Smart Package Lockbox

Dominic Amalfitano, Daniel Corredor, Brandon Dziewior, Michael Light

College of Engineering and Computer Science, University of Central Florida, Orlando, FL, 32826, USA

Abstract – This paper presents the design methodology utilized to achieve a personal smart storage unity for use with package delivery and drop-off. The use of the technology aims to reduce the impact of porch pirates/theft of deliveries to homes. This goal should be achieved in an easy to use and cost-effective manner.

Index Terms – IMU, Smart Lockbox, Firebase, Keypad, React Native.

I. INTRODUCTION

In today's electronic age the amount of online shopping and the ease in which products can be obtained has increased dramatically. With this increase there are more and more package deliveries to the American homeowner. These homeowners cannot always be home at the time of their delivery due to other matters or large delivery windows for example, anytime Tuesday. For those buyers that order packages regularly or order expensive items there is a need for a sense of security and safety in those deliveries. The current market offers several solutions to this but our group feels that these options fall short in one or several categories. The current market solutions include expensive, durable lockboxes with no smart functionality, or a few less expensive options that suffer from a durability and security standpoint. As a group we aim to achieve the smart functionality while still offering a durable and secure way to store the deliveries. Additionally, not all homeowners may feel secure with letting a delivery service directly into their home with solutions such as Amazon Key.

Our solution will achieve the security and smart functionality through the use of several hardware and software components. The Smart Package Lockbox will include an alarm, lid sensor, IMU, backup battery, and keypad in order to allow for secure storage. Through the use of a Wi-Fi module along with an online database, web service, and mobile app the smart functionality and alerts will allow for an overall easy to use and secure product. All hardware components will be contained safely inside the box itself with exception to the keypad which will be mounted to the outside.

In order to provide information for a user who is away the project will also incorporate a mobile application. The application is being implemented so that there is an iOS and Android mobile application. This allows for almost no user to be left out from being able to access the Smart Package Lockbox wirelessly. Initial setup of the lockbox will need to be done on the website. The website can also be accessed anywhere that there is internet access. Using both of these in conjunction with Firebase's real-time database the user information and lockbox data can be stored in real-time and accessed from anywhere.

The system as a whole will allow for users to receive deliveries in a secure manner. A block diagram showing a high-level system design can be seen in Figure 1 below.

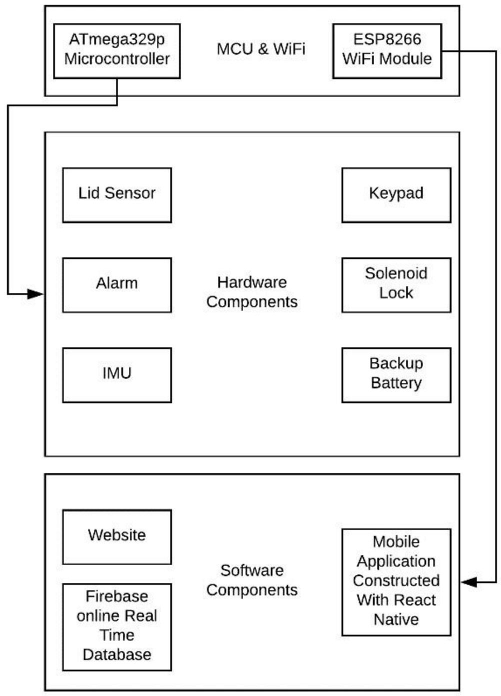

Figure 1. High Level Project Overview

Once the user goes through initial setup of their Smart Package Lockbox they will be able to set primary and secondary access codes. This allows for the user to have their own access code and if they so choose, give a secondary code to a close friend or family member. To open the lockbox the user must have an access code. Upon the box being opened an alert will be sent to the Smart Package Lockbox primary user's email and phone if they have notifications enabled and the mobile application installed on their device. From the website and the mobile application, the user will also be able to view their information as well as edit this information and view the lockbox status.

II. REQUIREMENTS

The overall requirements of the project can be grouped into several categories. These requirements are established in order to meet different goals of the project along with making it marketable against the current existing products today.

A. Power Requirements

The Smart Package Lockbox will run on an American standard wall outlet power output of 120V at 60 Hz AC during primary power. For any reason if there is a loss of this primary power source our system will run a minimum of 24 hours on the backup battery power supply.

B. Security Requirements

In order to deter theft and overall increase the security offered by the lockbox the systems internal alarm will have a minimum Sound Pressure Level (SPL) of 85 dB or higher from measured outside the box.

C. Enclosure Requirements

The enclosure itself should contain 4 to 12 cubic feet of interior storage in order to accommodate most package deliveries. Additionally, the enclose will be weather resistant due to the fact it will most likely be placed out in the elements on someone's porch.

D. Wireless Communication

The system's internal Wi-Fi module will support a minimum range of 50 meters. This is in order to accommodate for different home layouts and locations of routers/modems.

E. System Cost

To compete with the other products currently on the market the overall material cost of the system should not exceed $250. As a group the development cost shall not exceed $500. The system cost ignores any development costs from user error.

III. HARDWARE

The hardware used to achieve this project include several different components. Of these components they include a MCU, IMU, WiFi module, lid sensor, alarm, keypad, and a backup battery supply. Most of the hardware components were operated on by the electrical engineering members of the team.

A. MCU

The MCU (Microcontroller Unit) is the brain of the project. The microcontroller will be taking all of the data from our sensors and using this data to relay information to the user when necessary or preform key functions. There is no image rendering or high-level decision making so we do not need an expensive or higher end MCU. The ATmega series of MCU are widely used and supported with plenty of helpful recourses and available peripherals.

B. IMU

To aid in deterring theft we needed a way to detect abnormal motion and possible tampering with the lockbox. Several options were explored and many of the components that we had researched such as a gyroscope and accelerometer were packaged nicely into an IMU (Inertial Measurement Unit). The accelerometer along with the gyroscope together can detect sudden changes in motion the lockbox endures. These sudden changes could indicate blunt impacts in order to break into the lockbox. Or they could indicate if a thief were trying to take the lockbox as a whole. Example output data received from the IMU can be found in tables 1 and 2 below. Table 1 provides the orientation in all three axes (x, y, z) using degrees per second. This is measured using the IMU's internal gyroscope. Table 2 shows the acceleration in those same three axes. The data is provided in G forces and taken from the accelerometer.

X	Y	Z
0.32	0.44	1.02
0.41	0.38	0.98

Table 1. Gyroscope Values in Degrees Per Second

X	Y	Z
0.12	0.08	1.12
0.04	0.10	1.07

Table 2. Accelerometer Values in G forces

As can be seen from the values in tables 1 and 2 above the data taken at different points in time when the IMU is not in motion. Due to this the data is sampled with a given amount of error to be expected.

C. Wifi Module

The WiFi module which can be seen below in Figure 2 is a crucial component in the creation of this project. The WiFi module serves to provide the connection between the Smart Package Lockbox itself and the online communication such as the website and mobile application. Through the use of the WiFi module we are able to send and receive data to and from the lockbox. This enables sensor data, keypad data, alarm data, and power data to be relayed to the user. Additional, wireless connectivity options were explored for the use of this project but the use of WiFi succeeded due to its signal reliability through barriers. Other explored options saw drastic decrease in signal reliability from obstructions. This presents a problem since our product is designed to be used most likely on a front porch. This being said there will either be a wall or door blocking direct view to the box and the signal needs to be reliable in order to ensure a good user experience and accurate data. Furthermore, from Figure 2 below the WiFi chip itself which is actually just below the quarter is almost equivalent in size to the quarter. This allows for a compact design which helps to lower cost and maximize the internal storage of the lockbox itself.

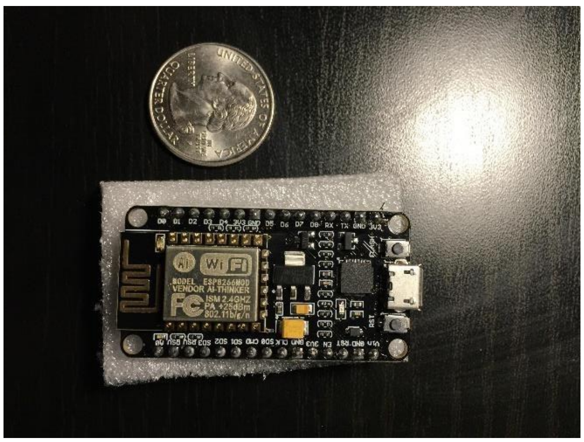

Figure 2. Size of WiFi Module Compared to Quarter

D. Lid Sensor

The lid sensor serves to provide a method to detect forceful entry. So long as the proper keypad password is entered the lid sensor does not trip the alarm. However, if for whatever reason the lid sensor is opened and the keypad password was not entered the alarm will trip and send a notification to the user.

E. Alarm

The alarm will serve as an additional theft deterrence. Upon hearing an alarm in most cases all but a determined thief will leave the scene. The alarm will be loud enough to be easily heard by an owner indoors as well as to startle and cause concern in a potential thief. The main method of triggering the alarm will be from output data of the IMU. If data from the IMU passes a threshold level it will trigger the alarm for 30 seconds or until deactivation by the primary user. The alarm can be deactivated by the mobile app, website, or by entering the primary user's saved key entry.

F. Keypad

The keypad will serve as the primary method of entry. We are using a 3x4 keypad which contains digits 1-9. The keypad will be connected to an analog pin and through the use of voltage divider the voltage on the pin will be measured to determine which key is being pressed. The key values and their corresponding register voltages can be found in Table 3 below. Upon the user entering the correct key sequence the lockbox will unlock. A primary user lock override may be implemented from the website or mobile app in case of issues or damage to the keypad. Upon 5 unsuccessful keypad entries the lockbox will notify the primary listed user. All keypad saved entries must be 4 digits long.

Key Value	**Register Voltage**
1	0.1 V
2	0.3 V
3	0.5 V
4	0.7 V
5	0.9 V
6	1.1 V
7	1.3 V
8	1.5 V
9	1.7 V

Table 3. A Table of Key Values and Register Voltages

G. Backup Battery

The backup battery will be two lithium ion polymer batteries in series. Each battery is 3.7 V providing a total voltage of 7.4 V of total power. The purpose of the backup battery is to ensure functionality of the box when primary power is lost. This could be for a number of reasons. User error could cause the box to be unplugged from primary power.

Attempted theft could also cause the box to become unplugged. If a thief were to unplug the box in an attempt to disable alerts while he/she tried to steal the contents the backup power would notify the user that the box has become unplugged and allow other alerts to still be transmitted.

H. Solenoid Lock

The solenoid lock serves as a mechanical component to keep the box locked and secured. Upon the keypad receiving the proper password the solenoid lock will disengage and allow entry to the user. Due to the design of the solenoid lock it will allow closing without issue but will catch if it is attempted to open without inputting the proper keypad. The solenoid lock can be seen in Figure 3 below.

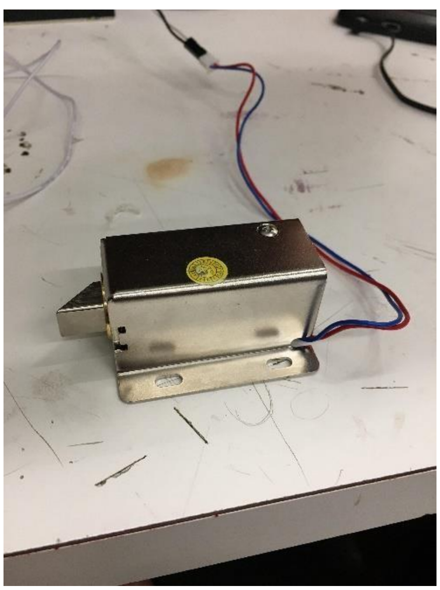

Figure 3. Solenoid Lock

A summary of all of the hardware components along with their interactions between each other can be seen in Figure 4 below. So long as the battery is plugged into primary power the system will operate under normal conditions. If the system goes unplugged it will switch to secondary power along with sending an alert to the user. If any of the components (keypad, lid sensor, IMU) go past their thresholds an alert will be sent to the user.

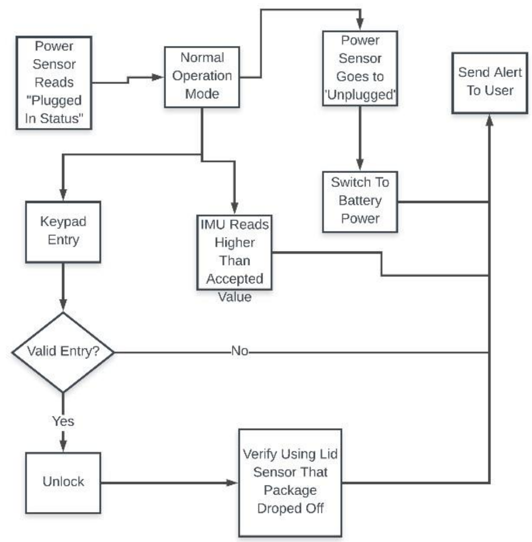

Figure 4. Hardware Flow Diagram

IV. SOFTWARE

The software of the project aims to ensure the reliability of the product while maintaining ease of use. This will be done through the use of a website using email as the primary form of communication. There will also be a mobile application which will serve as a secondary form of communication of the user chooses to download the application. The mobile application will be available to both iOS and Android users.

A. Website

The website serves as the primary way of setting up the Smart Package Lockbox. Upon initially getting a Smart Package Lockbox the user will receive a product key. After visiting the website and creating a login the user will proceed to add a lockbox. From here if the product key they enter matches a currently unused lockbox in the database the lockbox will activate and they will become the primary user. Next, the primary user will have to set up an access code which will originally be the first 4 numbers of their product key. After these steps the basic setup is over. More advanced options such as secondary keypad passwords can be added but are not necessary. Also, the user can add their phone number for text notifications if they so choose but the only necessary method of communication for initial setup is the email. The website homepage can be seen below in Figure 5.

Figure 5. Website Homepage

B. Firebase Realtime Database

Firebase realtime database was chosen as the method of storing user information. The database is real time so it will update quickly from user changes and input. This will allow the data sent from the lockbox to be visible and interpreted by the user. The database will also store the lockbox ID for initial setup when the user first gets the lockbox. Data will also be pulled from Firebase to be viewed on the website when the user wants to access lockbox data. This data that will be stored includes the alarm state, keypad passwords, the lid state, and if the box is connected.

C. React Native Mobile Application

The React Native mobile application will be developed for users who are on the go. As the main reason behind the design of the project is for users that are not home at the time of their deliveries. This being said they will most likely not have a computer on the go to access the lockbox. The solution to this is our mobile application. React Native was used in order to build one application and port it to both an Android and iOS application. This will allow for almost all users to be able to download and use the application. If we were to just do an Android or iOS app we would lose out on roughly half of all users. The mobile application will serve as a secondary form of access with more basic and relevant information for the user. The user will not have access to certain settings or options available on the website.

V. Project Testing

The project testing can be broken down into hardware and software tests. The individual hardware components were connected to the MCU and tested using the Arduino IDE. The values were monitored using the serial terminal to ensure proper functionality. As the pieces were individually tested the code was manipulated to incorporate all components simultaneously without issue. Alone the components worked fine but when all put together we needed to ensure that one function or delay was not interfering with the proper operation of another component. A visual of the hardware connections can be seen in Figure 6 below.

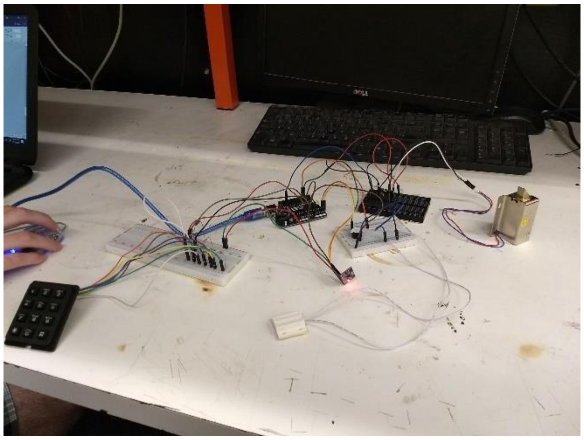

Figure 6. Hardware Connected to Arduino Uno

The software testing incorporated the WiFi module as well as the website, Firebase database, and mobile application. The WiFi module was initially set up and then tested with connection to the database. Similarly, the website and mobile application were developed and tested with integrating to the database.

VI. CONCLUSION

In conclusion, the aforementioned materials and methods were required in order to complete the requirements of this project. The Smart Package Lockbox will be an easy to use and affordable alternative to the available options currently on the market. All the current options lack in at least one of 3 major categories: ease of use, affordability, or security. Our Smart Package Lockbox will excel in all 3 of these categories.

VII. ACKNOWLEDGEMENT

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VIII. REFERENCES

i. *Arduino - Software*, www.arduino.cc/en/Main/Software.

ii. Basrai, Murtaza. “Top 10 Editors For React Native Mobile App Development.” *Icicle*, 9 Sept. 2016, www.icicletech.com/blog/top-10editors-for-react-native.

iii. “Mobile Operating System Market Share Worldwide.” *StatCounter Global Stats*, gs.statcounter.com/os-marketshare/mobile/worldwide.

iv. *Pocket AVR Programmer Hookup Guide*, learn.sparkfun.com/tutorials/pocketavr-programmer-hookup-guide/usingavrdude.

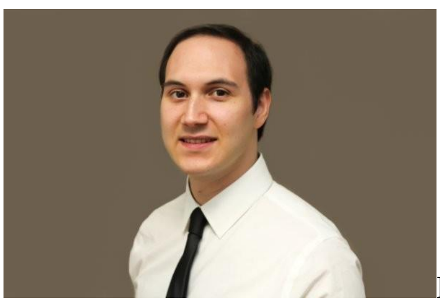
v. “ATmega328P Datasheet.” *Microchip*, ww1.microchip.com/downloads/en/De viceDoc/Atmel-42735-8-bit-AVRMicrocontroller-ATmega328328P_Datasheet.pdf.

vi. Tawil, Yahya. “Understanding Arduino UNO Hardware Design.” *All About Circuits*, 1 July 2016, www.allaboutcircuits.com/technicalarticles/understanding-arduino-unohardware-design/.

vii. “AI-3035-TWT-3V-R Datasheet.” *Puiaudio*, www.puiaudio.com/pdf/AI-3035-TWT3V-R.pdf.

IX. BIOGRAPHY

Dominic Amalfitano is a Computer Engineer receiving his Bachelor in Computer Engineering in July of 2018. He hopes to pursue a successful career at a well-known engineering company in Orlando, FL.

Daniel Corredor is a Computer Engineer receiving his Bachelor in Computer Engineering in July of 2018. He will be pursuing career options and plans to move to North Carolina with his wife within the next year.

Brandon Dziewior is an Electrical Engineer receiving his Bachelor in Electrical Engineering in July of 2018. He plans to pursue a career out of the state of Florida.

Michael Light is an Electrical Engineer receiving his Bachelor in Electrical Engineering in July of 2018. He plans to continue employment at a well-known engineering company in Orlando, FL.