POLITECNICO MILANO 1863

SCUOLA DI INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE

IOT Homework - Exercise 1

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1.1. Connectivity

To satisfy all the requirements across both a $500\,\mathrm{m}^2$ underground warehouse and a $1\,\mathrm{km}^2$ outdoor yard, we selected **LoRaWAN** as our communication protocol.

The main reasons for this choice are:

- **Coverage**: two LoRaWAN gateways (one mounted indoors and one outdoors) are deployed to provide connectivity across both areas. The indoor gateway ensures coverage within the underground area. The outdoor gateway is expected to cover most of the $1\,\mathrm{km}^2$ yard. If testing reveals blind spots or weak signal areas, additional gateways can be added to improve coverage
- **Resilience**: two LoRaWAN Network Servers are deployed to provide fault tolerance
- **Cost efficiency**: each forklift node costs approximately $12 and each gateway around $150; combined with the absence of recurring SIM or subscription fees, this makes the solution affordable and scalable
- **Scalability**: LoRaWAN facilitates horizontal scaling by simply adding new gateways or registering new end devices as needed

Each forklift transmits a single packet every 5 seconds containing:

1. GPS coordinates (latitude, longitude)
2. Odometer reading (cumulative distance)
3. Speed measured during the 5-second interval
4. Impact count (number of shocks above a 2g threshold in the 5-second interval)

1.2. Forklift Hardware

Each forklift is equipped with a LoRa transceiver and an ESP32 microcontroller which handles sensor data acquisition, processing, and transmission over LoRa.

Each forklift is also equipped with the following sensors:

- **GPS Module**: for outdoor positioning of the forklift
- **Wheel Encoder**: for indoor positioning of the forklift, speed and travelled distance measurements
- **Accelerometer**: for impact detection

The GPS is used for outdoor tracking, while the wheel encoder maintains positioning and speed information when GPS signals are unavailable indoors.

1.3. Backend Architecture

Sensor data from each forklift is sent through the following path:

1. The ESP32 on each forklift collects data every 5 seconds from the onboard sensors and transmits it over LoRaWAN
2. A nearby LoRaWAN gateway (either the indoor or outdoor unit) receives the packet and forwards it to a LoRaWAN Network Server
3. The LoRaWAN Network Server handles packet security, and then forwards the processed data via an HTTP GET request to the ThingSpeak API
4. ThingSpeak receives, stores, and visualises all of the data through individual dashboard channels dedicated to each forklift

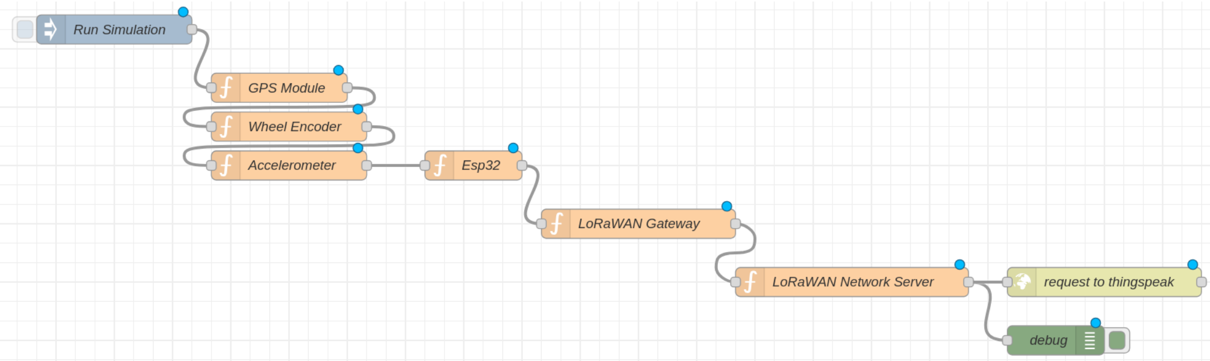
The system is resilient thanks to network servers that ensure continuous operation. Using ThingSpeak eliminates backend maintenance, as it handles data storage and visualisation out of the box. The architecture is also highly scalable: adding new forklifts only requires device registration and dashboard setup.

1.4. Forklift Pseudocode

```
// ---------------------------------- GLOBAL VARIABLES
const G_THRESH = 2.0;        // g-units above which count as impact
int odom_last = 0;           // last odometer reading
int shock_count = 0;         // number of shocks since last send

// event handler for the accelerometer measurements
void onAccelSample(x, y, z) {
    if (abs(x) > G_THRESH || abs(y) > G_THRESH || abs(z) > G_THRESH)
        shock_count += 1;
}
// ---------------------------------- SETUP
void setup() {
    Serial.begin(115200);
    initGPS();
    initLoRa();
    initAccel(onAccelSample);
    initOdometerSensor();
    odom_last = readOdometer();
}
// ---------------------------------- LOOP
void loop() {
    // read from sensors and compute payload values
    gps = readGPS(); // {lat, lon}
    odom = readOdometer();
    dist = odom - odom_last;
    odom_last = odom;
    speed = dist / 5.0; // m/s over the last 5 s
    // grab and reset impact count;
    impacts = shock_count;
    shock_count = 0;
    // build and send payload
    payload = pack(
      gps.lat,
      gps.lon,
      odom,
      speed,
      impacts
    )
    LoRa.send(payload);
    // sleep for 5 seconds
    sleep(5000);
}
```

1.5. System Block Diagram



The flow components are:

- `GPS Module`: function block that simulates the collection of the location of the forklift
- `Wheel Encoder`: function block that simulates the collection of the location, speed and travelled distance of the forklift
- `Accelerometer`: function block that simulates the collection of the impact data
- `Esp32`: function block that simulates sending the sensor's measurements via LoRaWAN to a nearby LoRaWAN gateway
- `LoRaWAN Gateway`: function block that simulates a LoRaWAN gateway, forwarding the payload to the appropriate LoRaWAN network server
- `LoRaWAN Network Server`: function block that simulates a LoRaWAN network server, responsible for forwarding the sensor's data via an HTTP GET request to ThingSpeak
- `request to thingspeak`: http request block that simulates the actual GET request sent to the ThingSpeak API to save the data and display it on ThingSpeak dashboards