Universal Bike Sharing Lock

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1 Introduction:

1.1 Background:

While there exist a growing number of bike sharing services throughout the US and the world, these systems are restricted to only one type of specially-designed bike [1]. Our project aims to expand the idea by allowing for a sharing service to be independent of the type of transport being shared, and to hopefully encourage more people to use these smaller, cleaner methods of transport as well.

The main component of the project would be a locking device that would act as the “bike rack” for the method of transport, which would allow a user to lock/unlock the two-wheeler for their ride. This locking rack device can be attached to an existing bike rack, but is designed to be somewhat versatile in where it can be installed.

1.2 Objective:

The popularity of bike-sharing services has been rising throughout the world, including New York’s bike sharing service, Citi, helping contribute to the ever-increasing 450,000 bike rides estimated to occur in America’s largest city [1]. Professor Lav Varshney proposed expanding on this concept by creating such a system for sharing mopeds, which have a similar ease of use like bicycles and roughly the same amount of emissions, as well [2].

Our project widens the scope of his idea by attempting to create a system that can be used for other similar methods of transport like scooters and mopeds. The goal is to help increase the use of these cleaner methods of transportation by building a device that can expand the accessibility and reach of bike-sharing services to more types of transport (and more people).

1.3 High-Level Requirements:

1. The rack device must allow for a user to unlock the bike and ride it within a few minutes using a phone app (from ~1-3ft away).
2. The rack device must allow for a user to easily return and lock the bike within a couple of minutes.
3. The rack device must be able to secure a bike, scooter, or moped when they are not in use (i.e. it should be strong enough to prevent someone from removing the bike from it).

2 Design:

The main focus of development of the project contains three main components: the rack locking device, an ID tag wire/chain (connected to the bike) to attach and remove from the rack device, and a cell phone app to wirelessly open the rack device.

The rack device's locking mechanism will utilize a push-pull solenoid (which opens and closes based on the amount of voltage given to it). Next, the functionality of knowing when a two-wheeler has been returned will utilize an RFID module. Lastly, control of the lock via phone will be handled with a Bluetooth transceiver.

In practice, a web server of ride information would be implemented, but is not a part of the scope of the design course, so will be left out of the project.

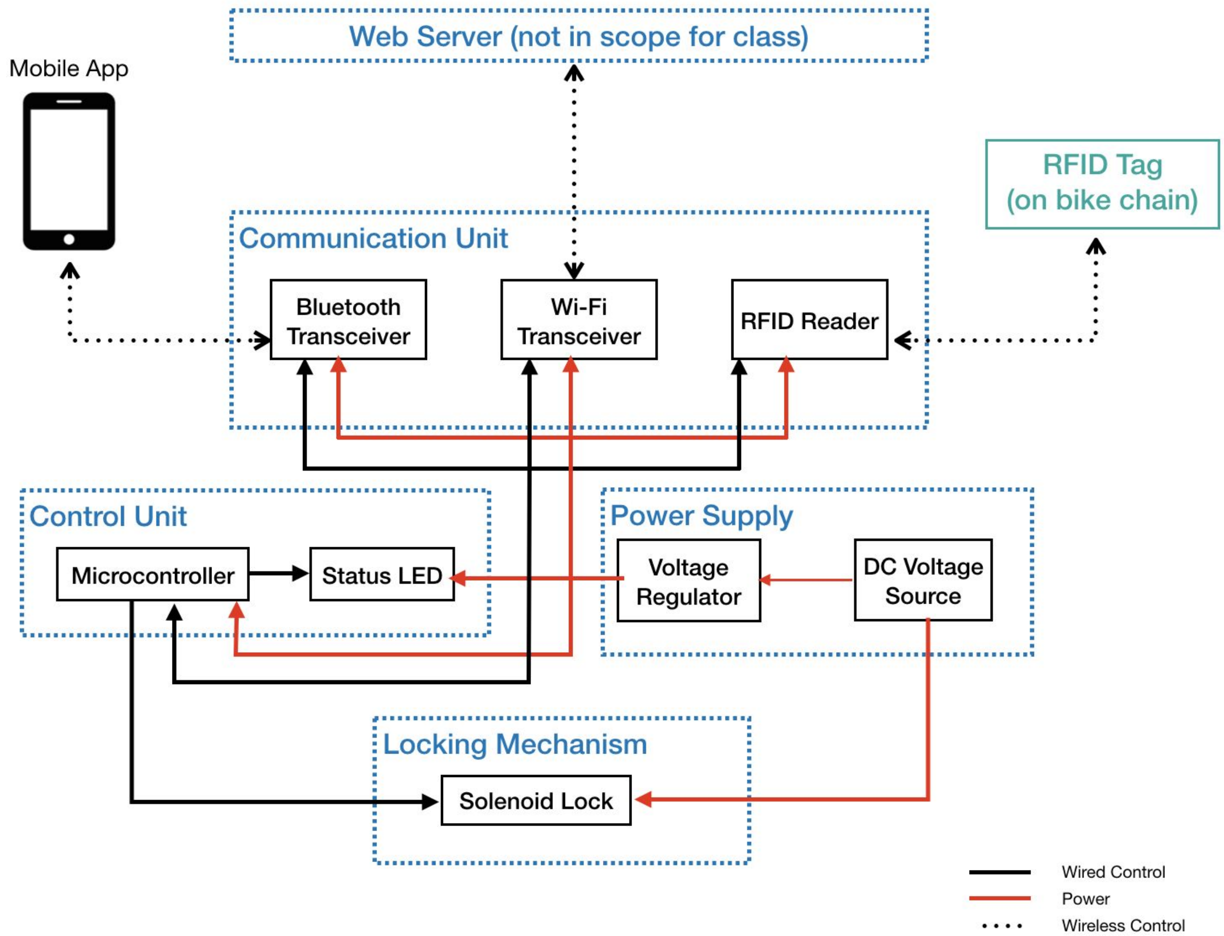

Figure 1. Block Diagram

The rack device is intended to be capable of being secured on an existing structure (a metal bike rack, wall, etc.) with the holes built into the base of it, that is intended to be used for screws or metal wires. In practice, the encasing for the rack device would be made of a strong material to prevent it from damage or burglary, but still accessible to the vendor of the bike-sharing service.

The RFID tag would be attached to a bike chain/wire that is affixed to the actual bike itself to prevent the user from removing it. Ideally, it could be stored in a basket or compartment on the bike, or be retractable, but it must not be able to be removed from the user. It could be affixed permanently or only removable by the bike vendor.

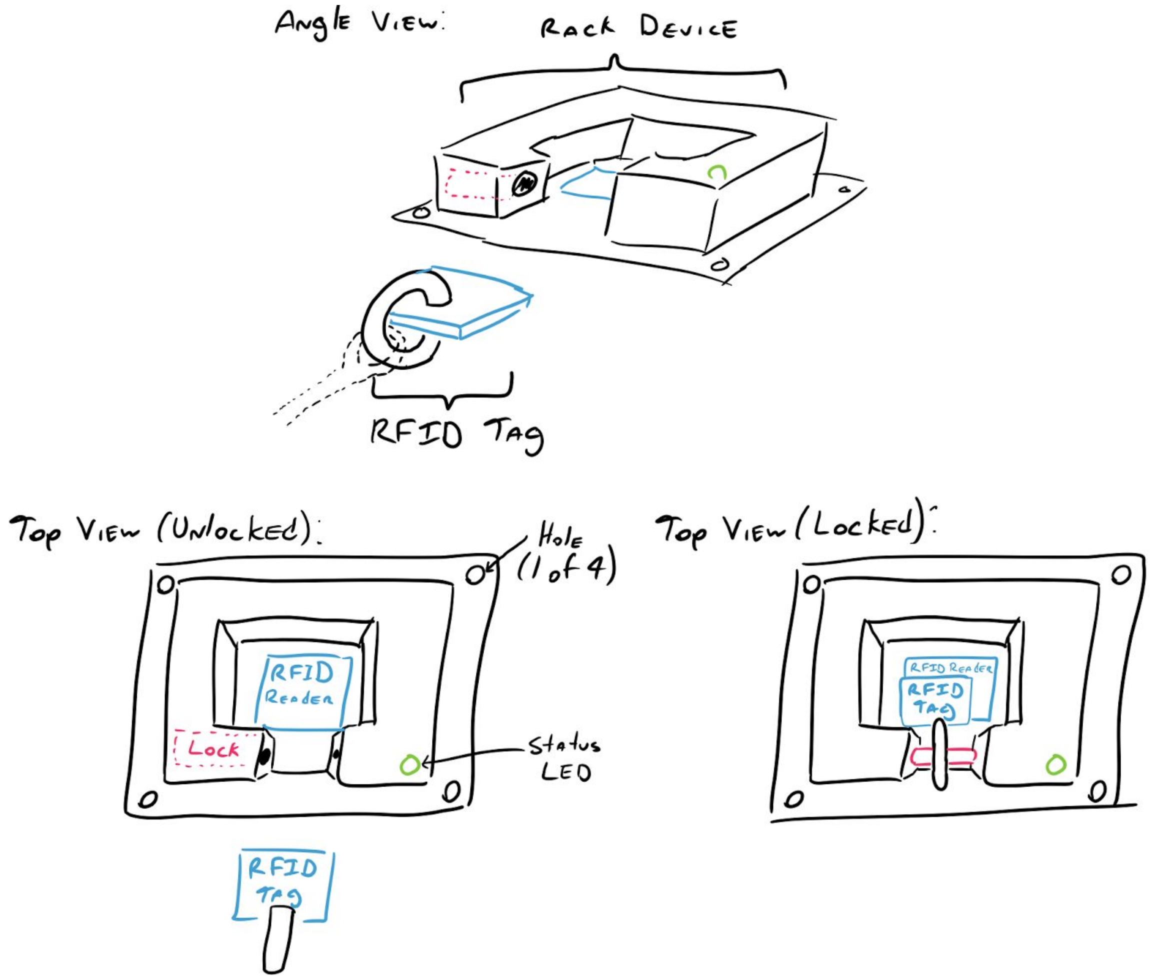

Figure 2. Physical Design

2.1 Power Supply:
The power supply must be able to adequately power all electrical components of the device to ensure proper functionality. It should also be able to manage different voltages for the locking mechanism and the other electronic modules.

2.1.1 DC Voltage Source:
Our device is intended to be stationary and function, so a direct source of voltage is needed. The main destination for voltage will go towards locking the

solenoid lock, along with powering the microcontroller and the RFID, Bluetooth, and Wi-Fi modules.

Requirement: A readily available 24V (maximum) to power the solenoid locking mechanism, plus the other electronic components.

2.1.2 Voltage Regulator:
While the solenoid locking mechanism will require the full amount of voltage from the DC source, the remaining components of the device will need much less. We will have to step down the voltage values for the various components in the rack device using an IC regulator. The solenoid lock, MCU, and communication units will require regulated power.

Requirement: Must provide 3.3V and 1.2V +/- 5% from source voltage of 24V.

2.2 Control Unit:
The control unit is responsible for interfacing with all other components in the device and processing lock and unlock requests.

2.2.1 Microcontroller:
The microcontroller must be able to control the opening and closing of the locking mechanism by communicating with the Bluetooth module (for a user unlocking via password) and the RFID module (for a user locking via RFID tag). It should also be able to send bike information (i.e. if bike is present) to a web server via the Wi-Fi module. All of these operations require the microcontroller to be responsive within seconds, so we aim to use one from Texas Instruments' C2000 series. (Tentative decision: Texas Instruments TMS320F28377D).

Requirement 1: Must have maximum operating frequency of at least 100MHz to process information fast enough.
Requirement 2: 3Mbps UART throughput to quickly communicate with the Bluetooth and Wifi components.
Requirement 3: At least 400Kbps of I2C-bus throughput for quick communication with RFID module.
Requirement 4: Flash memory capacity of 512KB and RAM capacity of 128KB to accommodate incoming data from connected modules.

2.2.2 Status LED:
A Status LED will be used to inform the customer that the rack is operating properly, specifically, it will flash to acknowledge the RFID tag being successfully scanned.

Requirement 1: Must have a forward bias voltage of 3.3v or less.
Requirement 2: Luminous intensity of 10 mcd or more at forward current of 5mA or less for visibility and low power consumption

2.3 Locking Mechanism:
The main purpose of the locking mechanism is to secure the RFID tag lock (attached to the bike) by closing the physical loop of the device to prevent the bike lock from being removed.

2.3.1 Solenoid Lock:
A Solenoid Lock will be used to secure the bike chain. The RFID tag will be scanned and send voltage to the lock securing the vehicle to the rack.

Requirement 1: The lock must be able to close quick enough to securely clamp the chain when the tag gets scanned.
Requirement 2: The lock must be strong enough to not break when the vehicles attempt to ride away.

2.4 Communication Unit:
This unit contains all the components that interact with the user in some capacity for taking out a bike for use and returning it.

2.4.1 Bluetooth Transceiver:
This Bluetooth module is intended to allow a user's mobile device to open the locking mechanism for accessing the bike itself. We plan on using the HC 05 Bluetooth module.

Requirement: Must be able to communicate with a user's phone from 1 - 3 ft. away.

2.4.2 RFID Reader:
The main purpose of the reader is to be able to successfully scan the RFID tag attached to the bike's lock and allow for the rack device's locking mechanism to close automatically (for securing the bike's lock).

Requirement: Must be able to read an RFID tag 0.5 - 1.0 in. away.

2.4.3 Wi-Fi Transceiver:
The Wi-Fi transceiver is used to send various rental information to the web server (i.e. when a bike is taken out, if it is locked, etc.).

Requirement: TCP throughput of 8Mbps or greater for quick communication with web server.

2.5 Mobile App:
A simple mobile application will be used to send rental request and receive return information from the microcontroller. For this project, iOS or Android OS will be used.

Requirement: Communicate with rack device from 1-3 ft away to open the locking mechanism.

2.6 Web Server (Web App):
In practice, the web app would be the center of the "service" portion of the bike sharing service our device would be used in. The web app would send rental information (i.e. lock passwords, etc.) to the user, and receive rental information from the rack device (i.e return time, etc.). It not within the scope of the class, however, so it won't be implemented.

2.7 Risk Analysis:
The largest risk to successful completion of the project is coordinating communications between all three parts: the phone, rack device, and bike lock. We must ensure reliable and swift information transfer when the RFID tag gets scanned to secure the vehicle as well as correctly process payments of the rental.

3 Ethics and Safety:

In terms of making our project safe and ethical (especially by IEEE's ethics standards), one of the main aims of the project is "to avoid injuring… [others'] property", by protecting the vendor's bikes and scooters from theft [3]. We want our device to be able to respond quickly to a user's attempt at returning the bike (to lock it), but also want unlocking the bike to be safe and limited to those who rented it. Our goal is for returns to be as rapid as possible, along with having unlocking the bike be protected with multiple passwords (i.e. the user would have to send the rack device a specific code to unlock it).

Along with secure functionality, we will aim to build our electronics with the potential to be easily built in a secure encasing for the device to prevent damage or burglary. The lock must always be powered to work properly, so we decided to use a constant DC voltage to avoid the issue of the device running out of power and being unable to be locked.

Another issue we have to consider is making the device as noninvasive to its environment as possible. We aim to make the rack device small enough to set up on something like a bike rack, so can be well-incorporated in an urban setting like its existing counterparts.

Finally, the IEEE Code of Ethics' point to "seek, [and] accept… criticism of technical work" is a very important component of our project [3]. While we are focusing more on electronic hardware, our project would be part of a potential universal bike-sharing system, that would be a mix of interdisciplinary fields, be it software (for the potential web server app), mechanical engineering (for the locking mechanism and device protection), and even business (for the actual "service" our device would be used for).

We will seek the guidance of our official sponsor, Prof. Lav Varshney (the proposer of the original idea our project is based on), along with course staff and any other resources we can find to implement our project's functionalities as well as possible.

Sources:

[1] W. Hu, “More New Yorkers Opting for Life in the Bike Lane,” 30-Jul-2017. [Online]. Available: https://www.nytimes.com/2017/07/30/nyregion/new-yorkers-bike-lanes-commuting.html?mcubz=1. [Accessed: 18-Sept-2017].

[2] S. Dave, “Life Cycle Assessment of Transportation Options for Commuters.” [Online]. Available: http://files.meetup.com/1468133/LCAwhitepaper.pdf [Accessed: 19-Sept-2017].

[3] IEEE.org, "IEEE Code of Ethics", 2017. [Online]. Available: http://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 19-Sept- 2017]