.2.

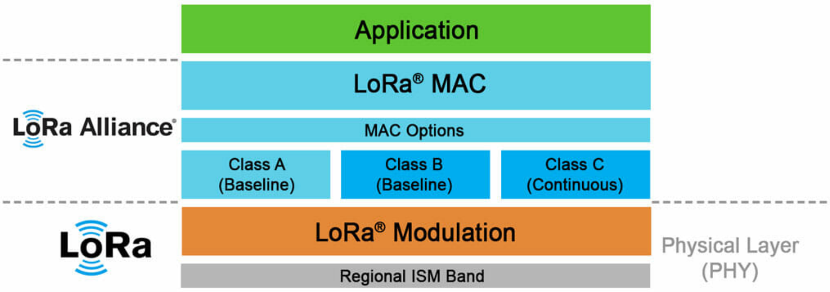

Figure 1: LoRa and LoRaWAN

2.2.1 Load Cells

Load Cells are the primary sensor for this project and should be able to detect the presence of mail. Load cells are used to measure force, and hence can achieve this task. The specific load cell used in this project, is a strain gauge load cell. Strain gauges in the cell are arranged in a way that applying force changes resistance of the gauges in arranged in a wheatstone bridge and hence send out a voltage. This voltage is very small, and hence must be amplified. This amplification is done with the HX711 board, which makes it readable for the microcontroller (ESP32-S3). More specific details regarding these equipment can be seen in Section 3.2.4.

2.2.2 Tilt Switch

Tilt switch is being used to detect the opening of the lid of the postbox. There are multiple types of tilt switches mechanical (rolling ball/ liquid mercury) or electronic (MEMs). The one used in this project is a mechanical rolling ball switch, due to its lower voltage requirement as well as it being a safer option. The functioning can be demonstrated by Figure 2. Whenever the switch is in a specific orientation the

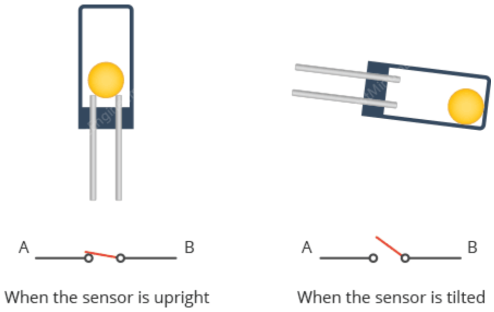

Figure 2: Tilt switch working

ball allows for contact and hence making an electrical connection, else there is no connection.

2.2.3 LDR

A light dependent resistor is just a resistor which varies its resistance based on the light intensity. This can be detected and hence compared to a threshold to check if the box is open or not.

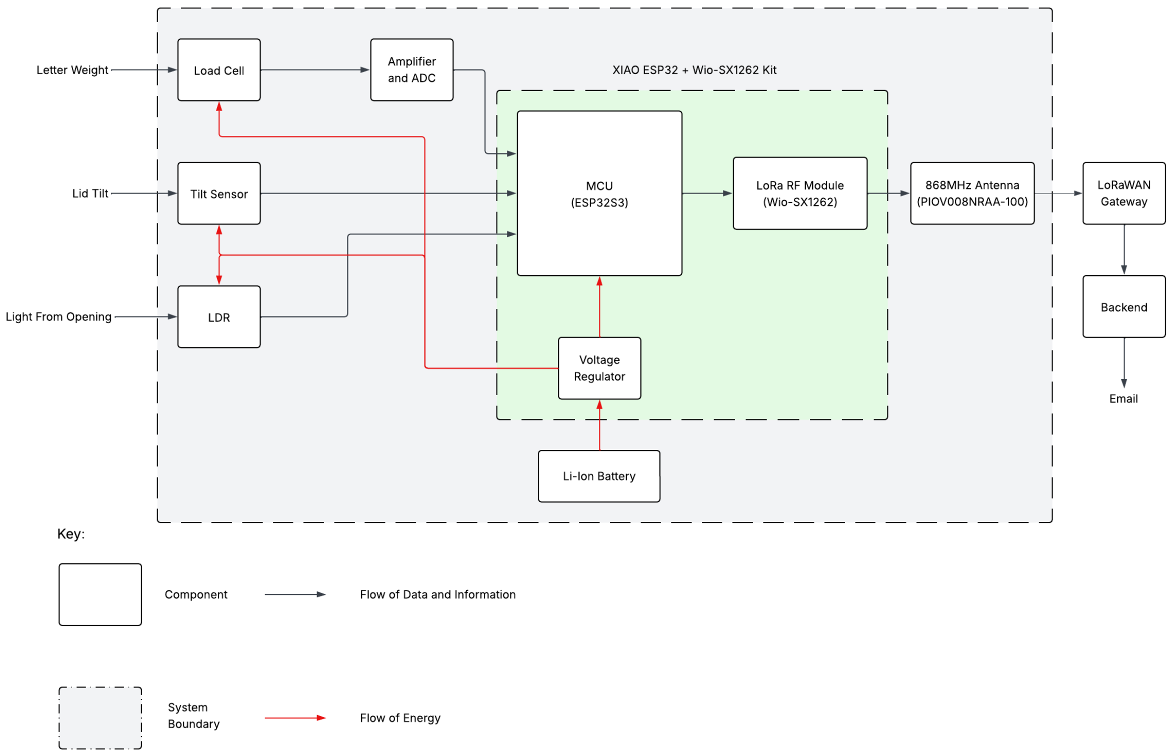

Figure 3: Functional structure diagram of the system architecture

3 Methodology and Design

3.1 Design Approach

3.2 System Design

3.2.1 System Architecture

3.2.2 Schematic Design

3.2.3 3D Design

As understood from Section 2.2.1, to reliably detect any weight, the load cell must be allowed to bent as easily as possible. To prevent any mail from "'missing"' the detection platform, the platform must cover the entire box area. The design which allows us to do this is shown in Figure 4.

(a) 3D Model of Load Cell Arrangement *(b) Platform for mail detection*

Figure 4: 3D Model of detection platform

The height with the hex nuts, allow the load cell to have clearance to bend during load from the upper platform. The off center screw platform on both platform allow for best readings from the load cell.

The size of the upper platform should match the post box size, however the lower platform allows for flexibility, it can be made just large enough to not cause toppling over and allow us to place necessary modules (such as the HX711).
Some other design considerations include the requirement of the platform being rigid and lightweight, to allow load cell to be as sensitive as possible. A good material to use for the platform is wood. The screws should also be flat with the platform, to prevent mail from tearing / getting stuck. Keeping all these design considerations in mind, the following final product can be seen in Figure 5.

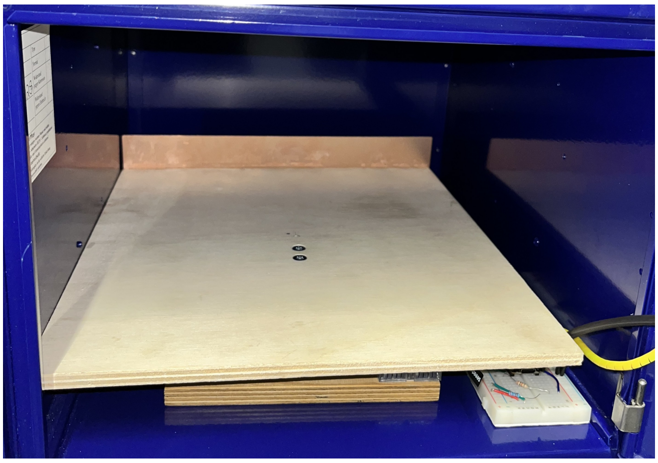

Figure 5: Final product inside the post box

3.2.4 Bill of Materials

This is an estimate of the materials required to make this project, these are all over estimates, as all components/materials except 2.1 - 2.6 were used from the university stock.

Item	Part	Description	Qty	Notes	Price (€)
1.0 Mechanical Components					
1.1	Top Plate	Detection Plate	1	Wood (40x30x0.5cm)	5.00
1.2	Bottom Plate	Base for load cell	1	Wood (15x15x0.5cm)	3.00
1.3	M4 Screw	Top plate screw	2	-	1.00
1.4	M4 Hex Nut	Height spacer nut	4	-	0.50
1.5	M5 Screw	Bottom plate screw	2	-	1.00
1.6	M4 Hex Nut	Height spacer nut	4	-	0.50
2.0 Electrical Components					
2.1	Load Cell + HX711	Load cell + Amplifier module	1	JOY-IT	6.40
2.2	Tilt Switch	Ball tilt switch	1	IDUINO	0.94
2.3	LDR	Light resistor	1	SERTRONICS	1.35
2.4	Battery	1800 mAh Li-Ion	1	SOLDERED	10.24
2.5	MCU + LoRa	Xiao ESP32 + SX1262	1	Seeedstudio	11.68
2.6	Antenna	Longer antenna	1	Amphenol-SAA	2.69
2.7	– kOhm resistor	Through Hole	1	YAGEO	0.10
2.8	– kOhm resistor	Through Hole	1	YAGEO	0.10
2.9	Wires	Jumper wires of different length	-	-	0.30
				Tax (VAT 20%)	8.96
				Grand Total (€)	**53.76**

Table 1: Combined Mechanical and Electrical Bill of Materials with Total Cost

3.3 Validation Method

4 Results and Implementation

4.1 Implementation

4.1.1 Backend Implementation - Application Layer

The LoRaWAN is able to send the bits to The Things Network. However for these to be actually useful to the user they must be decoded and used to represent relevant information for a user, this includes the mail status, the battery and which post box it is. For this first a payload decoder must be made. This is made keeping in mind how bits were encoded in the first place. The decoder can be seen in Code 1

```
function Decoder(payload, port) {
    if (payload.length < 4) {
        return [
            { field: "ERROR", value: "Payload too short or empty" },
            { field: "RAW_HEX", value: payload.map(function(b){return ("0" + b.toString(16)).
        ];
    }

    var id = payload[0];
    id = parseInt(id.toString(16));
    var stateByte = payload[1];
    var valueID = payload[2];
    var val = payload[3];
    var statusText = "Unknown";
    var valueType = "Unknown";

    if (stateByte === 0x04) statusText = "Tampering Alert";
    else if (stateByte === 0x05) statusText = "Heavy Mail";
    else if (stateByte === 0x06) statusText = "Medium Mail";
    else if (stateByte === 0x07) statusText = "Light Mail";
    else if (stateByte === 0x08) statusText = "No Mail";

    if(valueID === 0x09) valueType = "BATTERY";

    if (id === 0x33) box = "SAN Postbox";
    else box = "Unknown box";

    return [
        { field: "DEVICE_ID", value: id },
        { field: "STATE_CODE", value: stateByte },
        { field: "STATUS_MESSAGE", value: statusText },
        { field: "BOX_NAME", value: box},
        { field: valueType, value: val}
    ];
}
```

Listing 1: Payload Decoder Function for LoRaWAN

4.1.2 Issues

4.2 Validation Results

5 Discussion

5.1 Product Evaluation

5.2 Potential Improvements

6 Conclusion

6.1 Project Summary

6.2 Future Work

Appendix