PROJECT PROPOSAL:
Big Box, Small Package - Secure Drone Delivery

Team 11: Timothy Wong, Phillip Jedralski, Christian Fernandez

ECE 445- Spring 2020

TA: Xihang Wu

1. Introduction

1.1 Objective

We introduce an innovative IOT receptacle that a delivery drone can dock with and securely deposit small packages. The basic function of the receptacle is that it can receive a drone delivery and hold it safely until the consumer comes to retrieve it. With drones becoming an increasingly more popular consumer and commercial venture, the need for drone accessories is therefore in demand. With the advent of delivery services like Uber Eats and Grubhub, alternative services are becoming increasingly competitive. Combining the accessibility of drones, and the delivery service of small items like food and store packages, prompts the idea of using drones for delivery. However, even with a demand for such a service, investment in drone infrastructure is needed. Giving drones a location to land and deliver packages would make it simpler and more convenient to operate drone delivery at a mass scale, even at a more primitive level. With our project, we aim to create the prototype to a delivery receptacle that will be able to stand up to the rigors of drone package delivery.

1.2 Background:

On December 28, 2020, the Federal Aviation (FAA) announced a major update to the rules of unmanned recreational and commercial drones. A major change is that all drones that weigh more than 0.55 pounds must be identified through a registered "Remote ID"(enforced starting September 2023) [1]. The second and arguable groundbreaking change was the relaxation of restrictions of drones flying over people and property at night for commercial pilots. Previously, this activity required waivers from the FAA. This change is likely to expedite the commercialization and integration of drones into the airspace. There is great market potential for UAVs in many big industries ranging from security and inspection to agriculture [2]. One high potential area that we focus on in the project is the delivery industry. Major e-commerce organizations including Amazon, UPS, Walmart have all heavily invested in the research and development of drones and drone infrastructure for commercialization. According to Amazon, 75 to 90 percent of purchased items weigh under 5 pounds [4]. Drone delivery opens the avenue towards < 1 hours delivery, night delivery, and reduces the need for human middleman between warehouse to consumer.

Much of the research done on drone delivery has been focused towards the drone such as obstacle avoidance, noise reduction, battery technology, etc. There is less being done to interface a dropped off package to the hands of the consumer. Delivered packages are prone to theft. This is a particular problem with drones since it is difficult for drones to drop off a package securely without dangerous contact with people or tricky obstacle avoidance. Risk of theft also increases with night delivery as there is increased duration that a package can be stolen since the consumer is asleep. We propose a receptacle that drones can land atop and deposit a package for the consumer.

1.3 Physical Design:

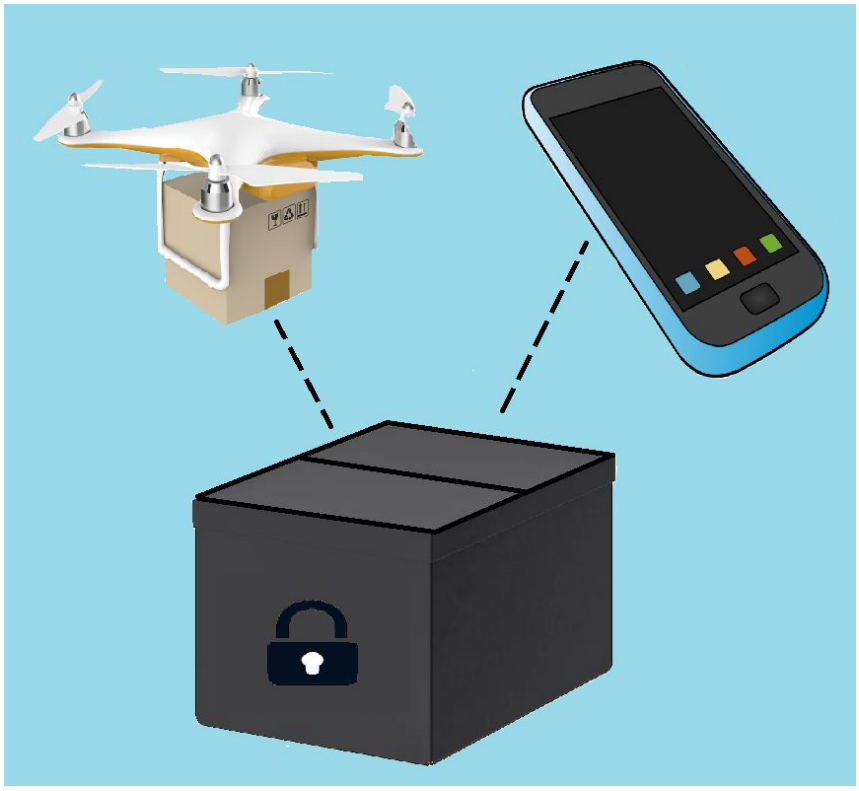

Figure 1: Physical Design

1.4 High-Level Requirements list:

- Communication with the drone to know when to open the dropoff door.
- The receptacle opens up for the delivery to be dropped off and closes in a secure fashion to store the package.
- The receptacle can be opened or closed by the consumer.
- Notification to the consumer that package has arrived.

2. Design

In this design, we break the project up into three main blocks, the drone, the receptacle, and finally the web applications. The drone component will consist of a drone with the necessary RF transmitter, allowing communication between the drone and the receptacle. The receptacle will contain the majority of the hardware components, including the receiver, power system, wifi module, control unit, and the mechanical system. The wifi module and the control unit will then interface with a web page and mobile application designed to inform the user of any packages that have arrived.

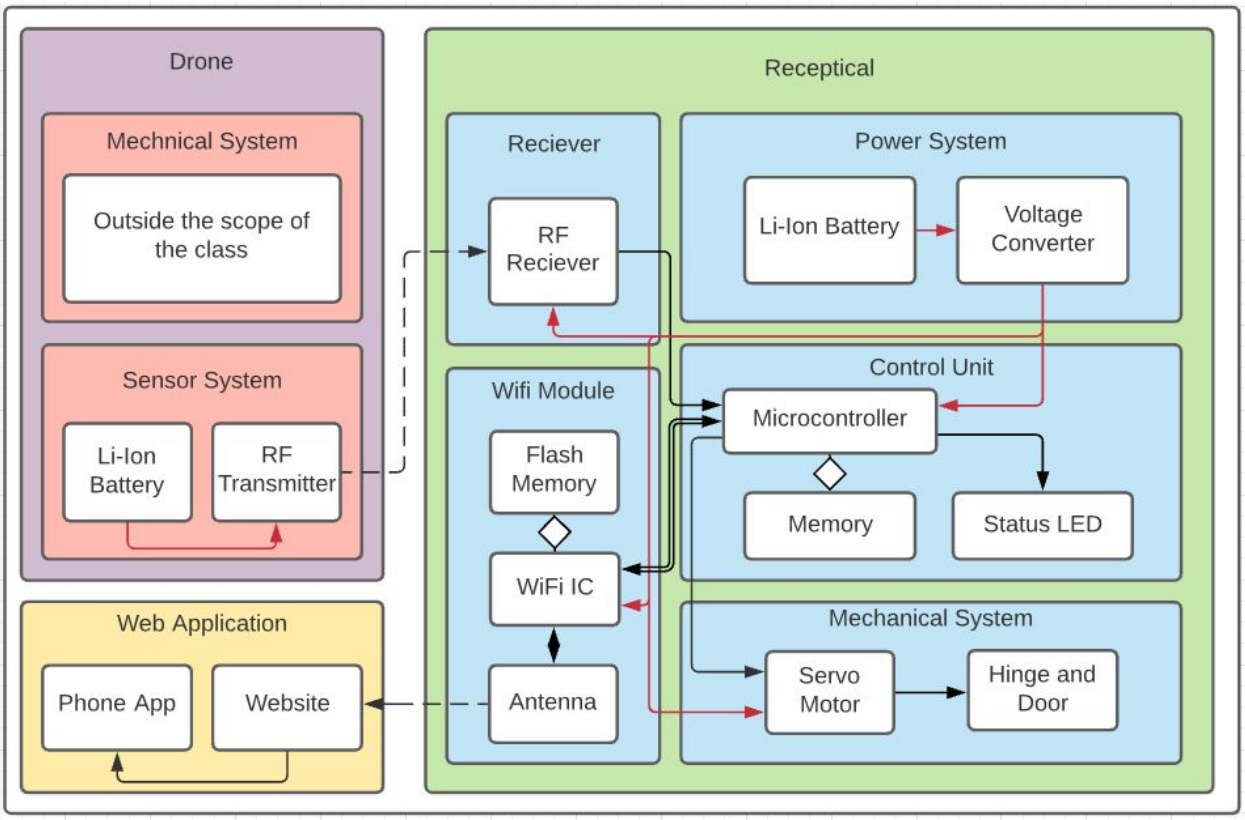

Figure 2: Block Diagram

2.1 Power Supply

A power supply is necessary to keep the receptacle operational at all times. With the use of an internal battery pack, managing different subsystem voltages consistently is possible, safely and securely. With a secure power supply, the receptacle can operate without the threat of power loss due to environmental disasters and inclement weather.

2.1.1 Li-Ion Battery

The main receptacle can be located in convenient locations regardless of access to an external power supply. This ensures that regardless of weather conditions, the receptacle won't lose power and will be able to reliably service their customers.

1. Requirement: Able to provide 200mA and 3.85V to 4.3V for 24 hours.

2.1.1 Voltage Converter

All the integrated circuits and microcontrollers within the system nodes require a steady 3.3V input voltage to maintain functionality.

1. Requirement: Able to regulate voltage to 3.3V ± 5% from a nominal 3.85V source.
2. Requirement: Able to maintain integrity at temperature ranges from 32℉ to 100℉.

2.2 Control Unit

The control unit is a key feature of any design, where many features need to be controlled. In this design, the microcontroller, memory card, and LEDs will work together to control all the internal signals used within the receptacle box.

2.2.1 Microcontroller PCB

The ATmega328 microcontroller will be used to interface with all controllable components. The PCB has resistors, capacitors and a crystal oscillator. IO ports will send signals for the motors that will open the door and to a servo motor that acts like a lock to lock the door.

1. Requirement: Able to send PWM signals to the servo motors.
2. Requirement: Able to support TCP/IP for the WiFi module.
3. Requirement: Has as a USB connector to be externally programmed in C.

2.2.2 SD Memory

With the limited memory on the ATmega328 chip, external memory will be required for complete operation of the control unit.

1. Requirement: Provide enough memory for the control unit program.

2.2.3 Status LEDs

With many of the features embedded into the box, it is necessary to have some external indication of the internal operations. Therefore, it is key to have LEDs displaying the status of the packages delivered in the box, as well as any issues the receptacle might have.

1. Requirement: The LEDs must be visible from approximately 2-4 meters away.

2.3 Wifi Module

The WiFi module will be used to communicate back to the server which communicates to the mobile/web application. It does not need high bandwidth since it conveys fairly basic information such as when the door is opened/closed signifying when the package was delivered and when someone picks up the package.

2.3.1 Antenna

To extend the range of the wireless transceiver since the receptacle will be typically placed a significant distance from the home and the central server, an antenna is needed. Since the wireless notification has a minimal bandwidth requirement, cost efficiency can be improved by selecting a lower bandwidth antenna.

1. Requirement: Must allow access at a distance of at least 100ft.
2. Requirement: The antenna must transmit at the standard wireless range frequencies of 2.4 Ghz

2.3.2 WiFi IC

The WiFi IC serves the purpose of transmitting the notification that a package has arrived wirelessly to a central server where it is displayed to the user. For this purpose we chose the ESP32 which includes a 32-bit microcontroller and a wireless transceiver.

1. Requirement: Must support IEEE 802.11 standard for wireless networks
2. Requirement: Must support standard communication methods such as SPI and UART

2.3.3 Flash

The flash memory module stores the program memory for the WiFi IC. Our estimates for the program size are below 1MB, and as such we can reduce the cost for this component accordingly.

1. Requirement: The memory card must be able to hold up to 4 MB of data.

2.4 Web Application

Once the package has arrived it is necessary to take the package arrival into account, and let the user know when it is time to pick up their parcel. With a web application, we will be able to have a web server store information about package information, such as logs and other order history. From there a smartphone application will send user's notifications right to their phone and make it easy to keep track of their deliveries.

2.4.1 Smartphone App

The smartphone app notifies the user that their package has arrived.

1. Requirement: Notify the user within 1 minute of the package's arrival.

2.4.2 Web Server

Displays delivery information in a web format for the user to view, logs delivery history in a secure database for future viewing.

1. Requirement: Able to receive delivery information wirelessly from from the receptacle and store data for future retrieval.

2.5 Sensor System

An important feature of our design is the drone's ability to detect and communicate with the receptacle. This requires the use of sensors in the form of radio frequency transmission from the drone to the receiver on the receptacle box. This gives a way to determine when the drone has reached its destination, thus informing the end user of their package's arrival.

2.5.1 Li-Ion Battery

The lithium ion battery must be able to keep the RF transmitter continuously powered while communicating with the RF receiver on the secure receptacle.

1. Requirement: Continuously supply a constant 12VDC.

2.5.2 RF Transmitter

Radio frequency transmitter for communication with the receiver on the receptacle, notifies the receptacle as to when the drone positioning is suitable for the release of the package.

1. Requirement: Transmit at least > 10 meter range. (GPS accuracy is ~5 meters)

2.5.3 RF Receiver

Radio frequency receiver for communication with the transmitter on the drone, notifies the user as to when the package has arrived at the destination and being deposited in the receptacle.

1. Requirement: Reception to at least > 10 meter range.

2.6 Receptacle Electromechanics

2.6.1 Door Motors

A small 5 VDC motor reels sliding door on top of the receptacle open and close. This is also the same door that the consumer can open with his/her smartphone to pick up their package.

1. Requirement: Must be strong enough to pull the sliding door fully shut/open.

2.6.2 Servo Motor

A small 3.5 VDC motor will be used to lock the doors together shut.

1. Requirement: Must be able to unlock when the doors are closed and lock when the doors are closed.

2.7 Risk Analysis:

The most crucial module in this project is most likely the RF communication module between the drone and the receptacle. The receptacle IOT hinges on the assumption that communication occurs successfully so that the receptacle can open and close at the proper time so that a package could be deposited in it. This module is also tough for us because none of us have much experience working with RF communication.

3. Ethics and Safety

Our project raises several issues in regards to the safety and ethical use of our design, not only because of the fact that the drone sector is heavily regulated, but also because of our added constraint of making a secure design.

As the secure dropbox is designed to be placed outside in a similar function to a mailbox, the receptacle will need to follow the latest IP requirements, to prevent not only the inner circuitry from moisture damage, but the package as well. Not ensuring such precautions violates IEEE Code of Ethics, #9, which stresses avoiding the injuring of other persons, including their property [3].

Careful consideration will also have to be put into the operation and modifications of the drone as well. Since we will be attaching a sensor module to the drone containing both a battery and an RF module, accounting of the weight of the drone in accordance with FAA regulations is required. Drones over 250 grams must be registered with the FAA under Part 107, and must have visible markings for identification displayed on the drone at all times [1].

With the main purpose of the receptacle being delivery of packages in a secure manner, access to the inner contents should be restricted to the owner of the dropbox for which packages are delivered, and the drone service that is performing a delivery that is explicitly requested by the owner.

Collection of user data, an issue of increasing relevance in the digital era, raises the question of who should have access to a user's data, in the case of our project a history of the deliveries sent to the owners delivery box, including information about the arrival time as well as the authorized sender of the package. It is our belief that user data belongs first and foremost to the user, and will only make such data available to the respective owner. Regarding the security of the transfer of this data over a wireless network, requires a level of security and encryption to uphold #1 of the IEEE Code of Ethics, to paramount the safety, health, and welfare of the public, which includes protection of users' privacy [3].

4. References

[1] faa.gov. 2021. 'Certificated Remote Pilots including Commercial Operators'. [Online] Available at: https://www.faa.gov/uas/commercial_operators/ [Accessed 17 February 2021].

[2] Ackerman, R., 2021. 'Things are Looking Up for the Commercialization of Drones'. [Online] Securitymagazine.com. Available at: https://www.securitymagazine.com/articles/94331-things-are-looking-up-for-the-commercialization-of-drones [Accessed 12 February 2021].

[3] Ieee.org. 2021. 'IEEE Code of Ethics'. [Online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 15 February 2021].

[4] C. Guglielmo, "Turns Out Amazon, Touting Drone Delivery, Does Sell Lots of Products That Weigh Less Than 5 Pounds," *Forbes*, 03-Dec-2013. [Online]. Available: https://www.forbes.com/sites/connieguglielmo/2013/12/02/turns-out-amazon-touting-drone-delivery-does-sell-lots-of-products-that-weigh-less-than-5-pounds/?sh=2ed6d239455e. [Accessed: 18-Feb-2021].