Design of a Low-Cost, Low-Power Smart Lock

Analysis of the Digital Dakota Network

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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

The term "digital divide" refers to unequal access to digital technology within a society (Brown, 2020). Throughout the last decade, global phenomena have shown just how destructive this concept can be. For example, during the COVID-19 pandemic, communities with lower levels of access to telecommunications struggled to keep up with a world that became digital overnight (Roese, 2021). As technology becomes more sophisticated and more integrated with our society, the digital divide within our societies is likely to expand, leading to an even greater degree of inequality than currently exists. The question then is, how do we continue to innovate while avoiding the expansion of the digital divide?

Through the use of digital communication and algorithms, smart locks provide users with a sense of convenience and security that simply cannot be provided by traditional locks (*How Do Smart Locks Work and Are They Safe*, n.d.). This convenience and security comes at a price however. Popular smart locks cost around $250 dollars, and require complete replacement of the current lock and a persistent WiFi connection to function (Graham, 2022). Adoption in low-income communities is unrealistic, leading to the expansion of the digital divide. To address the downfalls of current smart lock technologies, I propose the development of a smart lock system that is low-cost, low-power and does not require the replacement of the current lock, and by extension a persistent WiFi connection. In order to create a system that provides similar benefits to a set of diverse communities, I will draw on the STS framework of technological momentum to analyze the role that broadband internet access played in the initial challenges encountered by students using the Digital Dakota Network. More specifically, I will examine how broadband internet started shaping educational initiatives, and how communities on the wrong end of the digital divide struggled to adapt to new, digital forms of education.

While technical innovation is a leading factor in the adoption of smart locks, a nuanced understanding of the digital divide that can be created by a technology is needed to facilitate widespread adoption. A smart lock design that fails to consider social factors and caters only to affluent communities will only expand the digital divide, and lower-income communities will struggle when the technology shapes society in the future, as was the case with broadband internet and the Digital Dakota Network. In the next two sections of this paper, I examine in detail a technical proposal for a low-cost, low-power smart lock design, and an STS proposal for a project which analyzes the failed adoption of the Digital Dakota Network. As I work on both the proposed smart-lock and STS analysis, I will apply insights from the study of the Digital Dakota Network to formulate a design that is accessible and low-cost, that innovates while not expanding the digital divide.

Technical Project Proposal

The proposed low-cost, low-power smart lock aims to provide a customizable, open-source security solution for existing physical locks. Current iterations of the smart lock concept have produced products that work exceptionally well, securing users' homes by connecting Internet of Things (IoT) devices to secure servers through reliable communication protocols, which effectively manage and maintain the lock's status (*How Do Smart Locks Work and Are They Safe*, n.d.). However, this convenience comes at a high price point. Existing smart locks typically cost around $250 and almost always require replacing the current door lock (Graham, 2022). Consequently, access to one's home is solely reliant on an internet connection and not a physical key. Furthermore, many existing systems operate with proprietary protocols and hardware, limiting the degree of customization possible. This results in inflexible and expensive smart lock systems that are unlikely to gain widespread adoption, particularly in lower-income communities.

Compared to existing systems, the proposed solution is open-source and offers a substantially lower price point. More importantly, the Low-Cost, Low-Power Smart Lock (LCLPSL) is designed as an attachment for existing physical locks rather than a replacement. This means that a physical bypass, in the form of a traditional key, remains available, enabling users to maintain control over their locks even in situations with unreliable connectivity. **Figure I** below illustrates the high level design of the LCLPSL.

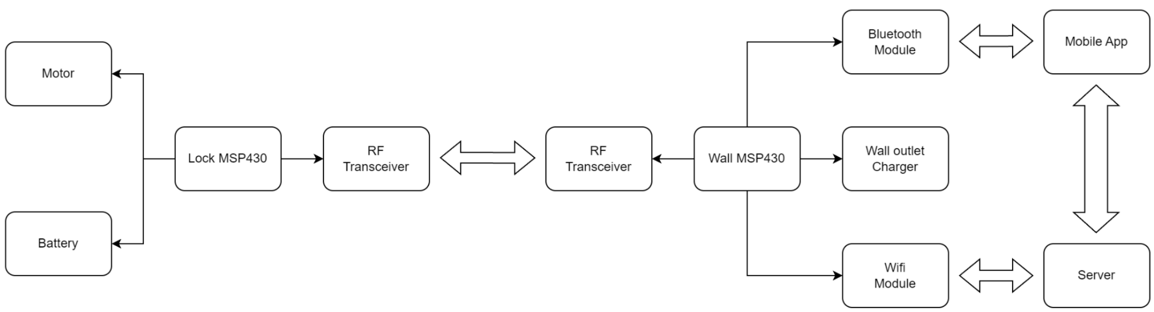

Figure I. LCLPSL High Level Design

Overall, the design is very lightweight and can be broken down into four subsystems. A brief description of each subsystem and its functionality is found below,

1. Mobile app: Serves as the user interface for interacting with the lock(s)
2. Web server: Maintains and transmits requests for altering the state of the lock
3. Wall controller: Receives and relays requests generated by the server
4. Lock controller: Uses a motor to physically change the state of the lock

The four distinct subsystems mentioned above will engage in communication with each other by employing low-power techniques and non-proprietary protocols. During setup, the mobile application will establish communication with the wall controller through low-energy Bluetooth. Communication with the server will be conducted using HTTPS, which ensures encryption and permits customization, given that it is a widely accepted, non-proprietary protocol (Cloudflare, n.d.). The interaction between the two controllers will occur via RF signals (radio frequency communication). Additionally, both controller devices will operate in a low-power mode when not actively engaged in communication, thereby reducing energy consumption and supporting long-term use.

The overall system comes at a cost of approximately $25, which is roughly one-tenth of the price of existing systems. The communication protocols employed, as mentioned above, use encryption to ensure the security of data transactions. Additionally, the underlying code is entirely open-source, enabling users to customize their systems to their specific requirements. Lastly, as previously mentioned, given that this is an extension for a traditional lock rather than a replacement, the same physical key remains compatible with the lock even after the installation of the LCLPSL.

Much like any user-facing system, the success of the LCLPSL will heavily rely on user feedback. As the system is being developed by a team of four students in ECE 4991 during the Fall '23 semester, it will undergo thorough user and technical testing to refine its design. Initial technical tests have indicated the necessity for an abstracted user library for chip programming, allowing users to customize their locks without needing to possess an extensive amount of knowledge on microcontrollers or programming. As the Fall '23 semester draws to a close, a prototype of the system will become available for testing, allowing for the collection of additional user experience data.

STS Project Proposal

In April 2002, Governor Bill Janklow of South Dakota issued a statement, proclaiming the advent of a new digital era of learning for students in South Dakota schools (Office of the Governor of South Dakota, 2002). The promise was that students in the state's public schools would have the opportunity to embark on a "virtual field trip" to learn about hurricanes, facilitated by a state-supported infrastructure known as the Digital Dakota Network (DDN) (Office of the Governor of South Dakota, 2002). However, nearly a decade after this promise was made, students at the rural Arlington School still found themselves having to "work around their slow connectivity" while accessing online content (National Telecommunications and Information Administration, 2014). Schools still did not have enough broadband capacity to let students use their own laptops, and as a result some "South Dakotans [were] left behind" (Office of the Governor of South Dakota, 2023). This raises critical questions: How did a promise go unfulfilled for an entire decade? What led to the significant digital divide between urban and rural students in South Dakota?

Current analysis of the struggles of the DDN points to the lack of broadband infrastructure as the root cause (South Dakota Governor's Office of Economic Development, 2023). Even as recently as 2019, South Dakota's governor stated that "lack of broadband" is a "big problem to tackle" (Noem, 2019). While true, this claim fails to take into account the amount of time the state had to build supporting infrastructure for the DDN. The DDN is not a project that was materialized overnight. The continuing struggles of the DDN are a result of the state's failure to realize the momentum accumulated by broadband technologies. Due to this failure, the state put off the construction of critical infrastructure projects which led to the current lack of access to broadband in a lot of the state's rural areas and schools (National Telecommunications and Information Administration, 2014). Viewing the struggles of the DDN as a symptom, as an effect of the lack of broadband infrastructure in the Dakotas, will prevent scholars from seeing what had been developing in the Dakotas for decades. In modern societies, there is no simple cause-and-effect relationship between society and technology; the relationship is two-way. The society of the Dakotas was influencing and being influenced by its technological infrastructure long before the struggles of the DDN. Additionally, and more concretely, failing to realize the momentum of technologies such as broadband will lead the state into similar mistakes in the future. State-supported programs will continue to attempt to utilize infrastructure that has not been fully built out, and the cycle will continue. Such mistakes are particularly costly because they transform the digital divide into a more concrete divide of knowledge and opportunity.

In contrast with current analysis of the struggles of DDN adoption, I argue that it was the state's failure to recognize the influence of broadband technologies over society that led to the struggles of adoption, rather than the lack of infrastructure itself. To frame my analysis, I will draw on the science, technology and society (STS) concept of technological momentum (Hughes, 1969, 106 - 132). Technological momentum refers to the theory developed by Thomas P. Hughes used to examine and contextualize the complex relationship between technology and society over time (Hughes, 1969, 106 - 132). In his theory, Hughes claims that once a particular technology becomes ingrained in society, it develops a momentum of its own, influencing and shaping social structures, behaviors, and expectations (Hughes, 1969, 106 - 132). Technological momentum highlights the challenge of redirecting technological development once a certain path has been established. Using technological momentum, I will examine the relationship between broadband internet and society and how this relationship altered both digital and knowledge divides in the case of the DDN. In addition to investigating broadband technology, I will employ the concept of a reverse salient to analyze why the DDN content delivery mechanism failed to provide equitable access to online educational material in South Dakota. The term "reverse salient" refers to a component of a technological system, in this case, the DDN, that prevents the system from functioning as expected due to its insufficient development.

To substantiate my analysis, I will rely on a wide range of news articles and government reports that document the adoption and associated struggles of the DDN from 2002 to 2015. More specifically, my sources will include press releases from the Governor's office and updates on the DDN from local newspapers. In order to effectively utilize the concept of technological momentum, I will require data on broadband infrastructure spanning the same time period. An invaluable resource in this regard is a case study report released by the National Telecommunications and Information Administration, which specifically focuses on South Dakota's network infrastructure during that time frame.

Conclusion

The proposed deliverable for the technical project is a low-cost, highly customizable smart lock designed for widespread adoption. The STS project will investigate the initial challenges faced by the Digital Dakota Network during its early adoption phase. Through the lens of technological momentum, this analysis will explain how the failure of South Dakota to realize the momentum of broadband technology resulted in the expansion of both digital and knowledge disparities across the state. Insights gained from the STS project will aid in constructing the proposed security infrastructure to be both innovative and widely adopted. Finally, the combination of findings from both the technical and STS projects will serve as a guideline on how to design innovative solutions for modern problems without contributing to the digital divisions in society.

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