IOT 2024-'25 final project: Smart Parking Reservation

Introduction

The project aims to offer the following service: a parking reservation system accessible through a responsive web application.
It includes two main types of components related to the IOT domain: **locks** and **gateways**.

- **Locks (left image)**: Devices resembling platforms with a mechanical arm (orange in the picture) that raises and lowers based on received commands. They are installed directly on individual **parking slots** and used to reserve them by physically blocking or allowing access with their arm.
- **Gateway (right image)**: Devices that send commands to the locks and retrieve their status. They contain a 433 MHz RF antenna, enabling two-way communication with the locks.

Each **parking lot** consists of multiple **parking slots**, and a lock is installed on each slot. These locks include several internal components:

- A **magnetic sensor** to detect the presence of a vehicle,
- A **small speaker** to emit an alarm in case of tampering,
- An **internal battery** that powers the device for several years, and
- A **mechanical arm**, as mentioned above, operated by an internal motor.

A **single gateway** is typically installed per parking lot, to manage all the locks by sending commands and collecting data. In addition to the RF antenna, the gateway features two Ethernet ports, allowing it to be accessed and managed via an internal portal with secure authentication.
These devices were provided by an external manufacturer, together with the needed documentation including their specifications and usage instructions.

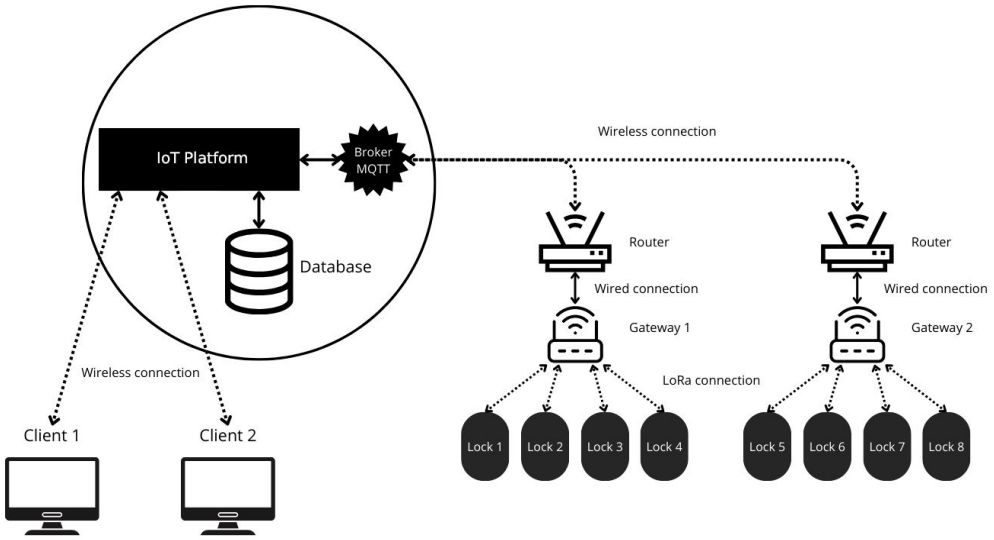
Adopted Protocols

The protocols and technologies used within the project are:

- **LoRa (Long Range) technology**: This spread spectrum frequency modulation is typically used for IoT systems, and enables communication with devices over long distances (from 5 km in urban areas to more than 10 km in rural areas), with a reliable connection which is resistant to noise. LoRa allows communication even inside buildings and has very low energy consumption, which signifcantly contributes to the long battery life of the locks. The communication protocol **LoRaWAN** is used for communication between locks and gateways.
- **MQTT (Message Queuing Telemetry Transport) protocol**: This protocol is used for the connection between the gateways and the IoT platform.
  All information is exchanged in JSON format, and four main types of topics are used:

  "/ID_gateway/up_link": Used for publishing information on the changed status of the locks associated with a gateway. Locks can be in the following statuses: reserved, occupied, free (neither reserved, nor occupied), out of order.
  "/ID_gateway/down_link": Used to send commands to the locks associated with a gateway.
  "/ID_gateway/down_link_ack": Used to acknowledge a command sent to a gateway.
  "/ID_gateway/heartbeat": Used for periodically publishing heartbeats of the gateways and associated locks to monitor their correct functioning.

Below is a diagram of the project structure:



Use Case Example

Alice wants to book a parking slot before reaching her destination by car. She logs into the web app and views a map displaying available slots near her area of interest. The web app is responsive, allowing her to access it conveniently on her smartphone. After selecting the desired slot, she enters the necessary reservation details, including her car's plate number and the duration of the reservation.

Once the reservation is confirmed, the corresponding lock raises its arm to prevent other users from parking in the reserved slot. Guided by the map, Alice drives to the parking slot and notifies the application upon arrival. The lock then lowers its mechanical arm, allowing her to park, and the device switches to the "occupied" status.

After Alice leaves the parking slot, the device automatically switches to the "free" status. If Alice's reservation expires before she reaches the parking slot or before she extends her reservation, the lock's arm lowers automatically, and the device switches to the "free" status.

Possible improvements

Some possible improvements are listed below:

- When booking, the license plate number of the car that will occupy the space is requested, but no verification is performed. Although more expensive in terms of energy consumption and budget, this could be implemented by using a camera installed on the lock and an Automatic Number Plate Recognition algorithm.
- Instead of verifying that the actual car is approaching the parking slot, a simpler and cheaper solution could be adopted to check that users have actually reached the parking slot by using the GPS coordinates of their smartphone.
- The magnetic sensor inside the locks could cause problems since anyone could place something metal on top of them. A solution would be to also insert a proximity sensor to increase precision and verify whether there is a car or not on top of the device.

Implementation Simplification

Unfortunately, most of the low-level details of the project cannot be implemented due to practical constraints. Therefore, both gateways and locks need to be simulated using software, with a standard Wi-Fi or mobile network connection.