Parking Reservation System

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Introduction

Objective:

We have all been in situations where we find ourselves driving aimlessly looking for public parking or having to park out of the way because no spots are available. This problem gets worse as cities grow—drivers in London spend an average of almost eight minutes looking for parking every day[1]. In the US, after accounting for time, fuel, and emissions, drivers lose over $70 billion[2] annually while looking for parking. Additionally, users often overpay for their parking spot. The average driver in the US spends "eight times more a year overpaying for parking than they do in parking tickets"[2]. These issues stem from not having a comprehensive system for parking that allows a user to effectively find available spots or to know that a spot will be saved for them on arrival.

Our solution is a comprehensive parking system that allows users to easily gauge the parking availability in a certain area before they start driving or simply reserve a spot ahead of time for a set window. Instead of having to deal with coin payment, garage systems, or blocked-access parking lots, the system will rely entirely on a parking meter and a companion app. Users will also have a choice to receive an RFID tag they can use to streamline their parking process.

Users will have two choices:

1) They can reserve a location ahead of time for a set window. On the day of their reservation, they can arrive at the lot, knowing they will have prepaid parking for the duration that they have selected.
2) They can also use the mobile app to find open parking spots. This functionality preserves the use of open, pay as you go parking locations, except it adds two additional features. Users can find parking spots quickly and easily on the map, thereby reducing time they spend driving while looking for a spot. Additionally, users will only be charged when they leave, preventing users from either overpaying for the spot or having to return to the spot to feed more time into the machine.

Background:

Some parking reservation solutions exist, such as SpotHero, where a user can prepay to park at a parking garage of their choice. Users, however, don't know exactly which parking spot they will be parking in and sometimes drive through multiple floors before finding an open spot. Users might also accidentally park in a spot that is reserved for other purposes, as is the case with garages that are shared with businesses, and end up getting towed.

In addition, there are some public garages have signs that display parking availability. Again, in this case, users do not know exactly where the open parking spots are, so users may waste time searching for them. Public parking garages generally have central payment points where users pay before they return to their cars, or users pay as they exit. Both of these methods result in time wasted and an overall inefficient payment process.

Our solution is efficient, as we assign spots. This results in less confusion and wasted time and effort. It also gives users the peace of mind knowing that they are parking in a legal spot from which they won't get towed. Finally, our reservation and meter system allow users to make payments painlessly, thereby improving the overall parking process significantly.

High Level Requirements:

- Each parking meter should be able to:
    - Communicate through an onboard screen and LED array the status (i.e open, reserved, paid, unpaid) of its parking spot
    - Use a proximity sensor to detect a parked car vs. open spot
    - Connect to the hub unit in the parking lot to communicate and receive data
- The hub unit should be able to:
    - Connect the backend logic and database with each of the meters in the lot
- The backend should be able to:
    - Communicate with the hub unit to store information on the open/parked spots and send reservation status of spots
    - Store account information for each user (including RFID tag info)
    - Aggregate all reservation information and use it to efficiently assign spots for reserved users, while also leaving spots available for open parking
    - Process all parking payment transactions

Design

Our parking reservation system requires five functioning subsystems to work together:

Power Supply

This subsystem will power all of our components with the appropriate voltage to function properly.

Mains Supply

For the scope of this class, our main power source will be a wall outlet. In real world deployment, this system will likely be given electrical wiring from power lines.

Requirement: Must provide a 120V output to power other components in this module

Voltage Regulator

The purpose of the regulator is to alter the voltage from the main supply to the desired voltage for the individual components.

Requirement: The voltage regulator will need to take input from a 120VAC wall outlet and output both 5V (+/- 5%) and 3V (+/- 5%).

Requirement: Power 3 meters and a hub for the purposes of this demo.

Parking Meter

The parking meter contains a microcontroller, WiFi module, RFID module, proximity sensor, and LCD screen, and is the main hardware component in this system.

Controller

We will be using an ATMEGA328 microcontroller to control all of the components onboard the meter

Part: https://www.microchip.com/wwwproducts/en/ATmega328

Requirement: Support the multiple UART communications we'll need to make with the RFID reader and the WiFi chip

Wifi Module

We will use a ESP8266 WiFi module for our project. With it, we can connect the meter to the hub unit to send sensor readings and receive commands.

Part: https://www.sparkfun.com/products/13678

Requirement: Take 3.3V power via voltage divider

Requirement: Communication through UART

RFID Module

We will be using and RFID Reader accompanied with RFID tags that come pre-programmed with a unique 32-bit ID for user verification.

Part: RFID Reader(ID-12LA) : https://www.sparkfun.com/products/11827

Part: RFID Button(32-bit, 125 kHz) : https://www.sparkfun.com/products/9417

Requirement: Take 3.3V(+/- 10mV to maintain accuracy) linear power supply via voltage divider

Requirement: Communication through UART

Proximity Sensor

We will be using an Ultrasound Proximity Sensor(HC-SR04) on each parking meter to know whether a car is currently parked in its corresponding parking space based on the sensor's output.

Part: Ultrasound Proximity Sensor(HC-SR04) : https://www.sparkfun.com/products/13959

Requirement: Take 5V(+/- 5%) power supply

Requirement: Accurately output whether a car is parked in respective spot.

LCD Screen

The LCD screen's purpose to display pertinent information to the user regarding the reservation such as time left and whether the user has been verified.

Part: RGB Character LCD(16x2) : https://www.sparkfun.com/products/10862

Requirement: Take 5V(+/- 5%) power supply

Requirement: Display relevant information to the user through color and text

WiFi Hub

The WiFi Hub acts as a wireless access point for the system, allowing the meters in its range to connect to the backend.

Raspberry Pi

The raspberry Pi has its own built-in power regulator, so it will be connected directly to mains supply

Requirement: Connect to local network and provide access point for meters

Mobile App

The mobile app is the primary user interface for this system. With this, users can interact with the system and get their parking information anywhere.

Requirement: Users will be able to make/view reservations

Requirement: Users will be able to check in/out to meters

Backend

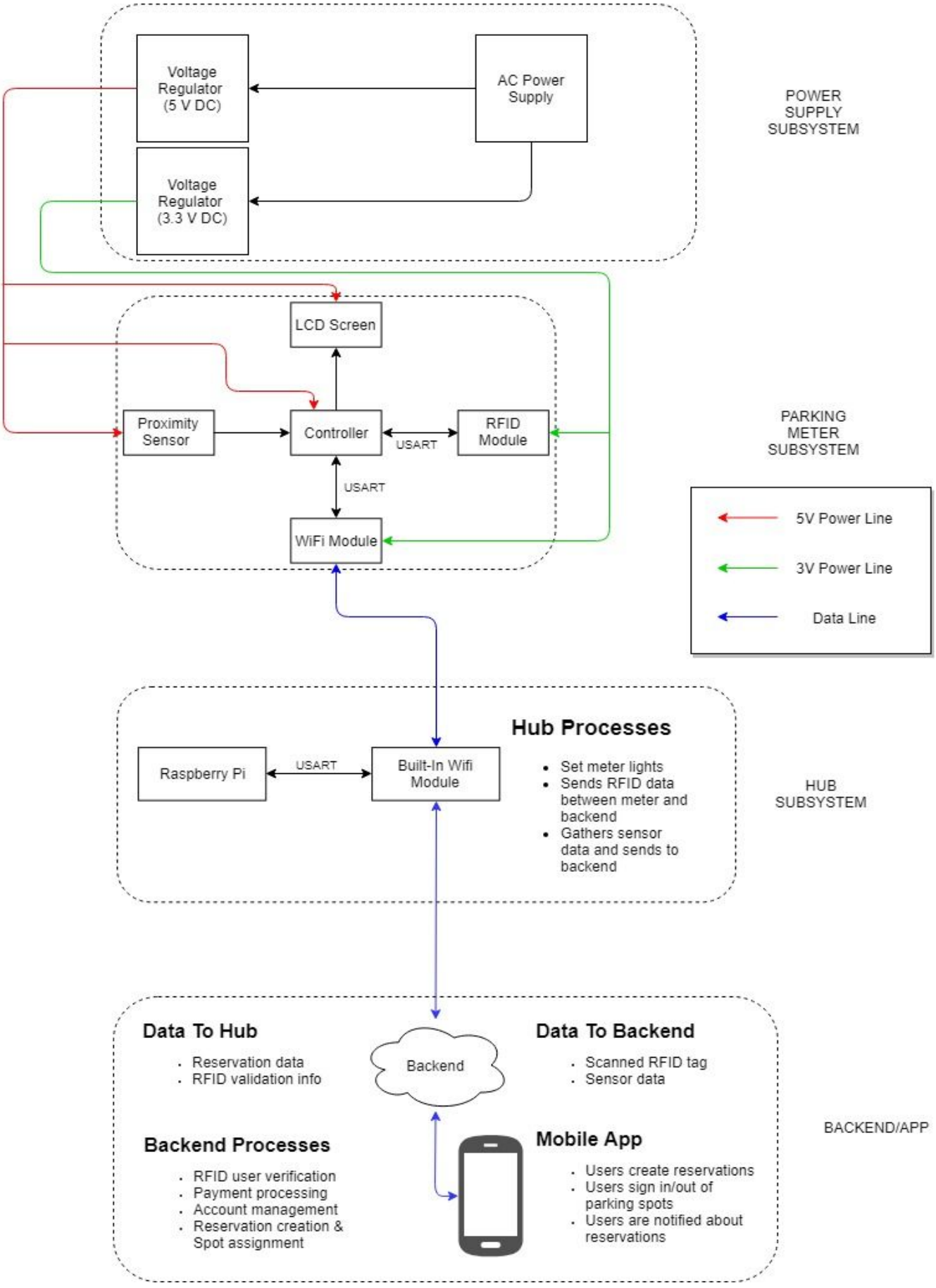
The backend is the location of all parking, reservation, and account data and the source of all commands to the parking meters. From here, the entire system can be controlled remotely.

Requirement : Take all reservations for the next day and combine them into as few spots as possible

Requirement: Store all reservations

Requirement: Remotely authorize and charge users

Requirement: Remotely send commands to the parking meters


Voltage Regulator (5 V DC)
AC Power Supply
Voltage Regulator (3.3 V DC)
POWER SUPPLY SUBSYSTEM
LCD Screen
Proximity Sensor
Controller
USART
RFID Module
USART
WiFi Module
PARKING METER SUBSYSTEM
5V Power Line
3V Power Line
Data Line
Hub Processes
Raspberry Pi
USART
Built-In Wifi Module
Set meter lights
Sends RFID data between meter and backend
Gathers sensor data and sends to backend
HUB SUBSYSTEM
Data To Hub
Reservation data
RFID validation info
Backend
Data To Backend
Scanned RFID tag
Sensor data
Backend Processes
RFID user verification
Payment processing
Account management
Reservation creation & Spot assignment
Mobile App
Users create reservations
Users sign in/out of parking spots
Users are notified about reservations
BACKEND/APP

Risk Analysis:

The biggest risk to getting our project to meet our high level requirements is the Parking Meter Subsystem. We will have to design a PCB that contains the Proximity Sensor, RFID Module, WiFi Module, LCD Screen, and Microcontroller. The WiFi module will need to communicate with each of the other components to send data to and communicate data from the backend. The fact that we have never worked with these parts before will present a challenge within itself before we work on modifying them to meet our requirements.

We have to be able to work with the RFID Module to be able to accurately verify user parking. This means getting the module to look for the appropriate user RFID code and processing it correctly to ensure a smooth reservation process. The RFID module is an essential component to our project and without it working we cannot verify reservations for our system.

In addition, we have to calibrate the Proximity Sensor such that it gives us an accurate reading as to whether a car is in present in the respective parking space. Given that the Proximity Sensor can read up to range of 4m we will have to make sure that the sensor is not picking up the presence of cars in neighboring parking spaces as well as ensuring the sensor is not reading any passing cars, humans, etc. Getting this calibration right is essential to our project as we cannot have a functioning reservation system without being able to accurately know whether a car is currently parked in a spot.

Safety and Ethics

Physical Safety:

As stated in the IEEE Code of Ethics[3] #1, our first goal is to ensure the health and welfare of the public. First and foremost, we will need to address physical safety concerns for our system. As our meters and hub unit will be placed in outdoor locations, they will need to be resistant to weather elements. We will place all components in a waterproof case that adheres to IP67 standards[4]. This ensures that our meter and hub units are protected from both dust and water in outdoor use cases. Additionally, another concern that we will need to address is the possibility of mobile phone usage while driving. To combat this, we will have a few different safety features. First, a user who has reserved a spot will be assigned a spot number well ahead of their arrival time, allowing users to ensure that they have all the information they need before they get behind the wheel of a vehicle. Second, much like what navigation apps like Waze do, we will display a safety warning to drivers. While this doesn't fully prevent drivers from using the app when on the road, it is as much as can be reasonably done to deter users from distracted driving.

Data Privacy:

Another issue that is paramount in today's environment is data privacy and security. As stated in the ACM Code of Ethics[5] 1.6, we aim to respect privacy. When a user provides us with their information, they trust that we make good decisions. This trust is not easily given, but very easily broken. In order for this system to be successful, we will need to collect a significant amount of user data. This may include some personally identifiable information (PII) and sensitive payment information. All user data will be encrypted before storage in our databases. We will be using a service such as AWS or GCP to store and process our data, and trust that these services will adequately protect our data from external attacks. Additionally, we will utilize retention limits, and fully anonymize parking location and transaction data once a certain time period has passed.

In addition to the issues addressed above, we pledge to honor and abide by the standards set by the IEEE and ACM. We will follow all laws and safety regulations set by the course as well as the campus as a whole.

References

[1] Sawer, Patrick. "Motorists Spend Four Days a Year Looking for a Parking Space." *The Telegraph*, Telegraph Media Group, 1 Feb. 2017, www.telegraph.co.uk/news/2017/02/01/motorists-spend-four-days-year-looking-parking-space/.

[2] Inrix. "Searching for Parking Costs Americans $73 Billion a Year - INRIX." *INRIX*, inrix.com/press-releases/parking-pain-us/.

[3] "IEEE Code of Ethics." *IEEE - Advancing Technology for Humanity*, www.ieee.org/about/corporate/governance/p7-8.html.

[4] "IP Code." *Wikipedia*, Wikimedia Foundation, 28 Jan. 2019, en.wikipedia.org/wiki/IP_Code.

[5] "The Code Affirms an Obligation of Computing Professionals to Use Their Skills for the Benefit of Society." *Association for Computing Machinery*, www.acm.org/code-of-ethics.