P2P Bikeshare Module

Team 24 - Matthew Daniel and Kanchi Shah

ECE 445 Project Proposal - Fall 2018

TA: Soumithri Bala

1. Introduction

1.1. Objective

Transportation is not only the fundamental problem of getting from point A to point B, but also a method by which to improve society. While existing forms of transportation such as cars and bikes have not changed recently for the vast majority of the world, the way in which we utilize those forms of transportation has seen massive innovation. Over the past few years, rideshare services and companies have transformed transportation and empowered both monetization of existing forms of transportation while also providing transport to those who do not own the requisite form. A common method of transportation on college campuses is the bicycle, an easy to use, affordable, and eco-friendly solution. While many students in college own bikes and use them regularly, far more either do not use their bikes as frequently as they expected, or do not own bikes at all. This gap is partially bridged by services such as Limebike and Veoride [1][3], but the proprietary nature of the service means it does not solve the issue for those who own bikes but do not use them frequently.

We propose a bikeshare lock module which allows the user to monetize their bike by renting it out to those who need one, all through a bluetooth connected smart-lock complete with tracking and anti-theft security measures. We will design the module to be self containing, a single hardware lock which performs all the functions and information necessary to rent out a bike with peace of mind, through communication with a phone application. Through this model, bike owners will be empowered to share their bike with those who need one, while being rewarded monetarily in place.

1.2. Background

The technology for our module is simple and widely used. Bluetooth authentication locks have already been developed, along with anti-theft tampering systems [2]. GPS tracking for bikes has been used extensively by services such as Limebike and Jump [1][3], though these all consist of proprietary bikes, not bikes owned by the user. As a result, while the assembly and design of our system contains many components and will be challenging enough for the course, it is proven that the foundation for this work exists.

1.3. High Level Requirements

1.3.1. Module must contain functioning autonomous locking system

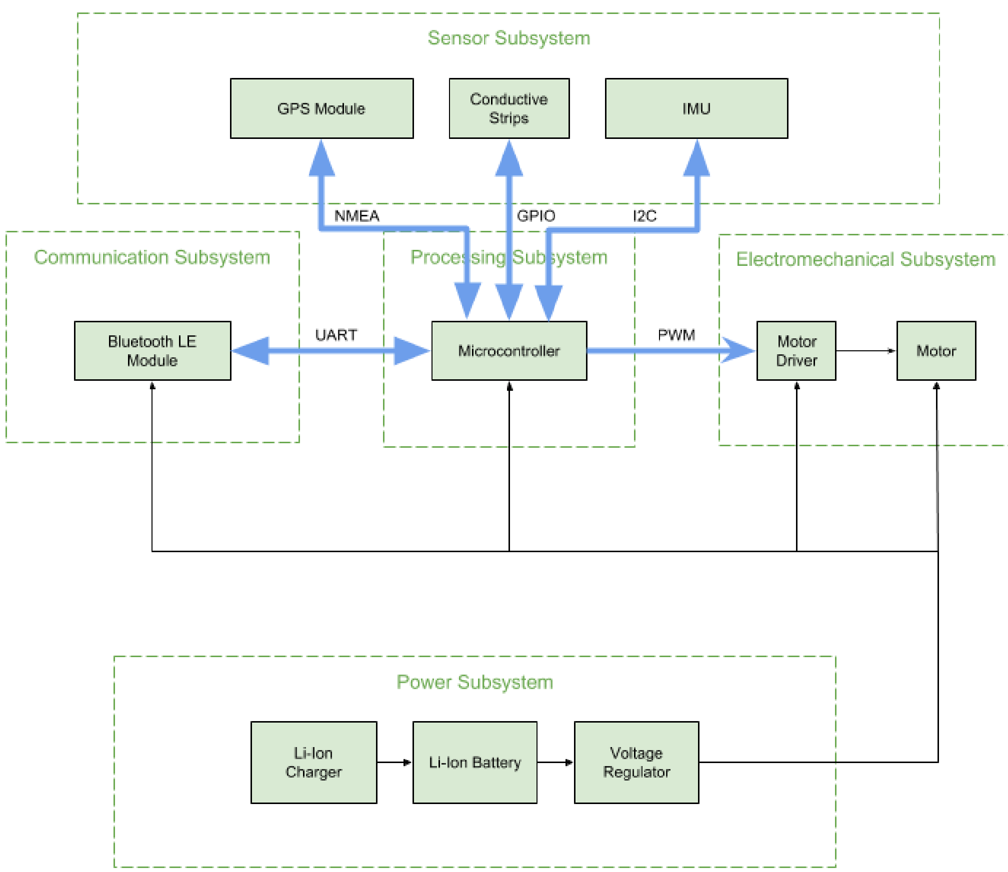
1.3.2. Locking must be as fast as possible, ideal latency less than 1500ms

1.3.3. Module must be able to operate for at least 3 days after one charge

2. Design

Hardware module consists of several subsystems: a sensor subsystem containing a GPS Module, IMU, and Conductive Stripe, a Communication Subsystem consisting of a Low-Energy Bluetooth Module, a Processing Subsystem consisting of a microcontroller, a Electromechanical subsystem consisting of a Motor Driver and Motor, and a Power Subsystem consisting of a Lithium Ion Battery, Lithium Ion Charger, and Voltage Regulator. The Power Subsystem will ensure that the device can operate for 3 days on one charge and supply power to all other subsystems, the processing subsystem will contain the control logic for the entire system, the communication subsystem will be used to communicate with the user's cell-phone app, the electromechanical subsystem contains the elements for the autonomous locking mechanism, and the sensor subsystem contains sensors to provide tracking information, as well as detect if someone is tampering with the lock.

2.1. Block Diagram



2.2. **Sensor Subsystem**

The sensor subsystem is required to collect information on where the bicycle is, as well as if the bicycle is being tampered with. This protects against theft and provides important data on bicycle location.

2.2.1. **GPS Module**

A GPS module is required to provide location information on the bicycle at all times. This is to prevent theft, as well as provide data on where the bicycles are so users can pick them up. This module will be polled every 500ms for location. A GP-20U7 Receiver from Sparkfun has been selected, which will interface over NMEA-0183 with the microcontroller.

Requirement 1: The GPS Module must be able to track the module within 2 meters even at speeds of up to 40 mph.
Requirement 2: The GPS Module should be easily polled at 500ms by the microcontroller over NMEA interface.

2.2.2. **Conductive Stripes**

The conductive strips will simply connect to the voltage regulated source and then be connected to an interrupt pin on the microcontroller. The voltage drop should be enough to trigger an interrupt.

Requirement 1: The conductive strips should shear entirely or experience an electrical break under any force that cracks the casing.

2.2.3. **IMU**

An IMU is required to detect tampering on the physical device itself. Any large spikes in acceleration, signifying tampering, will set off internal alarms and trigger the interrupt signal.

Requirement 1: The IMU should have a 3-axis accelerometer capable of determining sharp vibrations in any orientation.
Requirement 2: IMU should interface with microcontroller over SPI or I2C interface.

2.3. **Communication Subsystem**

The communication subsystem is required to transmit data between the user's cell phone app and the hardware module.

2.3.1. **Bluetooth LE Module**

A bluetooth module is required for communication between the microcontroller and the user's cell phone app, in order to tell the module when to "unlock" and "lock". This module must be able to operate on low energy, in order to meet module size and power constraints.

Requirement 1: Bluetooth module is able to connect to iOS and transfer data between phone and microcontroller.
Requirement 2: Bluetooth module operates over UART interface with microcontroller to send and receive data.

2.4. Processing Subsystem

The processing subsystem is required to handle all of the control logic of this entire system.

2.4.1. Microcontroller

The microcontroller proposed is the Atmega328p, which should be sufficient for the purposes of bluetooth authentication, pwm generation for motor driver, and sensor monitoring/GPS interfacing.

Requirement 1: Microcontroller is able to communicate over UART, NMEA, and SPI or I2C simultaneously, while also setting interrupts on GPIO.
Requirement 2: Microcontroller must be able to generate 0-3.3v PWM signal and send to motor driver.
Requirement 3: Microcontroller must be fast enough to process information and lock/unlock within 1500ms window from authentication request to bolt movement.

2.5. Electromechanical Subsystem

The electromechanical subsystem is required to allow for the mechanical locking and unlocking features of the hardware module.

2.5.1. Motor Driver

The motor driver can be a simple H-Bridge driver, capable of sourcing enough current from the battery to both drive the motor bolt inwards and outwards of the lock hole.

Requirement 1: Motor driver is capable of reversing motor motion.
Requirement 2: Motor driver can translate a 0-3.3v PWM into 6VDC motor drive signal.

2.5.2. Motor

The motor will be a simple 6VDC 100 rpm motor with a gearbox providing sufficient torque to push and pull the bolt.

Requirement 1: Able to provide enough torque to push and pull 100g bolt back with linear motion.

Requirement 2: Powered by 6V LiPo battery with 1000mAh

2.6. Power Subsystem

The power subsystem is required to supply power in order to keep the other subsystems working at all times.

2.6.1. Lithium Ion Charger

A charging IC will be used, much of the power system is still being researched.

Requirement 1: Able to charge Lithium Ion Battery to 80% within 4 hours.

2.6.2. Lithium Ion Battery

The battery should be able to supply sufficient voltage and current to the motor while still being lightweight and providing 3 days of life for system during normal operation.

Requirement 1: Able to fit size constraint, less than 50 cubic centimeters and 50 grams.
Requirement 2: Able to store enough charge to provide at least 150mA at 6V for 10 minutes and to provide at least 1000µA at 3.3V for 72 hours.

2.6.3. Voltage Regulator

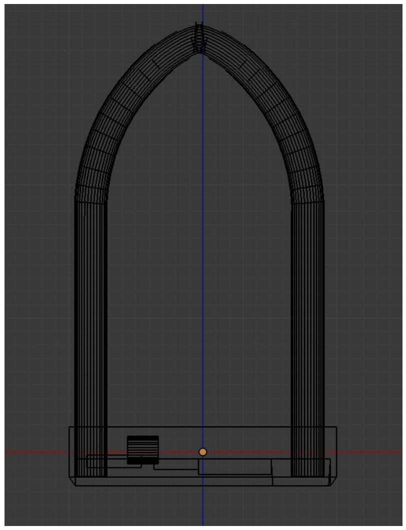
The voltage regulator should be capable of supplying 3.3V to the microcontroller, communication, and sensor subsystems at a low current. This will separate it from the battery output which should be capable of supplying higher current and voltage for the motor.

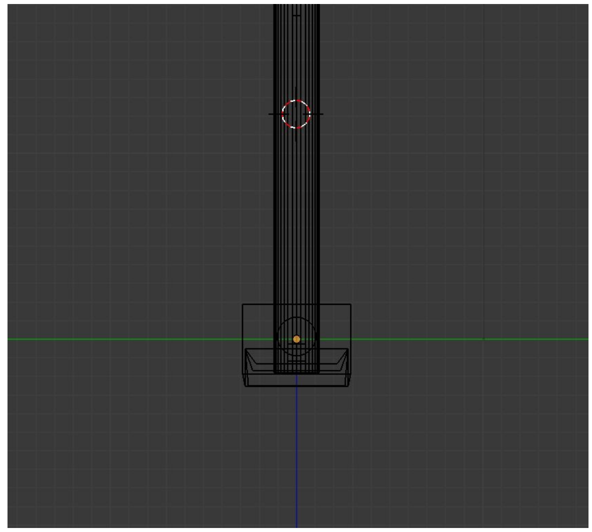
Requirement 1: Voltage regulator is able to translate 7.4v battery voltage into 3.3v for microcontroller/sensors/communication and 6v for the electromechanical system.
Requirement 2: Voltage regulator must maintain safe operating temperature at a peak current draw of 250mA (motor running full + bluetooth xfer + gps tracking).

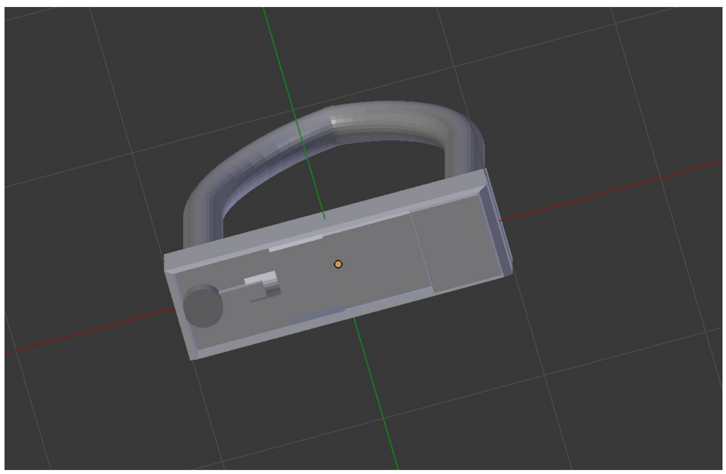
2.7. Physical Design

Tentative physical design is displayed below. We plan on consulting the machine shop to refine our physical design further.

Displayed below, our design consists of a U shaped upper section for the handle and a square box bottom which houses all of the electrical/electromechanical components. Here the battery is towards to right end of the housing, with PCB in the middle and motor towards the left where the bolt inserts into the end of the U-shape handle.







2.8. Risk Analysis

The mechanical/physical design and electromechanical interaction of the motor poses a significant risk to the project. The bike lock will be used in highly mobile situations, with multiple locks and unlocks per day. If there is small misalignment in the physical locking of the bolt from the motor into the U-lock, the entire module is effectively useless due to the jam. This sort of misalignment and failure in the electromechanical subsystem would void the whole project.

We will ensure that the physical casing of the lock is sturdy, and further research physical restrictions to place which can prevent misalignment and jamming.
In addition, our sensor subsystem consists of an IMU that sends an interrupt signal upon detection of excess vibrations in the module. Not only will this protect the system from external tampering, but it will also power off the system in case of a jam, mitigating the severity and damage to the module.

3. Ethics and Safety

There are several potential safety hazards involved with our system, specifically regarding the lithium ion battery. Due to the mobility of the system, there is risk of damage or wear and tear to the housing during normal bicycle rides (lock is dropped, lock bangs against hard surface, etc). Lithium Ion batteries are liable to catching fire due to thermal runaway when enough metallic particles compromise one spot of the battery [4]. Additionally, there are concerns with charging the battery at safe rates, as drawing too much current from the charger can also result in fire. As electrical engineers, by IEEE Code of Ethics #1, we are committed to holding "paramount the safety, health, and welfare of the public" [5]. This means ensuring that a fire does not occur, and users are never harmed by our system. To mitigate these risks, we will thoroughly test the system to ensure that regardless of the damage done to the physical module, the battery does not catch fire, and that under no conditions is the battery being charged with more than 6V.

In addition to safety hazards for the user, there also exists ethical concerns regarding the user's property. Since these bikes will be owned by consumers who choose to use our module, if the system powers down while the bike is unlocked, or if there is an issue with security keys for authentication, we are responsible for potential theft of a user's bike. In this sense, we are in danger of violating #9 of the iEEE Code of Ethics, which states that it is important "to avoid injuring others, their property, reputation, or employment by false or malicious action;" [5]. By opening the consumer up to the risk of damage or loss of property, our technology must take sufficient steps to mitigate this risk and make sure that any loss of property would only have occurred regardless of our module versus a normal bike lock. To this aim, we will ensure that when battery power is low we will auto-lock the bike and not allow unlock until battery is sufficiently charged to authenticate properly. We will also seek encryption methods to secure our authentication, and prevent a third party from spoofing the key or falsely authenticating to steal the bike.

In addition, our gps module collects information on the location of our user, and system collects other user identity information, which is a huge invasion of privacy if released. If this vulnerable user information was stolen by malicious individuals or organizations, iEEE Code of Ethics #1 and #9 would potentially be breached [5]. We will ensure this does not happen by encrypting and decrypting every piece of user information and only storing required information in a secure database. We will never, under any condition, sell this user information.

4. References

[1] "Theft and Destruction of Dockless Bikes a Growing Problem." The Washington Post, WP Company, 1 July 2018, www.washingtonpost.com/news/dr-gridlock/wp/2018/07/01/theft-and-destruction-of-dockless-bikes-a-growing-problem/?noredirect=on&utm_term=.33cdf758d0e5.

[2] "The Lock - Deeper Lock Smart Bike Lock." Deeper Lock, Deeper Lock, deeperlock.com/smart-bike-lock/.

[3] Kart, Jeff. “Call Up A Bike With Your Phone - Purdue Startup Is Expanding.” *Forbes*, Forbes Magazine, 12 Apr. 2018, www.forbes.com/sites/jeffkart/2018/04/11/call-up-a-bike-with-your-phone-purdue-startup-is-expanding/#1c4bba093939.

[4] “BU-304a: Safety Concerns with Li-Ion.” *Lithium-Based Batteries Information – Battery University*, batteryuniversity.com/learn/article/safety_concerns_with_li_ion.

[5] Ieee.org, "IEEE IEEE Code of Ethics", 2016. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 29- Feb- 2016].