Anti-Package Theft Locking System

Improving the Last-Mile: Eliminating Package Theft through Delivery Codesign

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Electrical Engineering

By

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November 1, 2021

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Since the late 1990s, the upward trend in e-commerce sales has brought increases in package theft (*E-Commerce Retail Sales as a Percent of Total Sales*, 2021; Risher et al., 2020). At a rate of 1.7 million packages stolen and missing daily, porch piracy is a widespread problem that has impacted up to 36% of Americans (*Protect Against Porch Piracy*, n.d.). To reduce delivery costs and supply chain strain while increasing convenience, retailers and delivery services primarily use unattended deliveries; however, this leaves packages vulnerable to theft (Stickle et al., 2020). Porch piracy is a problem for consumers in rural and urban areas who lose time and money to package theft and retailers that may have to choose between losing or reimbursing customers (Stickle et al., 2020). This technical capstone project focuses on developing a tiered-access locking system to address delivery theft. This product uses a master code, along with one-time and time-limited passcodes, to permit access to a door, package slot, or package box in order to conceal and protect packages. While there are some existing ideas to prevent package theft, most are not prevention measures; instead, these inadequate solutions are for delivery tracking and porch monitoring. Delivery tracking offsets responsibility onto the consumer, and porch monitoring allows consumers to prove theft and receive compensation for their losses. Currently, there is a disconnect between consumers and delivery services in the last-mile delivery supply chain due to their distrusting relationship, which leaves packages vulnerable to theft. Delivery services and consumers can develop a mutually beneficial solution to address package theft and streamline last-mile delivery. By applying the framework of users and sociotechnical systems, this research will investigate how delivery

services can work with consumers to prevent package theft and increase supply chain integrity.

Technical Topic

E-commerce retail sales have steadily increased since the late 1990s, placing large strains on the last-mile supply chains that deliver packages to consumers' front doors (*E-Commerce Retail Sales as a Percent of Total Sales*, 2021; Commendatore, 2020). As retailers and package delivery services search for ways to handle these pressures, their solutions must address increasing package thefts. Unattended package delivery has created a disconnect between consumers and package delivery services, leaving an opportunity to eliminate package theft and improve the consumer experience through promoting communication between these parties.

The anti-package theft locking system aims to tackle the problem of doorstep package thefts. This technical research project is part of the Capstone Design course at the University of Virginia's Charles L. Brown Department of Electrical and Computer Engineering. The project selection criteria include project difficulty, problem addressed, and skills utilized from electrical engineering courses. The design criteria include power consumption, a $500 budget, lock and unlock functions, a backup power source, and current and voltage overload protection. A tiered access system, keypad, integrated camera, electric strike, and web application enable multi-level user access. A primary user, presumably a resident, has a master code that enables full access and system control. There are also one-time use codes sent to delivery drivers for access to a secure package

drop-off: inside a door, package slot, or package box. Upon pressing a button, the integrated camera records the delivery process until the system returns to its locked position. After which, these recordings transfer to the cloud, which the user can access from the web application. Additionally, the web application will handle secure passcode generation and management for the keypad and will timestamp lock and unlock operations. This web application serves as the user interface so that the primary user can seamlessly integrate this anti-package theft solution into their last-mile delivery experience. Figure 1 shows an abstracted diagram of the system.

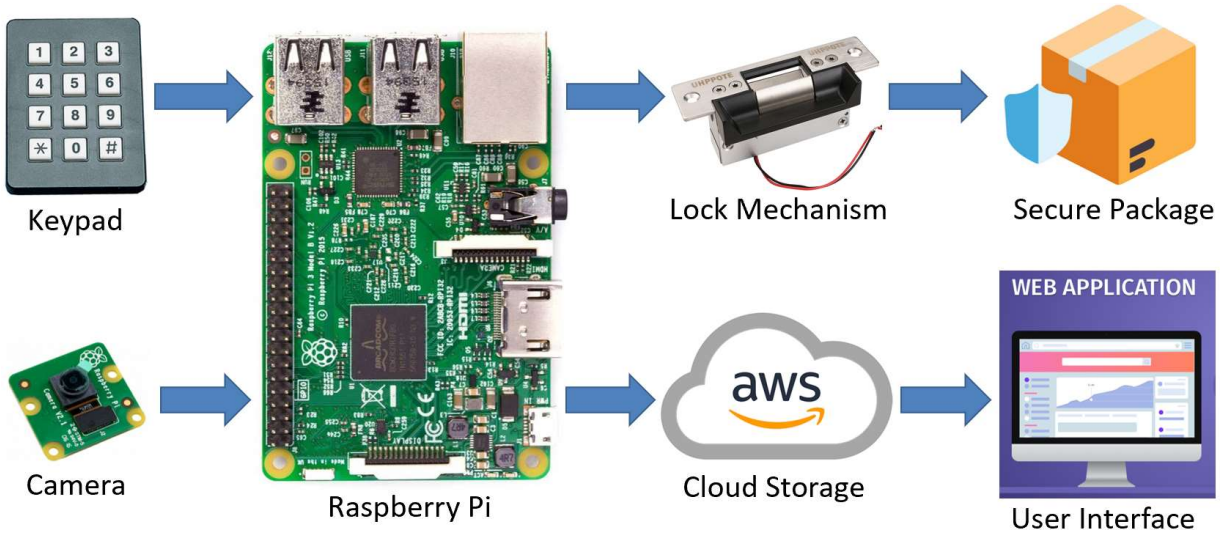

Figure 1. System Block Diagram

My responsibilities for this project include circuit design, electronic component selection, printed circuit board layout, and testbed development and integration. Because of my background in circuit design and electronic devices, I am heading the electrical hardware development and demonstrating the intended operation of the integrated system. The main constraints of this project are: relying on the house's main power line,

implementing a backup power source for power outages, and developing a trustworthy design to ensure package safety and consumer adoption.

There are existing package lockers and keypad lock solutions; however, these package lockers reside away from a consumer's house, resulting in significant time and distance obstacles to obtaining the package. Keypad locks are intended for a single user and do not support multi-level access, so there is only one passcode at a time, and passcode modification is complex. Amazon Key is a service bundle that is most similar to the anti-package theft locking system. This system allows Amazon delivery drivers to secure a package in the user's garage; it records the package delivery process and comes with a mobile application user interface. While this system has many similarities, it only works for Amazon deliveries, and there are numerous instances of Amazon deliverers stealing packages (*Amazon.Com: Amazon Key | In-Garage Delivery*, n.d.; *Atlanta Woman Says Video Shows Amazon Driver Stealing Package*, 2021; Archive & feed, 2020; Hoggard, 2019). Although Amazon offers delivery protection for those that use Key, the anti-package theft locking system is far more versatile in application, as it can work in conjunction with all retailers and delivery services.

So far, the project team has completed the circuit design, a demonstration of locking and camera hardware, secure passcode generation, the passcode management system, and video upload to the cloud and web application. In the coming weeks, the team will receive the manufactured printed circuit board, integrate the hardware and software, and test the locking system to demonstrate intended behavior.

Improving the Last-Mile: Eliminating Package Theft through Delivery Codesign

With the transition toward e-commerce retail, there has been increased pressure placed upon package delivery supply chains and more opportunities for package theft (Commendatore, 2020). This research explores improving last-mile delivery through the framework of Sociotechnical Systems and Users, where the user—in this case, the e-commerce customer—is inspected in the process of developing new solutions that involve the consumer and the sociotechnical system (Hess & Sovacool, 2020). This research proposes a codesign methodology, where the package delivery services change the last few feet of the delivery process based upon the designs of e-commerce customers (Edmunds et al., 2013).

Tallbear and Edmunds's work with a codesign methodology reveals several key factors to incorporate in a last-mile delivery codesign process and reasons to apply this framework in designing solutions. Most importantly, this work presents codesign as a way to "Engage an array of stakeholders ... with different knowledge, skills, and experiences, as well as different resources, sources of power and prestige, and interests in the project" (Edmunds et al., 2013). By incorporating consumers as active participants in the design of sociotechnical systems, the codesign process aims to produce an optimal solution that incorporates the end user's needs, but it is not without potential issues. When applying a codesign methodology to the package delivery process, delivery services must understand the differing consumer frameworks, communication styles, and relationships with last-mile delivery parties. Additionally, these parties must recognize that it is "Easy to slip back into a public consultation process," which differs from the codesign process suggested and will

lead to ineffective solutions (Edmunds et al., 2013). Developing an understanding of the parties involved is critical to harness the benefits and minimize the downsides of the codesign process.

Vakulenko et al. investigated the consumer response to including parcel lockers in last-mile delivery and came to many valuable conclusions about interaction with service innovations. However, package lockers are not ideal for addressing package theft because they are located away from consumers' residences and are incredibly sparse in rural areas. A more suitable solution to package theft should emphasize user convenience in both rural and urban areas. Other parties in the package delivery process must understand the consumer desire for package security and delivery convenience and realize that the retailer and delivery service are equivalent in the eyes of a consumer. Additionally, new technologies in the delivery process will increase consumer expectations and concerns, and the initial interaction with the product will determine the consumer's decision to use this product (Vakulenko et al., 2019).

On the other hand, retailers and delivery services want to increase profits and market share. Last-mile supply chains rely heavily on unattended package delivery. This practice reduces delivery costs by an estimated 50% and is convenient for all parties involved when it works correctly; however, it does not protect against package theft. The average stolen package costs approximately $200. Depending on the situation, either a consumer, retailer, delivery service, or insurance company will bear the costs, so addressing package theft is of utmost concern to parties involved in the delivery process (Stickle et al., 2020). Additionally, delivery drivers want a streamlined drop-off process, and

law enforcement does not want to expend resources investigating package theft. After understanding the desires of each of these groups, it is apparent that the parties involved stand to benefit from improvements to last-mile delivery, which will drive them to participate in a codesign process.

Upon acknowledging each party's motivating factors, the codesign process requires the characterization of porch piracy. Package theft is a significant issue in all parts of the country—urban and rural. This crime mainly occurs during the day and close to a road, so packages are visible. These parcels are typically medium in size and include branding (Stickle et al., 2020). The key takeaway from the findings of Stickle et al. is that thieves target easy marks. The package theft process includes three phases: entry, execution, and exit. The most straightforward path to ensuring package security is introducing a new product that disrupts entry and execution. The key to this is concealing the package in a convenient, hidden location, reducing package branding, and incorporating monitoring and sound systems to deter the intruder (Stickle et al., 2020).

The codesign methodology is ideal for addressing package theft, given the delivery failure points—package branding, size, convenience, and visibility—and the involved parties: consumers, retailers, delivery services, delivery drivers, and law enforcement. Retailers and delivery services desire package branding as it is a relatively inexpensive marketing strategy and product differentiator; it is also an avenue for generating advertising revenue. However, it increases the likelihood of package theft, meaning it positively impacts retailers and delivery services and negatively impacts consumers and law enforcement. Codesign offers an avenue to learn about the effectiveness of package

branding from consumers. Companies can quickly eliminate ineffective package branding, but if deemed beneficial overall, branding may remain on parcels as this is the least likely determinant of package theft (Stickle et al., 2020). In the case of effective branding, last-mile solutions should focus more on size, convenience, and visibility. During the codesign process, retailer and delivery service data on parcel size and consumer input on residential integration will determine the appropriate size of the final product. Large packages are hard to steal discreetly, so the codesigned solution should focus on small and medium packages (Stickle et al., 2020). The most apparent solution to package visibility is a sealed storage area that is preferably locked. Codesign will result a streamlined solution for package drop-off by the delivery driver and package retrieval by the consumer in the case of a locked storage solution.

Codesign is essential to creating a solution to the package theft issues that currently plague last-mile delivery. Communicating the possible failure points of delivery and desires of parties involved with last-mile delivery will lead to a more appropriate solution to package theft. Increased delivery convenience, package security, and trust in e-commerce will create positive outcomes for consumers, retailers, package delivery services, delivery drivers, and law enforcement (Vakulenko et al., 2019).

Next Steps

The team will complete the technical project during the Fall 2021 semester. In the coming weeks, the assembled printed circuit board will arrive. After which, I can continue working on my primary responsibilities: circuit testing, testbed development, and hardware integration. The team is finalizing the web application integration and keypress detection algorithm. We will complete hardware-software integration and testing after the assembled printed circuit board arrives. Figure 2 shows the current GANTT chart for the technical project.

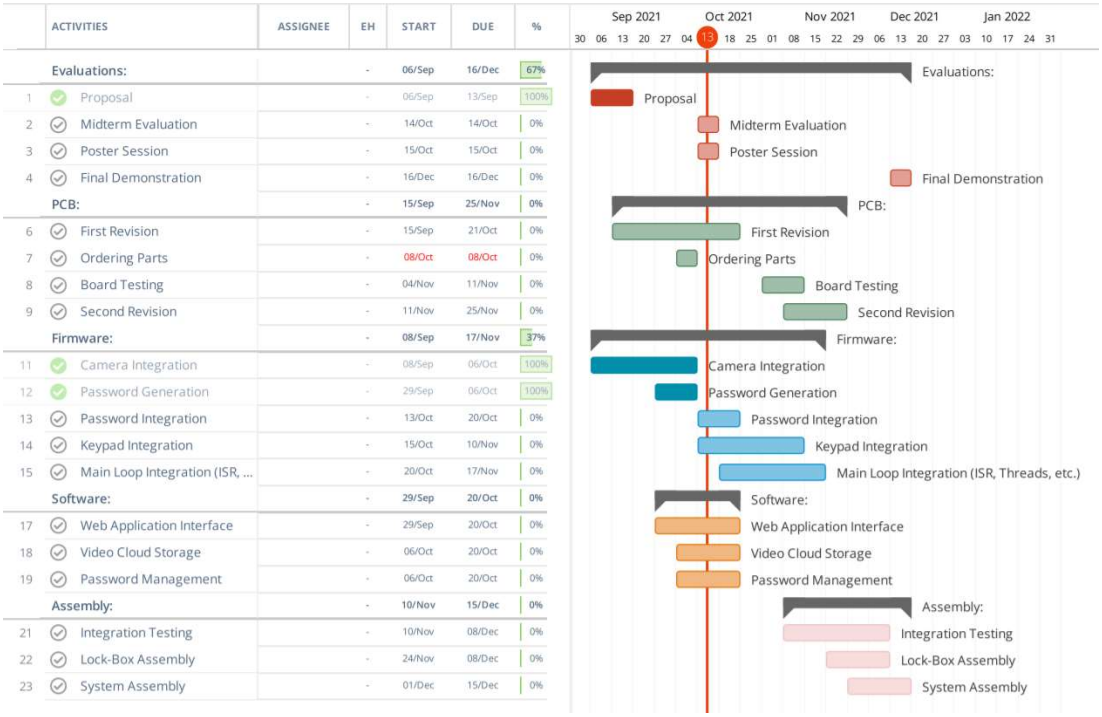

Figure 2. Technical Project GANTT Chart

For the STS project, future research will further analyze potential pitfalls in applying this codesign methodology to a new industry and system. More precisely, further research

will determine the impact of profit considerations, codesign approval, and production feasibility related to retailers and delivery services. I will also consider consumer and delivery driver response if retailers and delivery services have the final say in codesign approval and product features. Another future consideration is group selection for codesign, which will investigate proper sample selection and how to develop a product that addresses the problems of all parties involved, not just those in an urban setting or of a particular socioeconomic status, for example.

An additional strategy to advance this research will come from the continued investigation of how companies enroll consumers to combat theft in brick-and-mortar retail, cybersecurity, and surveillance. Finally, I cannot execute a codesign methodology, so I will determine the most critical elements and trade-offs of the codesign process in its application to address package theft issues.

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