**Thesis Portfolio**

**Smart Medication Organizer**
(Technical Report)

**The Internet as a Social Artifact: How Widespread Internet Access May Hinder Developing Nations**
(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Sairathan Rajuladevi
Spring, 2021

Department of Electrical and Computer Engineering

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**Sociotechnical Synthesis**

Matters of technological dependence and its societal implications must be carefully examined and researched across the world. Human reliance on technology is difficult to avoid given the rate of advancement in the world, and constant research must be conducted on technological impacts in society and culture. In many circumstances, technological dependence can benefit society, but as quickly as the advantages arise so can the consequences.

The technical paper details the design of an embedded smart medication organizer, which tracks medication dosage through convenient organization and timed reminders to signal which medications to take consistently. The embedded smart medication organizer was designed to ease the burden of keeping track of several medications which must be taken at certain times of the day. Given that there can be serious health consequences if a medication is neglected, the consistent tracking of prescriptions was achieved by the creation of an embedded medication tracker to store user medication information in a single device. The medical organizer tool has compartments for up to 6 types of medication, and the user is notified by the LEDs and screen to take from the given compartments at a given time. The value of the safely dispensing prescriptions in society is profound, with the embedded smart medication organizer delivering on key promises of data privacy, dosage consistency, and affordability.

The STS research topic focuses on issues surrounding wireless technologies and Internet access in developing countries. Given recent technological advancements in connectivity to developing countries, worldwide initiatives have been put in place to counter the divide between Internet access in impoverished and prosperous areas. However, while the Internet is often portrayed as an empowering tool with the potential of ushering in a new era of development, it could actually hasten unanticipated consequences to impoverished areas already burdened with hardship. Through actor-network analysis and a utilitarian ethics framework the paper discusses issues surrounding the digital divide between Internet access in developed and developing regions and evaluates the costs of increased Internet access in developing nations hidden by the category of economic growth.

The concepts brought up by technical paper and the STS research paper are bound together by the topic of technological dependence. While the STS research paper addresses the much larger influence of worldwide Internet access compared to the technical paper's medical influence, the reliance that exists from technological growth is a common trait between each. Both the smart medication organizer and the Internet had different deliverables, but taught me that the sociotechnical systems play a major role in technology development and analysis

**Smart Medication Organizer**

A Technical Report submitted to the Department of Electrical and Computer Engineering

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Sairathan Rajuladevi
Fall, 2020

Technical Project Team Members
Forrest Feaser
Quin Helfrick
Sean Davidson

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

Signature Sai Rajuladevi ______________________ Date 4/22/2021
Sairathan Rajuladevi

Approved ________________________________________ Date __________
Harry Powell, Department of Electrical and Computer Engineering

**6 Ohms Apart**

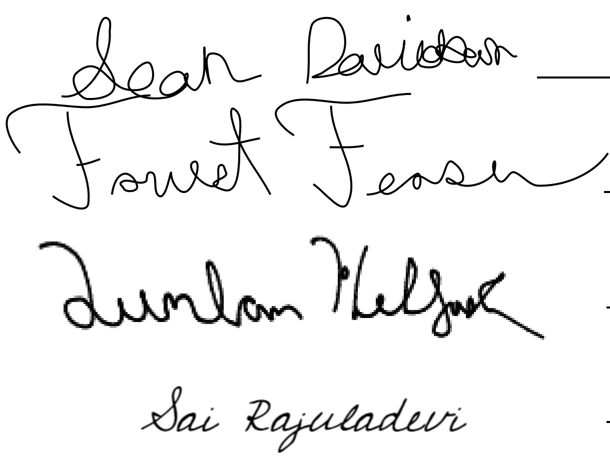
**Smart Medication Organizer**

*Sean Davidson, Forrest Feaser, Quin Helfrick, Sai Rajuladevi*

December 10, 2020

## Capstone Design – ECE 4440

## Signatures



Sean Davidson

Forrest Feaser

Quin Helfrick

Sai Rajuladevi

## Statement of work:

***Sean Davidson***

My primary responsibility was the manufacturing of the physical wooden box that would serve as the housing for the Smart Medication Organizer. Additionally, I worked with Sai on the front-end software before switching to Anvil. I used LightBurn laser engraving software to design and send instructions to the laser engraver making the components of the box. I then assembled the organizer after having designed a second container based on issues with the first design creating the final one used in this project. For the front-end software I primarily assisted Sai with the initial conceptual work in Python including a simple GUI and encryption. Eventually due to Sai's research we moved the project over to Anvil allowing for a more visually appealing GUI and streamlined design process.

***Forrest Feaser***

My primary responsibility was embedded software development and networking. I also helped Sai with the front-end software and worked with Quin on integrating and testing the MSP software, the driver software, and our PCB. With respect to the embedded software, I designed and implemented the primary lifecycle algorithm and data structures for our device, which included the storage, scheduling, and handling of medication events. I used the Wi-Fi booster pack to connect our device to a local network and the internet. I implemented the UDP server, added AES decryption, and designed the packet structure that our user application would use to communicate with the Smart Medication Organizer. I implemented the real-time clock module alarms and interrupts and configured it with a time server query on startup. On the client-side, I added AES encryption to the medication data packet and implemented input validation for the user data. During testing, I worked with Quin to debug software and hardware errors in the device and to film the final demonstration.

***Quin Helfrick***

My primary responsibility was the PCB design and testing. I worked with Sai to select the screen, speaker, and LEDs for the device. I referenced the manufacturers' datasheets to choose suitable resistors, capacitors, and other components to design a PCB capable of powering the system. I implemented an I2C interface to the LED controller to set the color and intensity of each LED. I wrote a small library using the SPI protocol for the EVE3 to display information on the screen and play sounds on the speaker. I tested the PCB and made revisions to the design as necessary. Additionally, I worked with Forrest to integrate the driver software into the control algorithm, resolve issues with the hardware, assemble the device and film our demonstration.

***Sai Rajuladevi***

My primary responsibility was the front-end software and user-interface design. I coded a Python socket script with Forrest and Sean, and coded and designed a front-end user interface with the Python based Anvil framework. I added error checking on the front end, and enabled an uplink from the Anvil server to connect and interface with the Python socket script, which made it so that the packet could be sent directly from the front-end software. I ensured that the packet being sent to the microcontroller via the UDP socket was in the correct output format specified by the network packet structure, and designed the WebApp so that the IP address is configurable.

In terms of specific website functionality, I built the user interface to use a modifiable Python medication list with add/remove/edit buttons, and converted the list to the packet specifications outlined by Forrest in the UDP packet structure. Additionally, I added a send to box button which would send data to the microcontroller based on a configurable IP field. Lastly, I assisted Quin in the initial stages of the project with choosing parts.

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## Abstract

The Smart Medication Organizer (SMO) is a wirelessly programmable, internet-of-things device that assists in the consistent self-administration of pharmaceuticals by patients, in order to reduce nonadherence. To accomplish this goal, the SMO provides timed auditory and visual indications to signal to the user to take their medications. The device encompasses a screen, a speaker, a wall outlet power supply, a microcontroller, and six medication compartments, each with an LED. The electronics are located inside an aesthetically pleasing wooden box to hide the details from the user. The device connects to a user's wireless local area network, where it can be reached from the user's personal or mobile device through a web application. The web application allows the user to configure when they need to take which medications, which compartment each medication is in, and dosage information. This information is encrypted to protect the user's data privacy and then sent to the device, where events are scheduled based on the information provided. When it is time for the user to take their medication, the speaker plays a sound to draw the user's attention, the LEDs indicate in which compartment the medication to take is located, and the screen displays other necessary dosage information. The user can stop the sound and LEDs by pressing an okay button to confirm they have taken their medication, and the next medication event will be scheduled automatically. The device is a compact, easy-to-use, and affordable solution to unintentional nonadherence.

## Background

Medical nonadherence is a patient's failure to sufficiently comply with a medical treatment regimen, which has been linked to 125,000 unnecessary deaths and $100 billion in health care costs each year in the United States alone [1]. Nonadherence can be intentional or unintentional, and it can vary in severity, but, altogether, the World Health Organization found that about 50% of patients do not adequately adhere to their prescribed medications [2]. The SMO targets the main causes of the unintentional nonadherence, namely forgetfulness or a complicated treatment regimen, with respect to pharmaceuticals [3].

Some simpler devices have been designed to target unintentional pharmaceutical nonadherence, including a pill box with a compartment for each day of the week or a pill bottle cap with a time-since-last-opened display, but patients who had access to these devices showed no notable improvements [4]. The SMO is a more comprehensive solution, as it actively prompts its users to take their medications.

There are a few commercial devices which are similar to the SMO, but our device has several advantages. The SMO is much simpler to fill than the MedMinder pill dispenser [5], as it has six compartments that are differentiated by type of medication, rather than twenty-eight separate compartments which the user must painstakingly fill with the medications they will need to take for each day. In addition, MedMinder's setup does not allow medications to be taken at different times during the day, whereas ours does. Furthermore, the SMO is lightweight and compact, while the MedaCube pill dispenser [6] is the size of a large coffee maker and thus unwieldy. Finally, the SMO is more affordable than mass-market pill dispensers. For example, the MedaCube costs $1,399 upfront, and the MedMinder requires a monthly subscription of $50. In short, the Smart Medication Organizer will be easier to use and maintain, more portable, more affordable, and, ultimately, more effective than other solutions.

The SMO project drew heavily from our coursework in the ECE curriculum. We used our knowledge of electronics, signals, and systems from the FUN series (ECE 2630, ECE 2660, ECE 3750) by designing a PCB to interface the hardware elements of our device (screen, LED driver, speaker, voltage regulator) with the microcontroller. Our project used an embedded microcontroller (ECE 3430) to drive the hardware, and we used our knowledge of data structures and algorithms (CS 2150, CS 4710) to design the control logic. We used our software development skills (CS 3240) to design a front-end web application to configure the device. We used our knowledge of computer networks (CS 4457) to create a wireless link between our device and the user application. Finally, we used our knowledge of cybersecurity (CS 3710) to encrypt the data transmission between the device and the web app to ensure our users' data privacy.

## Constraints

### Design Constraints

The constraint that affected us the most was time constraints on part availability. Towards the end of the semester, we broke our Wi-Fi chip and our screen, and we had to wait several days for them to ship from Digikey and could not make much progress during that time. Another limitation we had on parts was only being able to order two PCBs. After our first PCB did not work as intended we had to determine what was wrong with it and ensure that everything would work for the second board.

We would have liked a longer time to work on the project to develop some more advanced and complete features (some of which are mentioned in the Future Work section), but the shortened semester limited the scope of our project. Additionally, two of our team members were remote this semester, which reduced their capacity to help with the testing of physical parts and electronics.

When creating our device enclosure, the size of the box was constrained by the size of the parts, e.g. screen, microcontroller, PCB, that needed to fit inside of it. Conversely, we created the box a certain size so certain parts could fit, which made it difficult to change parts after the box had already been assembled.

We did not face many CPU constraints in our embedded environment as the MSP432 had much more processing power than we needed for our application. However, we did face some constraints in terms of software availability. We chose to use AES encryption because the MSP already had a library built-in. If we wanted to use a different type of encryption we would have had to implement it ourselves which would have taken a lot of extra resources. Furthermore, we were constrained by the need to communicate with a user application and considering what would be the easiest way for users to interact with our device. We were practically forced to use Wi-Fi communication, rather than say Bluetooth, because almost every user would have immediate access to Wi-Fi.

For the PCB, we were constrained by the minimum trace width, part spacing, and via size as specified by the PCB manufacturer. We were also constrained to a 2-layer PCB design in order to have our board produced in the class send-out.

Finally, we were constrained by our knowledge of front-end software. This led us to choosing Anvil as a development tool, as we found that it was an easy and quick way to get an aesthetic user interface running. In addition, we needed to be able to send custom UDP packets to a remote IP, and we found that many JavaScript frameworks that run exclusively in a browser did not allow for this. Anvil allowed us to separate our networking control from the UI itself. A specific constraint of the network implementation is that the socket script is required to be run in real time with the Anvil front end to ensure that the data is sent to the microcontroller. Without an uplink connection made between the development environment and the Anvil UI, the packet will not be sent to the microcontroller. To combat this, in production the interface and Python script would be hosted on specialized servers to make it easier to connect to the device and safely store user data. The user interface would then be optimized without the current setup time required to ensure that the UDP socket is linked.

### Economic and Cost Constraints

The budget allotted for the project was $500 of which we spent $434.84. The budget limited our selection of screens and possible iterations of the device. We had significant costs associated with the PCB assembly and miscellaneous parts, which contributed to nearly half the total budget at $218.68. Other major expenses were the microcontroller unit, Wi-Fi booster pack, and screen. The cost associated with assembly meant that the team had limited possible iterations of the PCB to create a working prototype. Therefore certain possible avenues of design were avoided to not potentially require more iterations than economically feasible. For example, buying the MSP and Wi-Fi booster pack pre-assembled was deemed more feasible than trying to create a PCB for a processor manually, as this would require more iterations to get right and would thus result in the overextension of the budget.

## External Standards

There were several external standards that influenced the design of our smart embedded medication organizer. By the Code of Federal Regulations, Title 47, Part 15 by the Federal Communications Commission [7], the device would be classified as an unintentional radiator, which is restricted by the radiation power above 9 kHz without a license. Additionally, the device uses parts that will not radiate with enough power above 9 kHz to interfere with other electronics, so we do not need a license.

The SMO communicates with the user configuration app via Wi-Fi which is regulated by IEEE 802.11 standards [8]. We chose the TI CC3120BOOST Wi-Fi booster packer for our board knowing that it complies with the wireless standards and would allow us to easily implement our wireless functionality.

The IPC sets multiple standards for the production of PCBs including track and component spacing as specified in IPC-2221A [9]. Additionally, IPC-A-600F [10] sets standards for solder masks, through holes, materials, plating, and other elements of PCB design that are utilized by the device.

The National Electrical Manufacturers Association [11] imposes standards on the enclosures that can be used for electronic devices, most notably placing restrictions on the types of materials that can be used and the qualities of those materials. The current state of our enclosure does not meet these standards for safety in many conditions. If the device were to go into production we would examine these standards more closely to ensure product safety.

The SMO uses AES-256 encryption [12] to secure the configuration info as it is transmitted wirelessly to the device. The embedded software and user software use libraries that comply with the standard in order to implement the encryption and in order to ensure that we would adequately protect our users' privacy.

The HIPAA federal regulations on data privacy for medical information, which are found in CFR § 164.306 [13], are followed, considering that our device will need to gather private medical information of its users to track their medications. Additionally, the health information is only stored locally on the device, and is transmitted through encryption when the user is programming the device, which ensures "the confidentiality, integrity, and availability of all electronic protected health information [that a system] creates, receives, maintains, or transmits."

## Tools Employed

KiCAD [14] was selected for its large library of symbols and footprints and the ability to import new ones, and was used to create the schematic for the device and layout the PCB. We had no prior experience with KiCAD but previous experience with similar software allowed us to quickly adapt to it. Code Composer Studio (CCS) [15] was used to develop the embedded software and debug the SMO during testing. We were familiar with CCS from our embedded programming class. We used GitHub [16] to maintain version control for our embedded software and user application. This allowed us to easily share our code and enabled us to work on separate features in parallel and seamlessly integrate our changes. We were familiar with Git from our coursework in software development. The Anvil [17] Python framework was selected for the WebApp development project due to its customizable components feature. This allowed us to drag and drop certain user interface components required for the project, such as a send to box button, and an add/remove/edit medication button/subcomponent. Anvil has an easy deployment feature with an uplink feature to a chosen integrated development environment, so the user interface was successfully paired to Python socket code. We had no prior experience using the environment; since the application and components were coded in Python, it made it fast to debug any errors and address any missing functionality. Lightburn Software [18] was used to send design information to a laser engraving machine when manufacturing the container. Lightburn was a required software package to use as it is the only software which communicates with the particular laser engraver used. Lightburn has advanced and basic functionality such as align horizontal, alight vertical, optimize, and laser intensity/speed which allow for economically use of materials to create the box. For testing the hardware, we utilized a Digilent Analog Discovery 2 [19] and a National Instruments Virtual Bench [20], both of which used to provide an external power supply and monitor voltages, waveforms, and digital signals. We had plenty of prior experience with these devices from our previous electrical engineering classes. Additionally, a Texas Instruments USB2ANY [21] device was used to send and receive digital signals. We had no prior experience with this device but its user interface and documentation were simple to understand.

## Ethical, Social, and Economic Concerns

### Sustainability

We can consider the environmental impacts of our device in three phases of its life cycle: production, operation, and end-of-life. Production is the process of manufacturing the device which may involve machinery that emits greenhouse gases and consumes energy. We are not very concerned with the sustainability impacts of this phase because our device is not meant to be mass produced in great quantities so there would be little impact. During the operation phase, the only environmental impact of our device would be its electricity consumption to power the screen, microcontroller, LEDs, and speaker. We are not very concerned with the sustainability impacts of this phase either because the device draws little power compared to most other consumer electronics, and it would use even less after it was optimized for production. The end-of-life phase elicits the most concern with respect to sustainability. Our device has several electronic parts, some of which contain environmentally toxic heavy metals. Thus, our device needs to be disposed of properly when it is no longer useful. We recommend that our users dispose of our device at designated electronic recycling stations, which are often managed by local governments.

### Health and Safety

Our device has a few health and safety concerns. One possibility is that the embedded software in our device could malfunction and prompt a user to take less or more than their recommended dosage of medicine, which could lead to health consequences. We have designed our software so that this should never happen, but this would need to be discussed in a liability agreement with our users. A safety issue with our prototype is that it is made out of a wooden (i.e. flammable) box and the electrical connections are not as clean and protected as one might like, which could lead to a fire or an electric shock. However, this would be taken care of if our device ever went into production as we would make the device out of a stronger, less flammable material and the electronics would be condensed and tested comprehensively for safety.

### Manufacturability

We believe our device would be well-suited for manufacture. The most challenging part would be the production of the enclosure. It would need to be made from some sort of plastic moulding, and then have the electronic parts installed inside of it. Since we have a custom PCB that manages the power and the LED controller, it would need to be manufactured separately. All of the other electronic parts (microcontroller, LEDs, screen, and speaker) could be purchased from other manufacturers and wired into our device. If our device were to truly go into production, we expect that there would be some significant changes in our design to make the device more compact and eliminate the excess power consumption from the microcontroller, in addition to changing the material of the enclosure.

### Ethical Issues

Ideally, the SMO will improve society by helping its users consistently take their medications, which will allow them to live longer, healthier lives, if they properly adhere to their medication regimen. The SMO will alleviate the user from constantly having to keep times, dates, and dosages on their mind allowing them to focus on whatever their given task at hand is. A particularly useful case for the organizer is situations in which the person whom the medication is for has a difficult time remembering to take their medications and requires the aid of another person. The SMO not only helps the person who needs to take medications but also assists the other person in being a caretaker.

We believe our device is ethical because it does not discriminate against any particular person. The device will function the same assuming the user provides the proper information regardless of the background, race or economical status of the user. The purpose of the device is to provide people with a quality of life improvement which is reflected in the design, programmability, and adaptability of the product.

Our team does not believe there would be a large economic impact from our device. Instead, the SMO affects the users by making sure medication is taken on time, which prompts healthier living. Healthier living does not guarantee but allows for improvements in other aspects of life such physical fitness, mental health and general contentedness with one's life. Through these potential advantages associated with healthier living from proper usage of the SMO the user will be more likely to work and improve upon themselves which may affect them economically.

In addition, our device transmits personal user information, which may include medication names and dosages, across a wireless network. This has the potential to leak private medical information to malicious actors if it is not properly handled. Our device is meant to be used on a private network, but to ensure the security of our users' information we encrypt all the configuration data that is sent to the device using AES-256 encryption before it is transmitted. For our prototype, we just had one encryption key, but if we had many users we would have a key for each user, which we would store securely with the servers for our web app. For the prototype, the encryption key was hardcoded into our microcontroller, but if the device were to go into production we would ensure that the key does not appear in code and we would store it securely on the device. Furthermore, in production we would also need to implement asymmetric public key encryption to get the symmetric key to the device when the user first activates it.

## Intellectual Property Issues

Our team has come to the conclusion that the Smart Medication Organizer in its current state would most likely not be patentable. The justification comes from the following patents which we will discuss: US7440817B2: Method and control unit for medication administration devices [22]; US9381139B2: Pillbox, medication management system and medication dispensing system [23]; and US9211233B2: Interactive medication dispensing system [24]. We will refer to them by the following names for the reminder of the section US74, US93 and US92 respectively. US74 is a patent on a container that intelligently helps the user by automatically scheduling events such as guided filling of the device, determining a schedule, and creating a medication storage map. The device described in this patent is similar to our team's SMO such that it has programmed scheduled events that remind the user on when to take their medications. Differences between US74 and SMO is that SMO does not guide the user in filling the container and SMO requires the user to manually map the medication. US93 is a pillbox style storage device with detachable storage compartments, automated medication dispensing and medication reminder system. The similarities between US93 and SMO are that both are pillbox style storage devices, have a reminder system and are manually loaded by the user. Differences between US93 and SMO is that US93 has detachable storage containers connected side-by-side with only one being allowed to open as determined by the reminder system. US92 describes a device that uses visual and audio cues for reminders, uses illumination of compartments and has a system for reminding when medications need to be refilled. The similarities between US92 and SMO is that both are a pill box style device, both use audio, visual, and illumination of compartments to aid in the reminding process.

Specific claims for the patents are the following: for US74 claim 1 is "A method for programming and controlling scheduled events for at least one object." This claim is independent and includes all limitations to program the patented device. US93 claim 1 is "A pillbox comprising a plurality of pill receiving compartments detachably connected with one another in side-by-side relation." This claim is also independent including all the information necessary to define the invention of a pillbox medication organizer. US92 is a continuation of another patent "U.S. patent application Ser. No. 12/606,643, entitled INTERACTIVE MEDICATION DISPENSING SYSTEM" and extends upon that patent's claims. US92 specifically is about the dispensing system including the body and communication system of the device. This claim is dependent on the main claim which it extends US92 describes in detail the housing and programming of the device which has the most relation to the SMO. Thus, the SMO does not convingly differ from the claims made by patents US74, US93, and US92 such that our team does not believe SMO in its current form is patentable.

## Detailed Technical Description of Project

The objective of our project was to design an IoT smart container for timed pharmaceutical medications which illuminates the corresponding compartment, gives dosage information, and presents medication names based on user configurable information. The technical details of the device are described in the following sections: Hardware, Embedded Software, User Software, and Device Enclosure.

### Hardware

The hardware consists of the main PCB, MSP432P401R launchpad [25], CC3120BOOST wifi booster pack [26], and the EVE3 display module [27]. The main PCB is powered via a 5V DC wall adapter and contains the LED controller, audio amplifier, power system, and connections to the launchpad and display module.

### Schematics

The schematics were designed using KiCAD and the schematic in Figure 1 shows the overall connections between the major components of the device. The MSP432P401R launchpad was selected due to its built-in debugging capabilities, hardware SPI and I2C interfaces, compatibility with the CC3120BOOST wifi booster pack, and our overall experience with it. The EVE3 display module was selected as most screens at our target resolution of 848x480 use a 24-bit RGB interface requiring more pins and more complex signalling then could be reasonably executed, whereas the EVE3 provides an SPI interface to the BT81x coprocessor [28] that handles the screen and speaker.

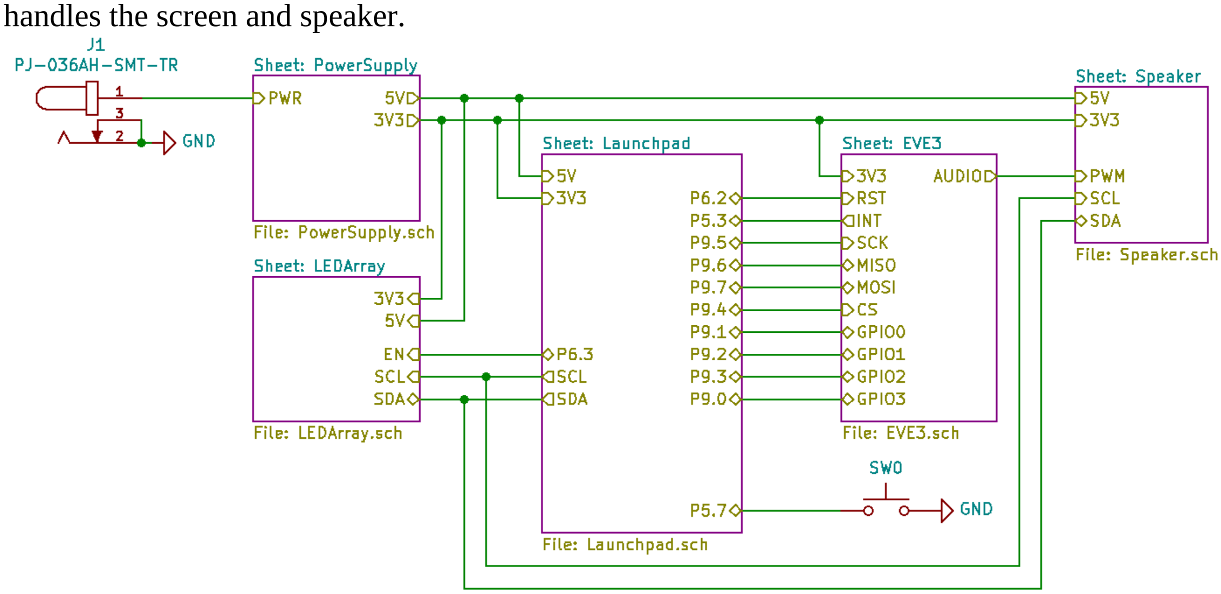


**Figure 1: Full Schematic**

The goal of the power system was to take the incoming 5V supply voltage from the wall adapter and provide a 3.3V supply rail to power the MSP432P401R, CC3120BOOST, and the

EVE3 display module. This is accomplished with the use of a TPS62827 buck converter [29] as shown in Figure 2. The output voltage of the buck converter is set with an external resistor divider using the formula $R_1 = R_2(V_{out}/0.6V - 1)$. The remaining bypass and filtering components were taken directly from the manufacturer's recommendations in the datasheet.

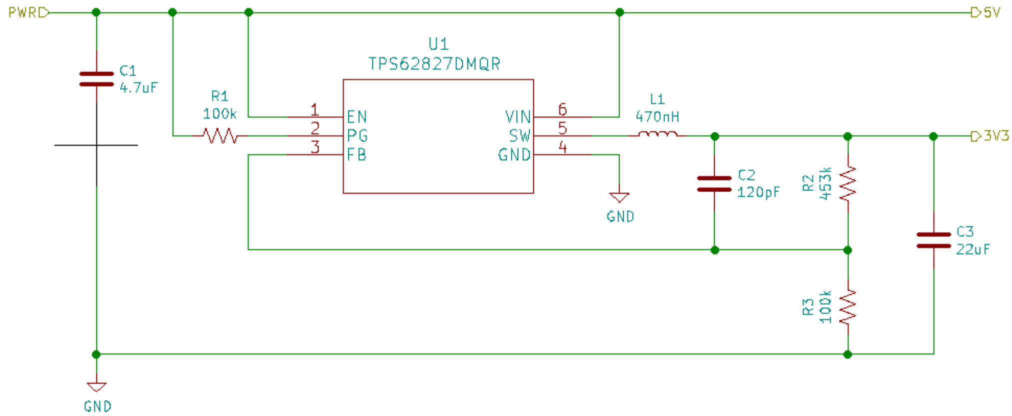


**Figure 2: Power Supply Schematic**

The LED system was designed to offload the complex calculations required to simultaneously control the color and intensity of the IN-S128TATRGB [30] LED's via PWM to a specialized LED controller. The LP5018 [31] was selected for this task due to its I2C interface and 18 outputs capable of independently setting the brightness of each of the 6 LED's 3 colors. To control the maximum current through the LED's a PVG3A103C01R00 potentiometer was used to allow finer control of the maximum brightness of the LED's. The bypass capacitors were taken directly from the manufacturer's recommendations in the datasheet.

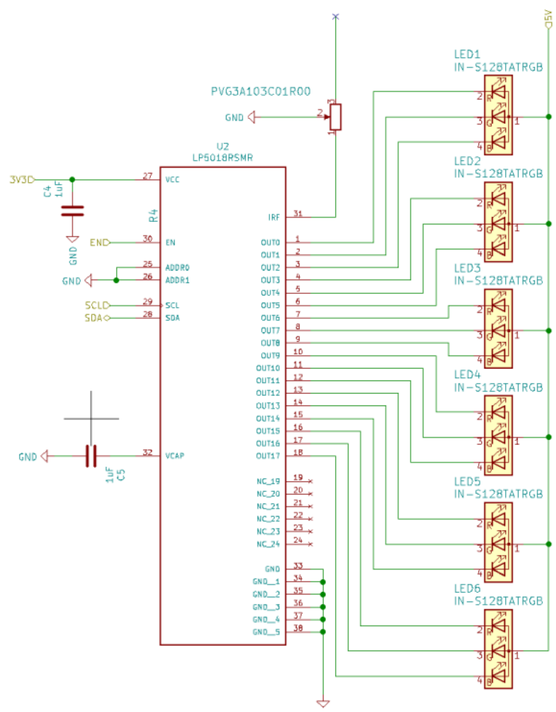


**Figure 3: LED Controller Schematic**

The audio system was designed to take the incoming PWM signal from the EVE3 display module and amplify it using the LM386 [32] audio amplifier to power the speaker. The design makes heavy use of the reference designs provided by the manufacturer to allow for software control of the gain and overall volume of the circuit as well as an optional bass boost via the MCP4451 [33] digital potentiometer's I2C interface. Ultimately the default value of 5k Ohms was sufficiently loud for our purposes and the volume control was instead left to the EVE3 module.

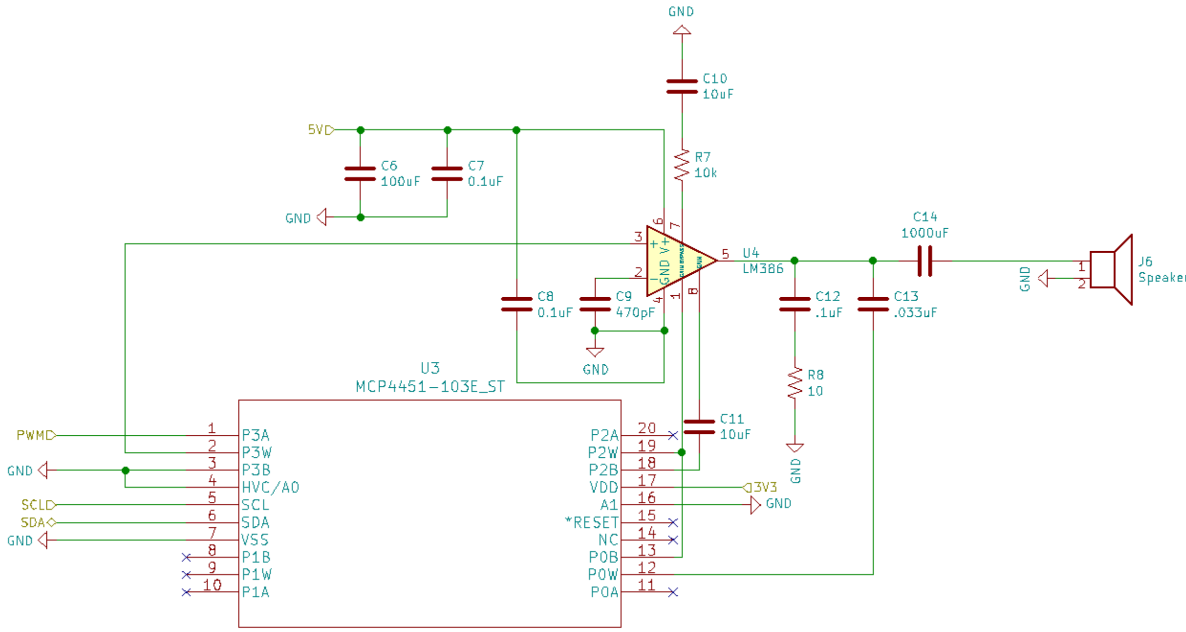


**Figure 4: Audio Amplifier Schematic**

## PCB Design

The PCB layout was designed using Pcbnew in KiCAD. The PCB is a 2-layer design with the top layer containing all of the surface mounted components and peripheral connections as well as the power traces and the majority of the signal traces. The bottom layer primarily acts as a ground plane with a few signal traces where necessary. Figure 5 shows the final layout of the board.

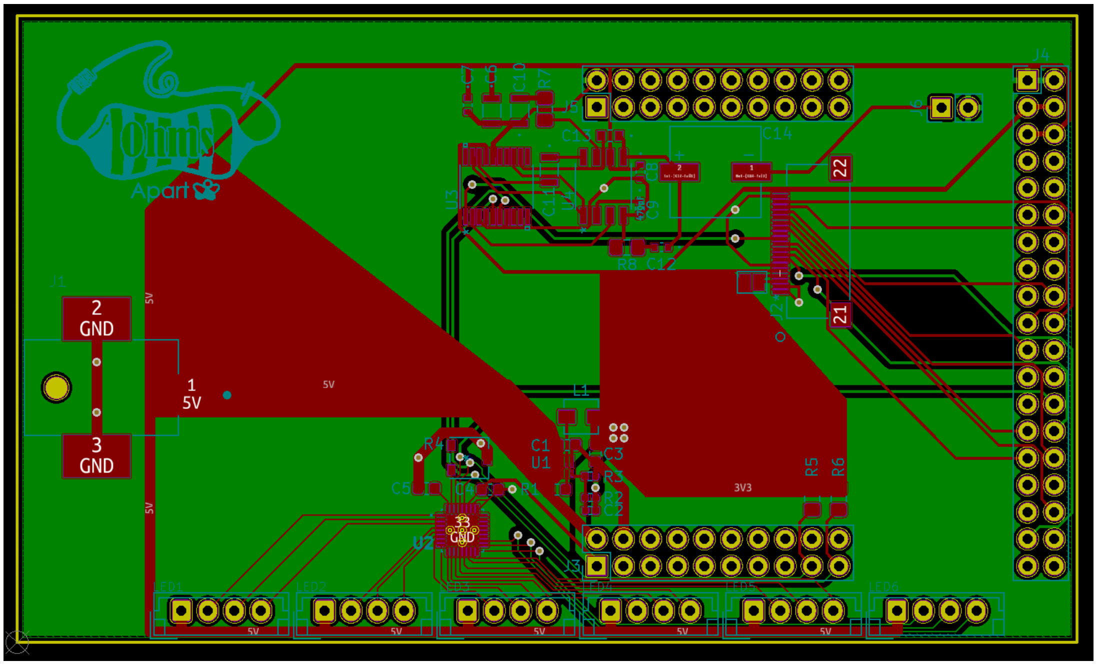

**Figure 5: Full PCB Layout**

The layout of the audio amplifier is shown in Figure 6. It was designed with the goal of creating a compact layout that minimized any noise in the audio signal that could interfere with the sound output.

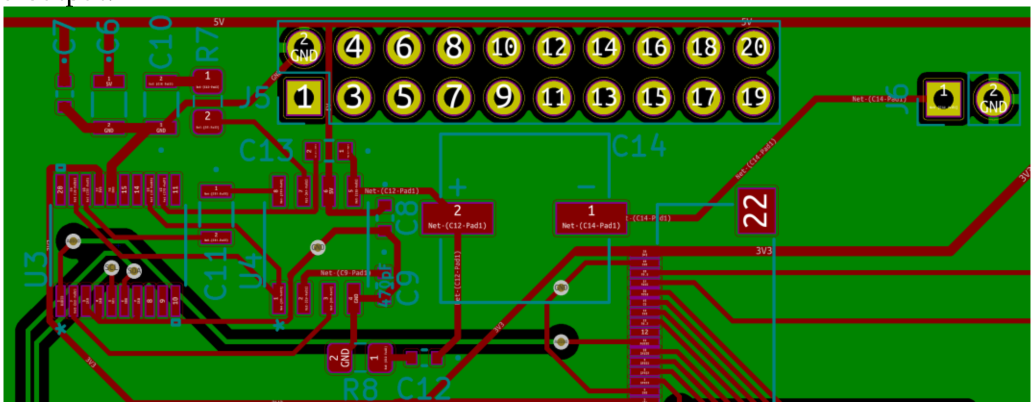

**Figure 6: Audio Amplifier PCB Layout**

The layout of the LED controller and power supply are shown in Figure 7. The layout of this part of the board including the large power planes and vias was taken directly from the manufacturers recommendation shown in the datasheet of the TPS62827.

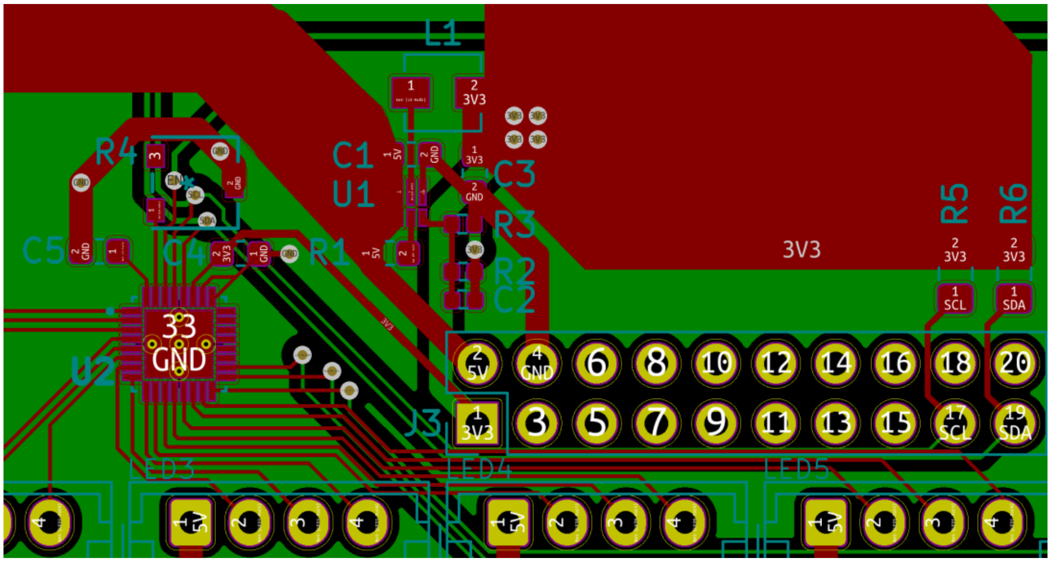

**Figure 7: LED & Power System PCB Layout**

## Embedded Software

The embedded software was controlled by the MSP432P401R microcontroller and the CC3120BOOST wireless networking booster pack. The software was divided into several modules: Wi-Fi connection, real-time clock (RTC) management, user configuration server, hardware drivers, and medication information management and lifecycle. The resources were managed by the TI-RTOS real-time operating system and many of the TI MSP432 SDK APIs were leveraged to simplify implementation.

When the microcontroller is powered on, the device connects to the user's wireless local area network using hardcoded login information and is assigned an IP address . (We would have liked the Wi-Fi connection to be initiated from the client-side, but the limited nature of the semester restricted some of the advanced features we had hoped to implement). Once the device is connected to the internet, it queries a remote time server and starts the RTC module with the current time information. The RTC module configures two interrupts: one that triggers every minute and updates the time/date on the screen and one that is triggered by an alarm which can be set in the RTC module. Additionally, after connecting to Wi-Fi, the device opens a UDP server that can be reached by the user application. When the server receives data it decrypts the packet using AES-256-ECB encryption and validates the input and then updates the device's medication information. The server expects the packet to be organized as follows: 1 byte to indicate how many medication events, $n$, the packet contains, followed by $35n$ bytes for the medication event data. Each medication is encoded as: 1 byte for the hour to take, 1 byte for the minute to take, 1 byte for the how many to take, 1 byte for which compartment the medication is in, 1 byte for the length of the med info spring, and 30 bytes for the med info string. The screen driver communicates with the screen (EVE3-50A) via SPI. The driver allows the SMO to display the date, time, and medication info. The screen also controls the PWM output to the speaker (SP-3020), which allows the SMO to start and stop the sound and manipulate the volume and pitch. The LED driver communicates the LED integrated circuit (LP5018) via $I^2C$, which controls the six RGB LEDs (IN-S128TATRGB) on the SMO. The SMO can turn on and off any of the individual LEDs and set the color and brightness.

The main SMO control logic algorithm is described as follows: When the UDP server receives a valid medication info packet, it clears any previous data that was set and stores the information contained in the packet. Then, the SMO finds the event which most closely follows the current time and schedules an RTC alarm for the event's time. When the alarm occurs, the SMO activates the LEDs specified by the event and sounds the speaker to signal to the user that it is time to take a medication. The SMO also displays the medication dosage and info string on the screen. The user can press the button (40-2388-01) to acknowledge the event and turn off the speaker and LEDs, or the event will timeout after 5 minutes. The next event is automatically scheduled when one occurs, and the whole process repeats indefinitely while the device is powered. The flow chart in Figure __ below depicts this process.

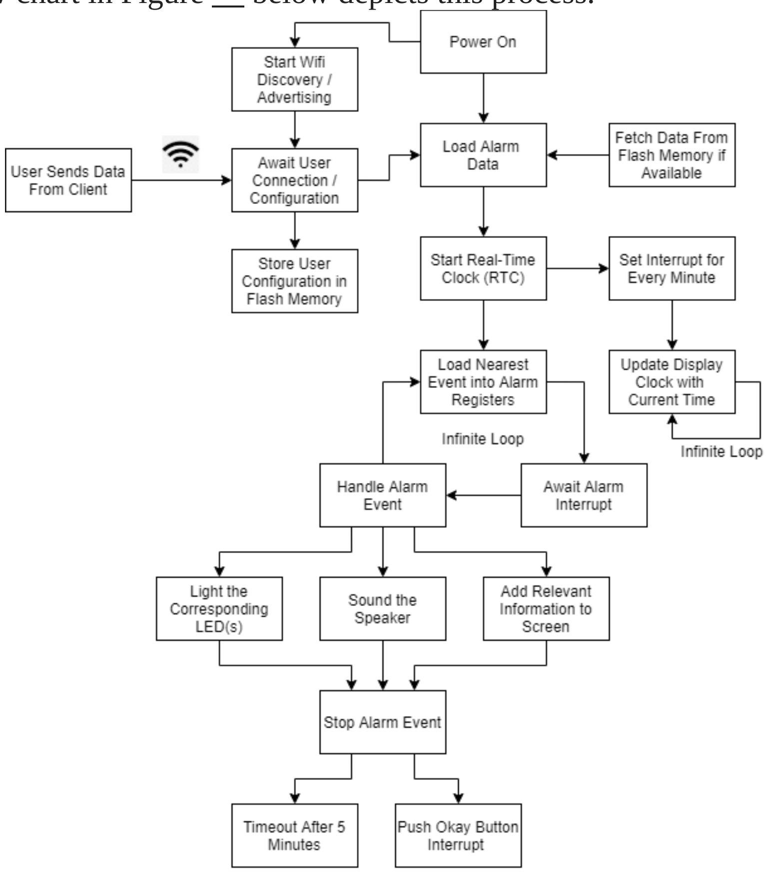


**Figure 8: Embedded Software Main Control Flow**

## User Software

The user software's purpose was to send a configuration packet to the SMO via a UDP websocket. The packet structure is depicted below, which was the basis of the Anvil WebApp components and Python code.

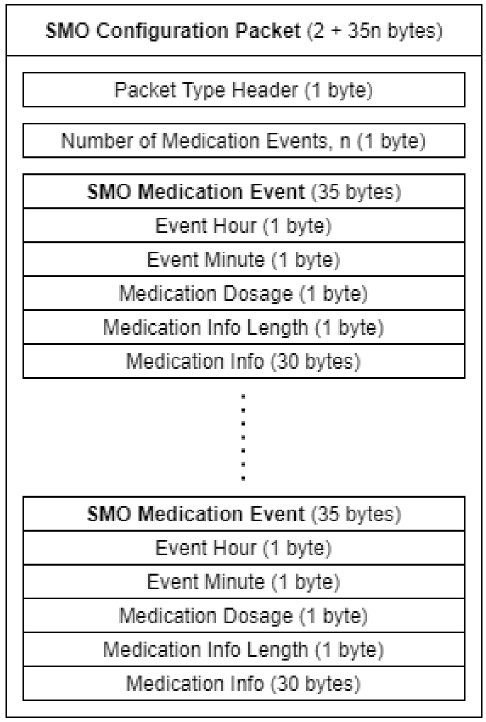


**Figure 9: SMO Configuration Packet Structure**

Using the Anvil Python framework, a user interface was developed to populate the fields of the SMO configuration packet structure. The interface features a simple data table that interacts with server code via an Anvil row template. The row template is part of a form structure that is linked to the data table directly, so any data on the form is updated instantly as changes are made. Shown below is the table once sample data is inputted/edited on the main WebApp page.

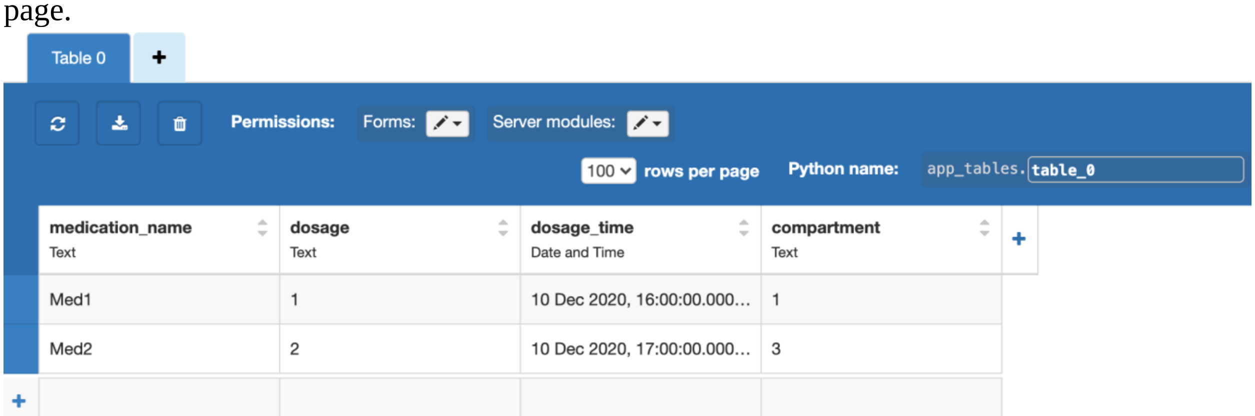


**Figure 10: Anvil Data Table Service**

Once the data table was set up, add and delete buttons were linked to the data table to add or delete a row of data specified by the front end form. An "add medication" header field and medication list component were linked to the data table to display the rows/current data of the data table. Using the Anvil data structure allowed the data to be edited directly in the form, which would then modify the data table instantly as changes were made. A configurable IP address field was then added, and a "send to box" button was added which would link to the

Python socket code using the uplink Anvil functionality. Shown below is the final WebApp user interface, with all the aforementioned components.

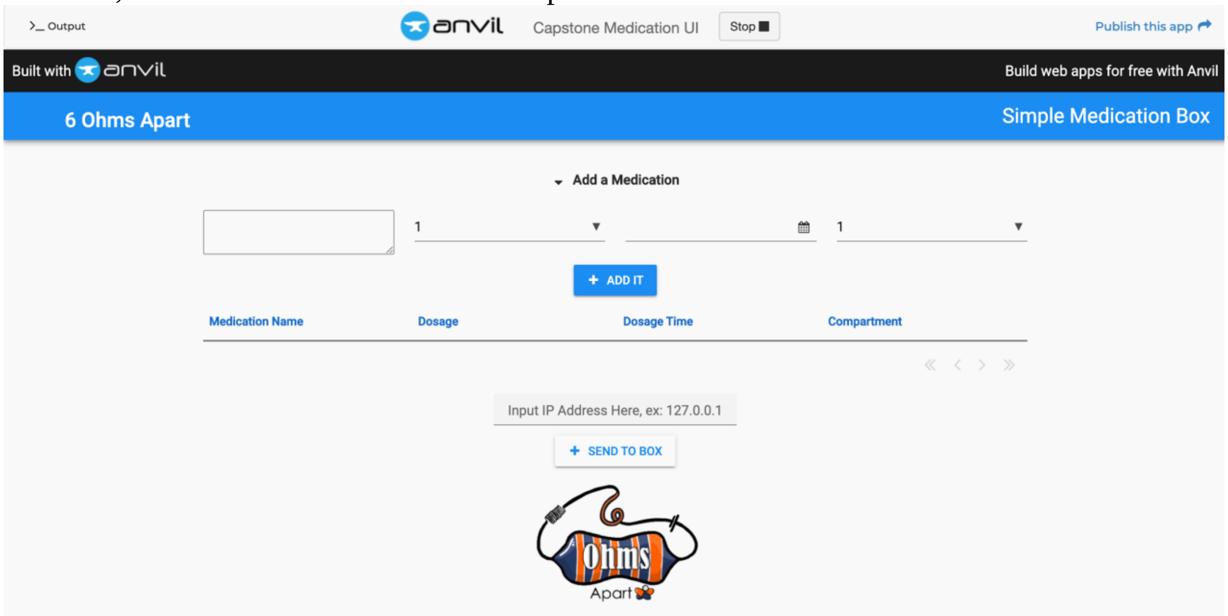


**Figure 11: User Interface Web Application Front Page**

To receive the data, a Python script was written based on the uplink feature of Anvil. The WebApp must be compiled and run in conjunction with the Python script to ensure that the data is sent to the correct UDP socket based on the user ID of the physical embedded medication device. Shown below is the output of the Python script once the medications and IP are provided and the “send to box” button is clicked in the user interface. The Python medication list is received from the Anvil front end software, and the encoded packets (1 for the each sample medication inputted), are sent to the corresponding IP and port specified by the embedded device’s network. AES encryption was added to the medication data packet on the microcontroller side to ensure that the users data is secured.

Lastly, error checking was implemented to ensure that the data sent to the medication box was error-free and the compartments corresponded to the correct sections of the embedded device (A-F). Shown below is a sample error that pops up when a medication is added to a compartment already in use.

The compartment would be then autocorrected to the next available compartment to make it easier for users who wish to use the device.

All the front-end Python code is provided with sufficient documentation. If the final embedded medication organizer were to go into production, servers would be hosted to make it easier to connect to the device, and ensure that the security of users would be protected via commercial encryption.

## Device Enclosure

The device enclosure was designed to house the medication in individual compartments, provide room for a screen, electrical components, speaker and button. The compartment was first sketched by hand shown in Figure 12, featuring six compartments, a centered screen, two speakers, a button and power cord. The final device shown closed in Figure 14 has the six compartments, screen and button however the speaker is now hidden beneath the lid of the container.

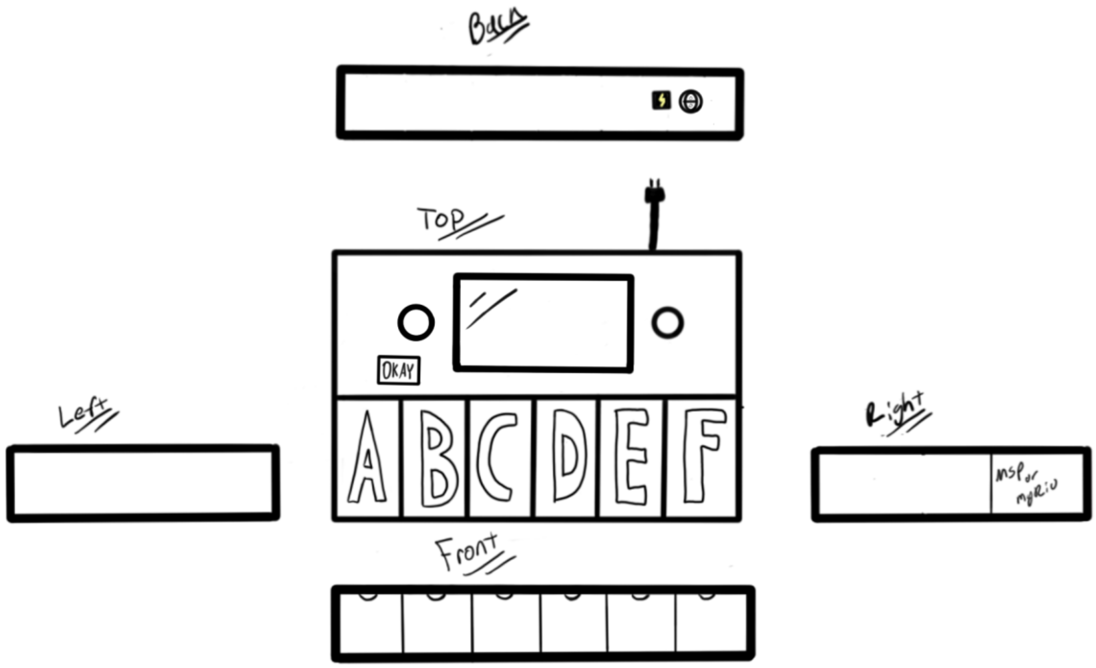


**Figure 12: Device Sketch**

The materials used to construct the container is a thin composite wood providing enough rigidity that the box is stable while being thin enough to cut with the laser. The letters are fully cut out and backed with acrylic allowing for light to pass through. Hinges are placed on each lid so that getting the medication out is easily accomplished. The enclosure was designed in Light Burn as individual panels then assembled with wood glue for most panels and screws for the lid/hinges.

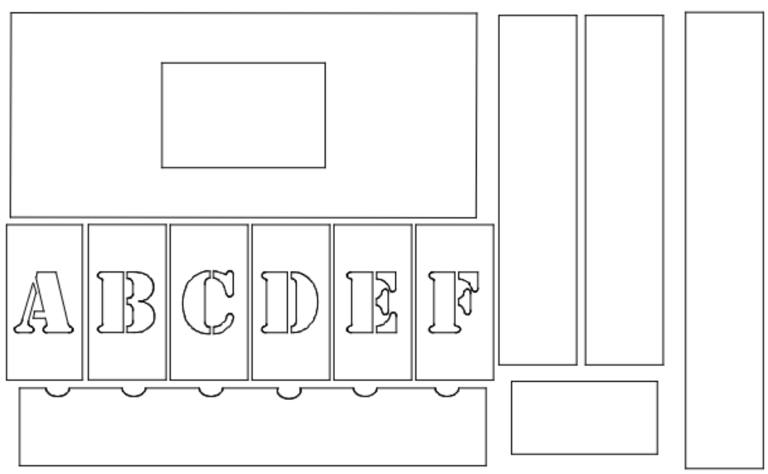


**Figure 13: LightBurn Cut-Out Front**

Figure 13 shows the enclosure as realized in Light Burn the panels filled the area of most of the sheet used to cut down on material cost.

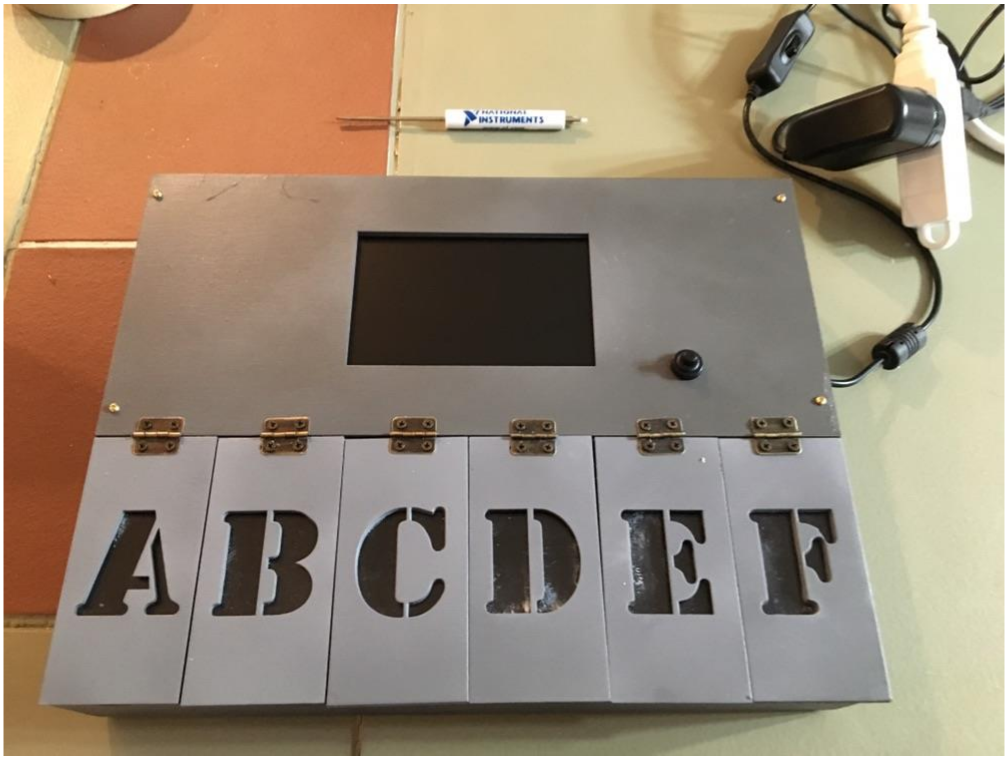


**Figure 14: Device Enclosure Closed**

Figure 15 shows the device enclosure with the lid unscrewed revealing the internal electrical components. The inside portion of the device was designed to provide ample room for additional components or modifications that could have occurred during the assembly process. The MSP, header board, and wifi booster are shown inside the enclosure with wires leading to power, button, LEDs and speaker.

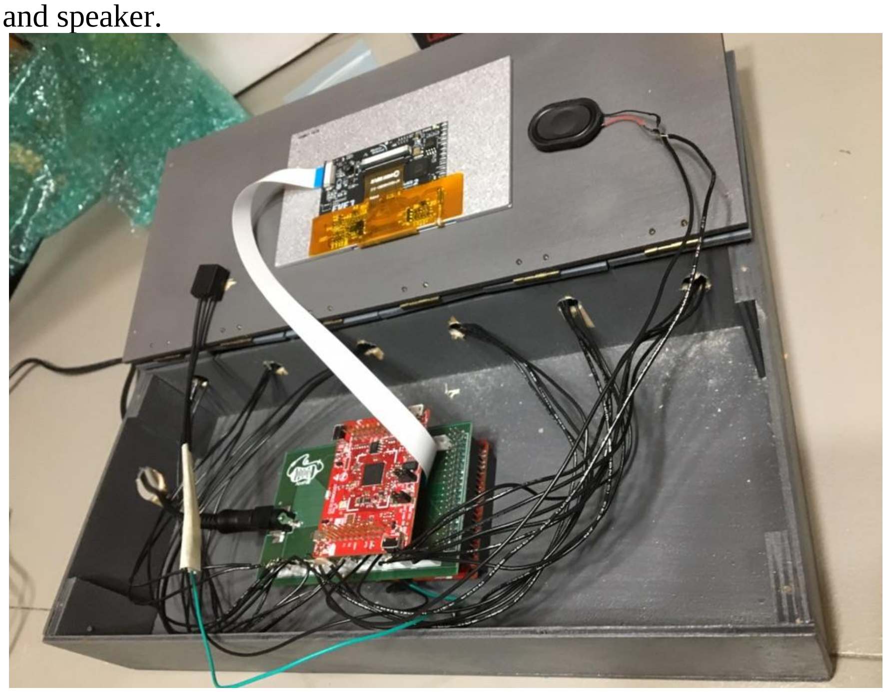

**Figure 15: Device Enclosure Open**

## Project Timeline

Shown below is the original Gantt chart timeline from the project proposal in September, 2020.

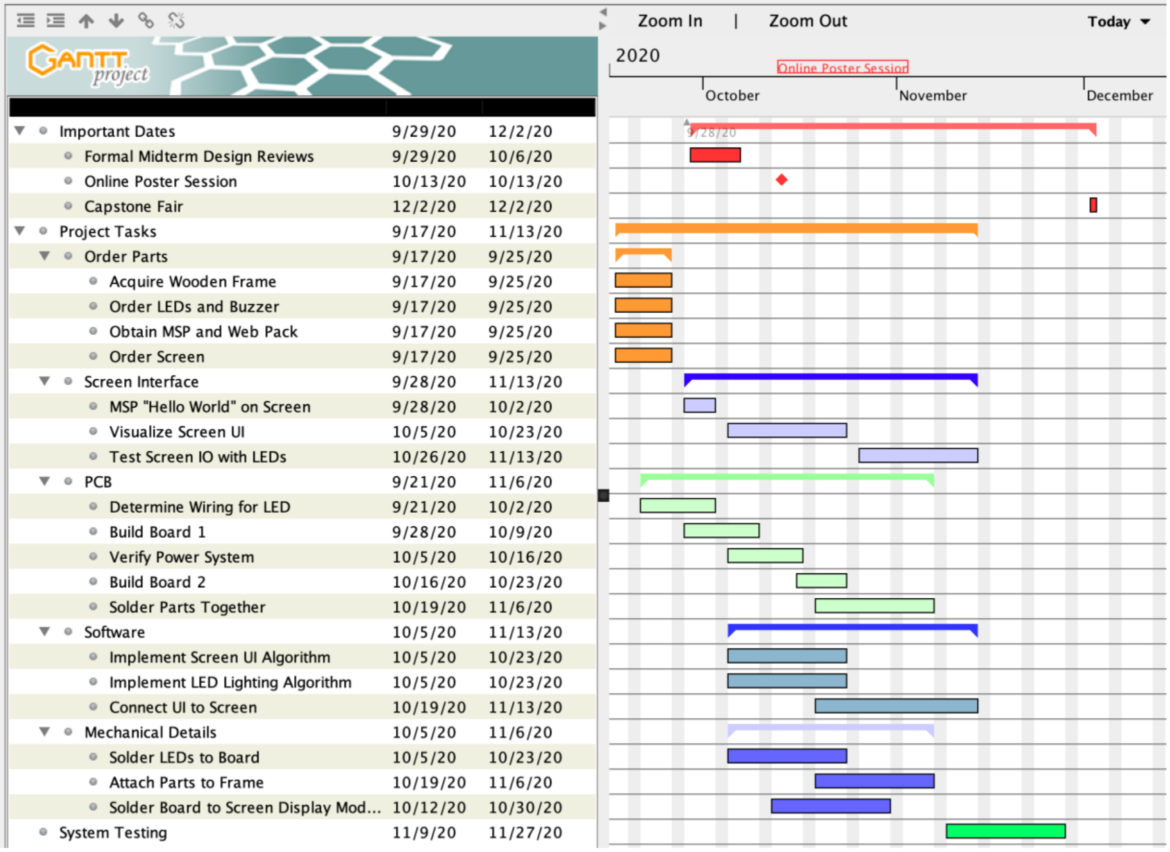


**Figure 16: Original Gantt Chart from Proposal**

The main components of the project were the PCB/Power system, the screen interface, software, and device assembly. Design of the PCB and enclosure were done in parallel, and finalized before low-level programming was completed. Most of the higher-level programming such as the web interface was completed once the wifi interface to the microcontroller was established, but the embedded programming and hardware design had to be completed before it could be tested.

Responsibilities for the project were divided as follows. Forrest headed the networking for the device, as well as the embedded software, with a secondary focus on the user facing software. Sean was responsible for designing the enclosure for the device and integrating it with the PCB design, as well as helping out with the UDP socket Python code. Sai primarily focused on the user application for the device, and provided assistance with the socket programming and choosing project parts in the initial portions of the project. Quin prioritized designing the PCB and assisted with software development and hardware testing as needed by the team.

Shown below is the final Gantt chart timeline, updated from the original proposal as of December, 2020.

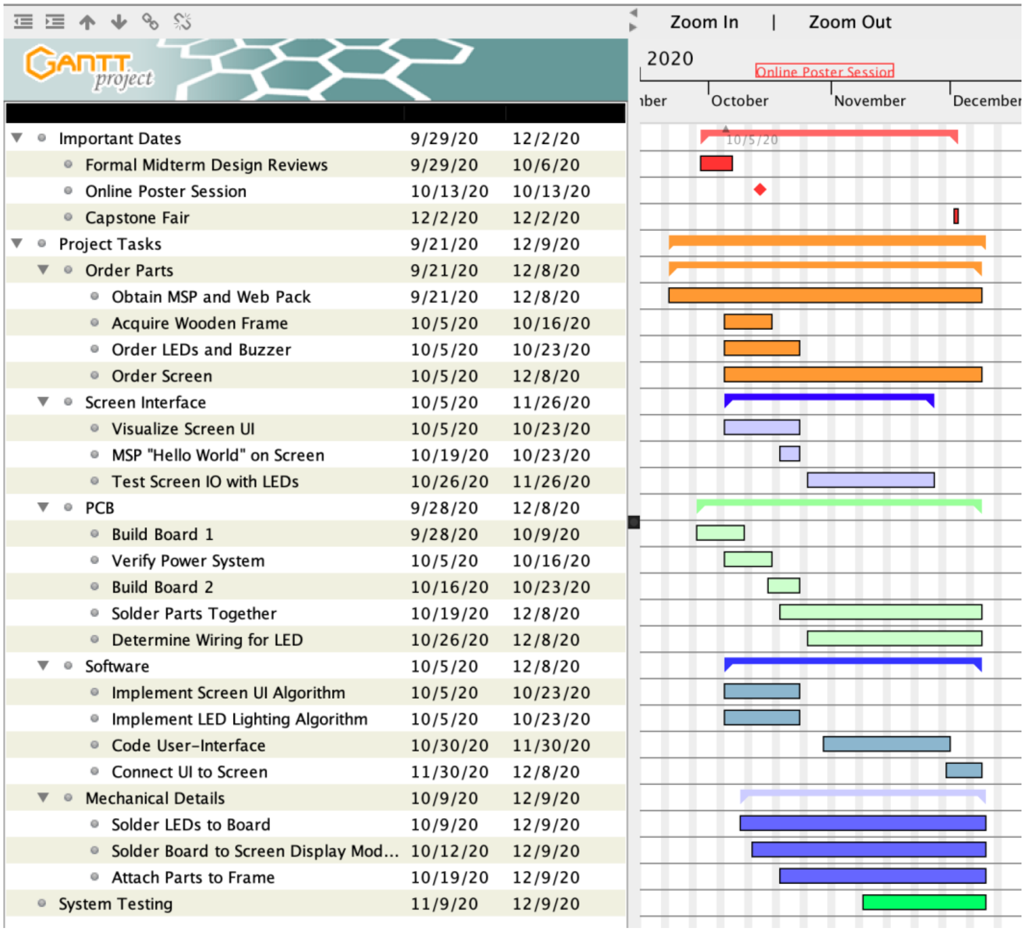


**Figure 17: Final Gantt Chart**

During the final phases of our project, we experienced a few issues with testing that delayed our progress. It took us longer than expected to write the drivers for the screen and LEDs so those dates had to be pushed back. Right at the end of the semester, we had to order another Wi-Fi booster pack and screen after they broke on separate occasions. Because we were done with everything except integration testing at that point, those issues resulted in a sort of dead period where there was not much we could work on. Fortunately we had just enough time to get everything working. Overall, we stayed very close to the original schedule except for the hardware malfunctions at the end of the project- pushing the end dates to what is shown above.

## Test Plan

### User Application Software Testing

The user interface software application was mainly tested by utilizing print statements in the Anvil Python environment. Most of the errors found were based on linkage issues from the Anvil data table service to the form component of the WebApp. To solve data linkage problems that could not be solved by using print statements, the data table was continuously monitored on the Anvil back end as sample data was inputted into the front end. Errors were caught primarily by inspection, and any errors that persisted were fixed by an error checking algorithm implemented at the end of the user interface coding process. Whenever incorrect data was inputted into the front end, the specific error was printed out to the console via an Anvil alert function, which would display a pop up with the name of the error, and attempt to automatically fix the error, when possible. On the Python UDP socket script side, testing was done by catching errors using the same general process as mentioned before with print statements. Regular expressions were used to filter incorrect information if the packet information from the front end was corrupted or contained incorrectly. The overall functionality of the user application and Python socket script was then confirmed by the embedded application and integration testing, which are outlined in the below sections.

### Embedded Application Software Testing

The embedded software application was mainly tested by printing events to the UART terminal to observe the progress of the software. This included: printing the IP address of the device when it had connected to the WLAN, printing that the UDP server had started listening for configuration data, printing when new configuration information was received and printing that the device had been configured properly with new events, printing that the RTC interrupt had occurred every minute, printing whenever the RTC alarm occurred and a new event was scheduled, printing the intended peripheral activation (LEDs, screen, speaker) for an event that occurred, printing the intended periodic screen updates (every minutes and at the beginning of each day), printing when the external button was pressed and whether or not it stopped an ongoing event, and, finally, printing whenever an error occurred, such as a module not loading correctly. This tested the proper functioning of our device, but the embedded application was also tested to ensure that it could handle some errors. For example, improper data was sent to the device to ensure that it could identify and properly ignore erroneous data. A sample of the application logs that show the proper functioning of embedded software is included to supplement the video demonstration.

### Hardware Testing

The power supply was tested by connecting the external power supply to the board and measuring the output voltages at test points located around the board. The first version of the board contained a more complex version of the power supply that included a backup power supply in the form of a rechargeable battery, however during testing the system experienced a catastrophic failure and the design was abandoned in favor of the simplified power system previously described.

The LED controller was initially tested by connecting the I2C pins to an external interface adapter and manually writing to the required registers. A driver was then produced for the MSP432, where it was discovered that the built-in pull-up resistors were insufficient for the I2C protocol and external resistors were added to the final PCB design.

The screen was tested using an external power supply and ribbon cable to 2.54mm pin header board. The library we intended to use for the EVE3 produced non-functional assembly code so we made our own small library capable of displaying text and simple graphics, while being better optimized for the MSP432s hardware SPI.

The audio amplifier was initially tested with a breadboard prototype built with components roughly equivalent to those used in the final design. The resulting design was then included in the final PCB iteration.

**Integration Testing**

The flowchart in Figure 18 below shows the integration test plan, which includes the user application, embedded application, hardware drivers, and hardware all working together. Specifically, this meant interacting with and configuring the embedded MSP432 application from the user web app, ensuring that the embedded application can interact with the hardware drivers throughout its lifecycle, and observing that the hardware was activated as expected. Because integration testing was performed only after all the other components had been tested individually it was a relatively simple task to get them working at once. The video demonstration attached to this report is essentially the reification of our test plan.

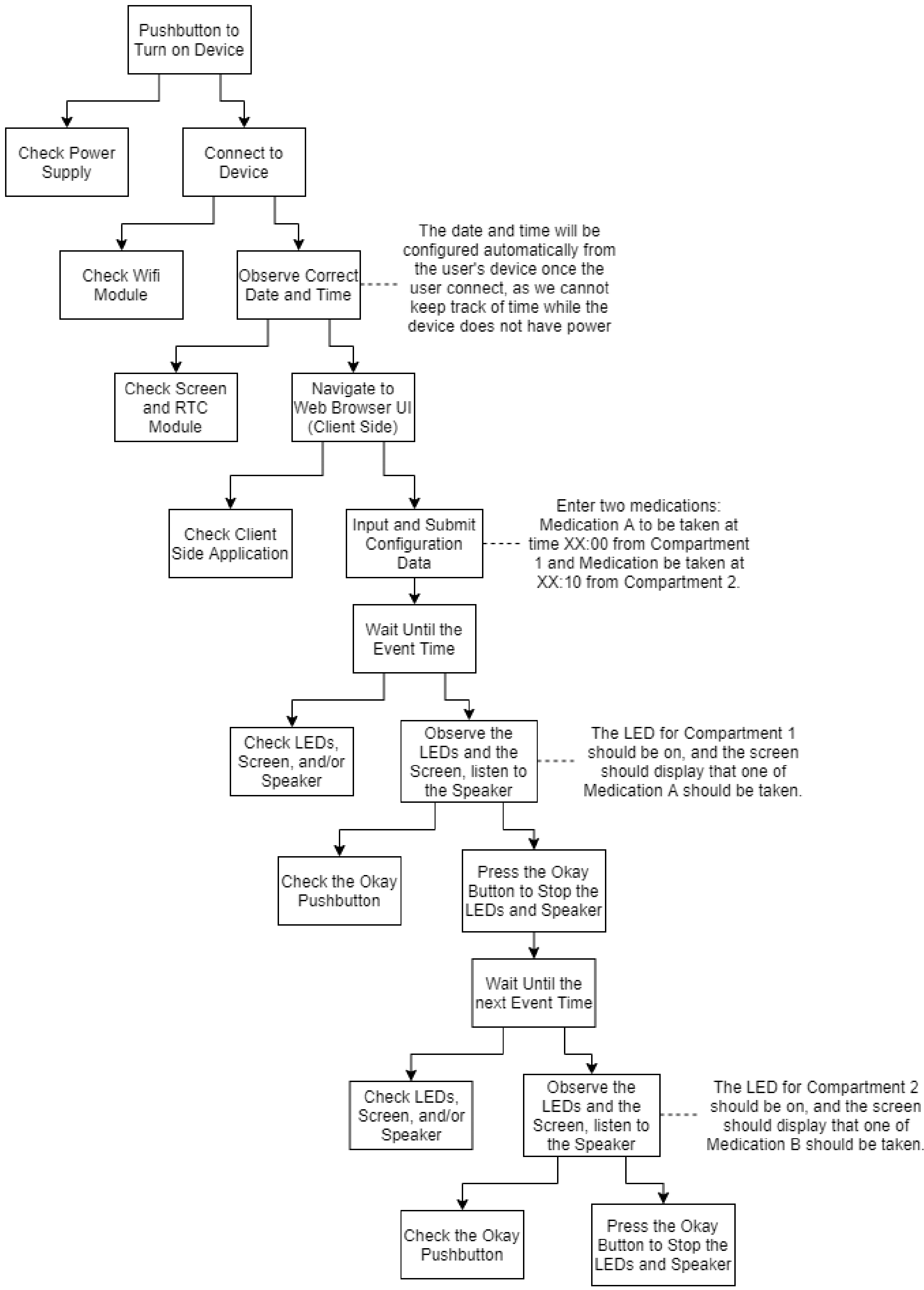


**Figure 18: Integration Testing Plan**

## Final Results

A video demonstration of our device's functionality is included with this report. In addition, we have attached the application logs from a separate demonstration of our device to depict what exactly the software is doing while the device is running. We believe that our device meets all of the requirements outlined in our proposal. This includes: (1) All parts fit/work on the container, (2) Wired power system successfully drives all parts of the device, (3) the user application can be used to configure which medications and which times, and is wireless, and is intuitive and visually appealing, and (4) The on-device screen displays the date/time and other useful/relevant information to the user. The video shows the device enclosure, the screen, the compartments LEDs, the speaker, and the configuration web app working as expected. We believe our project was a good choice given the short/remote semester as it was a challenging project that allowed us to combine everything we have learned in the ECE curriculum and learn some new skills, but yet it was manageable within the time frame.

## Costs

The total cost of the project including PCB production, components, and assembly was $434.84. A brief breakdown of our expenses is shown in Figure 21.

| Item | Quantity | Total Cost |
|---|---|---|
| MSP-EXP432P401R | 2 | $47.98 |
| CC3120BOOST | 1 | $35.99 |
| EVE3-50A-BLM-TPN-F32 | 1 | $57.19 |
| PCB Assembly | 4 | $117.00 |
| PCB Production | 2 | $70.00 |
| Misc PCB Parts | | $106.68 |
| **Total** | | **$434.84** |

**Figure 19: Breakdown of Expenses**

The MSP-EXP432P401R and CC3120BOOST represent a significant cost per unit and would not be suitable for a mass produced device. By substituting the equivalent microcontroller, associated resistors, capacitors, etc and board redesign we can estimate the production cost of each unit as shown in Figure 22.

| Item | Cost per unit for 10,000 units |
|---|---|
| PCB Production | $0.6852 (per JLCPCB)[34] |
| PCB Components | $73.02 |

**Figure 20: Estimated Production Cost Per Unit**

At 10,000 units the price per PCB decreases dramatically. The most expensive part is now the EVE3 module at $53 per unit at volume of 200+, this price could likely be reduced further by directly contacting the manufacturer or selecting an alternative component. The benefit of using pick and place equipment to assemble each board would likely result in a similarly dramatic reduction in cost but an exact estimate could not be determined.

## Future Work

There are several features of our project that could be added or improved upon. One of the main ones would be configuring Wi-Fi from the user application instead of hardcoding the credentials in the code. This would be much more convenient from the user's perspective, but it is more difficult than we initially thought. The device would have to initially act as a Wi-Fi access point that the user could connect to and transfer the credentials, and only then would the device connect to the user's network. The Wi-Fi booster pack we used supports this feature, but it would have been a much more rigorous process. It would also require securely transferring the network credentials to the device, probably using asymmetric public key encryption. Furthermore, the user application would have to somehow identify the IP address of the device without any action on the part of the user, which would be tricky. Another feature we would have liked to add to the SMO is a battery to power it (instead of a wall outlet) to make it completely portable. However, adding a battery presents a whole new series of issues when it comes to calculating and minimizing how much power the device uses. There are few ways we would have liked to improve to the appearance of the device. We wanted to make the screen display more information and with a more aesthetic graphical design. It would have been nice to make the box more compact and out of a plastic material to make it sturdier, sleeker, and less flammable. It would be nice to make our own microprocessor board to remove all the unnecessary power from the MSP432 and CC3120 to make our device smaller and lower power. The speaker makes a rather annoying sound that is not very enticing to users; we would've liked to make it play more of a jingle. We would've liked to have a mobile user application to improve convenience. We would've liked to save user configuration data after power off, so the user did not have to reconfigure it on every startup. Finally, it would have been nice to use some slightly more resilient or failsafe circuitry as we have several issues with destroying our hardware during testing.

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## Appendix

We did not include a complete code listing because our project is nearly 5000 lines, which is impractical to paste into a document when it is already attached in the Collab folder. The most important CAD files are in the body of the report, and any additional ones are in the Collab folder. The video demonstration is located in the shared Box folder. We have also included a sample log file from the embedded software operating in the Collab folder.

### Appendix A: Project Costs

| Item | Cost |
|---|---|
| MSP-EXP432P401R | $47.98 |
| CC3120BOOST | $35.99 |
| EVE3-50A-BLM-TPN-F32 | $57.19 |
| SP-3020 | $2.69 |
| LP5018RSMR | $1.55 |
| C2012X5R0J106K085AB | $2.24 |
| CL31B226KPHNNNE | $0.45 |
| C2012X5R1A475K125AA | $0.48 |
| GRM155R71H104KE14J | $0.20 |
| CL10B105KA8NNNC | $0.20 |
| TPS652170RSLR | $5.39 |
| TUSB320LAIRWBR | $1.82 |
| MCP2210-I/SO | $1.94 |
| PJ-036AH-SMT-TR | $1.36 |
| 046288020000846+ | $1.17 |
| LQM2HPN2R2MG0L | $0.93 |
| ERJ-P06J472V | $0.10 |
| ERJ-P06J204V | $0.20 |
| ERJ-P06J914V | $0.10 |
| PVG3A103C01R00 | $1.43 |

| | |
|---|---|
| 1043 | $2.97 |
| CSTNE12M0GH5L000R0 | $0.35 |
| USB4105-GF-A | $1.57 |
| B4B-EH-A(LF)(SN) | $2.24 |
| B2B-EH-A(LF)(SN) | $0.70 |
| 04JQ-BT | $4.87 |
| PREC001DAAN-RC | $0.56 |
| QPC02SXGN-RC | $1.00 |
| SP-3020 | $2.69 |
| PRT-12895 | $5.95 |
| 1012937890301BLF | $0.51 |
| MFR4-75KFI | $0.16 |
| IN-S128TATRGB | $2.86 |
| NTCLE100E3103HT1 | $0.66 |
| PCB1 | $35.00 |
| PCB Assembly 1 | $17.40 |
| PCB Assembly 2 | $7.40 |
| C0603C475K8PACTU | $0.31 |
| TPS62827DMQR | $1.82 |
| IHLP1212AEERR47M11 | $1.23 |
| RT0603BRD07100KL | $0.33 |
| CRCW0402100KFKED | $0.10 |
| CRCW0402453KFKED | $0.10 |
| GRM1555C1H121JA01D | $0.10 |
| PJ-036AH-SMT-TR | $1.36 |
| 046288020000846+ | $1.17 |

| | |
|---|---|
| PVG3A103C01R00 | $1.43 |
| SSQ-119-03-T-D | $10.05 |
| SSQ-110-03-F-D | $5.36 |
| 151660223 | $2.54 |
| ERJ-P06J472V | $0.20 |
| CL10B105KA8NNNC | $0.10 |
| C1608X5R0J226M080AC | $0.34 |
| PCB2 | $35.00 |
| PCB Assembly 3 | $11.00 |
| C0603C475K8PACTU | $2.15 |
| IHLP1212AEERR47M11 | $2.52 |
| RT0603BRD07100KL | $2.77 |
| CRCW0402100KFKED | $0.33 |
| CRCW0402453KFKED | $0.33 |
| GRM1555C1H121JA01D | $0.61 |
| PJ-036AH-SMT-TR | $2.72 |
| 046288020000846+ | $2.34 |
| PVG3A103C01R00 | $2.86 |
| SSQ-119-03-T-D | $6.70 |
| SSQ-110-03-F-D | $10.72 |
| 151660223 | $2.54 |
| ERJ-P06J472V | $0.94 |
| CL10B105KA8NNNC | $0.46 |
| C1608X5R0J226M080AC | $0.68 |
| MCP4451-103E/ST | $1.35 |
| C1005X7R1H104K050BE | $1.36 |

| | |
|---|---|
| C2012X5R0J106K085AB | $0.56 |
| CL10B333KB8NNNC | $0.52 |
| CGA2B2C0G1H471J050BA | $0.62 |
| GRM21BR60J107ME15L | $1.81 |
| ERJ-P06J103V | $0.20 |
| ERJ-P06J100V | $0.20 |
| UCM1A102MNL1GS | $0.79 |
| TPS62827DMQT | $4.18 |
| SWI25-5-N-P5 | $13.54 |
| MX1A-E1NN | $1.06 |
| PS1024ABLK | $1.26 |
| NCA2 | $0.93 |
| 40-2388-01 | $1.80 |
| B3J-1100 | $2.18 |
| B4B-EH-A(LF)(SN) | $1.87 |
| LP5018RSMR | $3.10 |
| PCB Assembly 4 | $36.00 |

## Appendix B: Bill of Materials

| Quantity | Reference | Part | Manufacturer Part No. | Manufacturer |
|---|---|---|---|---|
| 1 | C1 | 4.7uF | C0603C475K8PACTU | KEMET |
| 1 | U1 | TPS62827DMQT | TPS62827DMQT | Texas Instruments |
| 1 | U2 | LP5018 | LP5018 | Texas Instruments |
| 1 | L1 | 470nH | IHLP1212AEERR47M11 | Vishay Dale |
| 1 | R1 | 100K | RT0603BRD07100KL | Yageo |
| 1 | R3 | 100K | CRCW0402100KFKED | Vishay Dale |

| | | | | |
|---|---|---|---|---|
| 1 | R2 | 453K | CRCW0402453KFKED | Vishay Dale |
| 1 | C2 | 120pF | GRM1555C1H121JA01D | Murata Electronics |
| 1 | J1 | PJ-036AH-SMT-TR | PJ-036AH-SMT-TR | CUI Devices |
| 1 | J2 | 046288020000846+ | 046288020000846+ | Kyocera International Inc. Electronic Components |
| 1 | R4 | PVG3A103C01R00 | PVG3A103C01R00 | Bourns Inc. |
| 2 | R5, R6 | 4.7K | ERJ-P06J472V | Panasonic Electronic Components |
| 2 | C5, C4 | 1uF | CL10B105KA8NNNC | Samsung Electro-Mechanics |
| 1 | C3 | 22uF | C1608X5R0J226M080AC | TDK Corporation |
| 2 | J3, J5 | Header | SSQ-110-03-F-D | Samtec |
| 1 | J4 | Header | SSQ-119-03-T-D | Samtec |
| 1 | J6 | Header | B2B-EH-A(LF)(SN) | JST |
| 6 | LED1, LED2, LED3, LED4, LED5, LED6 | Header | B4B-EH-A(LF)(SN) | JST |
| 3 | C7, C8, C12 | 0.1uF | C1005X7R1H104K050BE | TDK Corporation |
| 1 | C6 | 100uF | GRM21BR60J107ME15L | Murata Electronics |
| 2 | C10, C11 | 10uF | C2012X5R0J106K085AB | TDK Corporation |
| 1 | C9 | 470pF | CGA2B2C0G1H471J050BA | TDK Corporation |
| 1 | C13 | 0.033uF | CL10B333KB8NNNC | Samsung Electro-Mechanics |

| | | | | |
|---|---|---|---|---|
| 1 | C14 | 1000uF | UCM1A102MNL1GS | Nichicon |
| 1 | R7 | 10K | ERJ-P06J103V | Panasonic Electronic Components |
| 1 | R8 | 10 | ERJ-P06J100V | Panasonic Electronic Components |
| 1 | U3 | MCP4451 | MCP4451-103E/ST | Microchip Technology |
| 1 | U4 | LM386 | LM386 | Texas Instruments |
| 1 | | EVE3 | EVE3-50A-BLM-TPN | Matrix Orbital |
| 1 | | MSP432 | MSP432P401R | Texas Instruments |
| 1 | | CC3120 | CC3120BOOST | Texas Instruments |
| 1 | | SP-3020 | SP-3020 | Soberton Inc. |
| 6 | | IN-S128TATRGB | IN-S128TATRGB | Inolux |

**The Internet as a Social Artifact: How Widespread Internet Access May Hinder Developing Nations**

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

Sairathan Rajuladevi
Spring, 2021

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

Signature Sai Rajuladevi ________________________ Date 4/22/2021
Sairathan Rajuladevi

Approved H Rogers ____________________ Date 5/4/2021
Hannah Rogers, Department of Engineering and Society

**Abstract**

Advancements associated with Internet accessibility measures in developing nations have dismissed significant costs under the guise of economic growth. Moreover, there is limited empirical evidence about the positive development impact of internet technologies in relation to systemic issues in developing countries (Galperin & Viecens, 2017). In this thesis, an actor-network analysis and utilitarian ethics framework will be used to investigate the relationship between obtaining Internet access and economic prosperity. An actor-network analysis framework is chosen in order to draw linkages between social constructs in developing areas, and a utilitarian ethics framework is chosen in order to substantiate or contradict the claims made by the evidence provided. This thesis discusses issues surrounding the digital divide between Internet access in developed and developing regions of the world and evaluates the potential for increased Internet access to alleviate issues of poverty. Given the current rapid growth of Internet-based technologies worldwide, this thesis presents a sociotechnical analysis on the costs of increased Internet access in developing nations.

## The Internet as a Social Artifact: How Widespread Internet Access May Hinder Developing Nations

Through the steady diffusion of wireless communication technologies over the past few decades, the gap of Internet access and infrastructure in developed and relatively prosperous areas has become more pronounced compared to developing regions of the world. Moreover, the notion that all technological improvements are equally helpful for developed and underdeveloped nations cannot be substantiated. To illustrate, some technical improvements in developing areas like increased Internet access are selected over others like improved water systems because they are viewed as more effective in fostering economic growth. Since there is relatively sparse infrastructure in place to allow people of developing areas to access the Internet, wireless technologies have often been seen as mitigators to poverty by helping the general population obtain various opportunities that would else not be available (Kirkpatrick, 2018). However, despite the significant growth of the Internet on a global scale over the past few years, poorer regions of the world continue to face a combination of obstacles to the rapid diffusion of Internet services (Petrazzini & Kibati, 1999). Furthermore, empirical studies on Internet access in developing countries raise issues on the image of the Internet as a benefactor to society due to unwarranted social and commercial involvement. Actor network analysis and a utilitarian ethics framework are being applied on a case-by-case basis to study the relationship between obtaining Internet access and economic prosperity. In order to evaluate the potential for the Internet to alleviate issues of poverty and hardship in developing regions of the world, the following question must be addressed: to what extent does the societal spread of internet connectivity and access help or hinder growth in third world countries? This thesis will demonstrate that the costs of Internet accessibility measures in developing areas must not be discounted under the category of economic growth.

**Determinants of Internet Access**

Issues surrounding the rapid growth of Internet technologies over the course of the 20th and 21st centuries are well documented yet still under-examined. In most countries with a higher Human Development Index (HDI) relative to other countries, Internet access has stimulated digital advances in the field of information technology and has resulted in massive fiscal growth. While economic development can be attributed to an increased rate of access and technological resources, the determinants of such development differ on both sides of the HDI. One of the major reasons is affordability. In many developing countries, there are lower levels of income and disposable income, and the amount of money that the general population has available to spend on services like Internet connectivity is very limited (Kirkpatrick, 2018). To this end, even when options for Internet connectivity are presented, many people in developing regions cannot afford the devices or accounts needed for access. A key consideration in both the developing and developed world is the centralization of Internet access in urban areas with higher economic development compared to rural areas. According to a study by Petrazzini and Kibati, despite the availability of creative pricing schemes, Internet services in most developing countries rarely spread beyond the capital and a few large urban centers. In Kenya, for instance, over 85% of the country's Internet users are in Nairobi, the capital; in Russia and Argentina, 64% and 60% of all users are in Moscow and Buenos Aires, respectively (Petrazzini & Kibati, 1999). Likewise, digital presence is more prevalent in urban areas of developed nations. In the United States substantial segments of rural areas still lack the infrastructure needed for high-speed internet, and what access these areas do have tends to be slower than that of nonrural areas (Perrin, 2019). For this reason, the applicability of the term "digital divide," which classifies the regional or national gap between those who have ready access to the internet and those who do not, has increased with Internet advancement.

Whether increased internet access can reduce poverty in countries with a small share of technology-intensive industries and a limited technology-absorption capacity remains largely uncertain (Galperin & Viecens, 2017). At its core, the internet is a general-purpose technology (GPT) that allows individuals and firms to share information in a vastly more efficient manner. Once Internet access is introduced to the public sector in developing areas, it connects individuals together for social or commercial purposes. However, in terms of disparities after successful adoption, certain aspects of location, industrial growth, social status, and education may be responsible for a possible decline in the rate of Internet diffusion. For ages 15 and above in 2002, India had the highest illiteracy rate (41.2%), followed by Ghana (26.2%) and then by Kenya (15.7%). In terms of Internet diffusion, the same countries had an average of 6.8, 1.9, 16.0 and Internet users per 1000 people, respectively (Ynalnez et al., 2005). While these statistics represent a small portion of all developing nations worldwide, it shows that not only one factor must be addressed if technology corporations continue to take a proactive role in spreading the Internet in developing countries. Furthermore, Aker et al. (2011) show that a rural Niger adult education program in which students learned how to use mobile phones increased the likelihood of rural–urban migration (Aker et al., 2011). Hence, with the widening of the current digital gap between urban and rural areas in the developing world, improved Internet access results in a lengthy poverty alleviation process regionally, with funds needing to disperse from a country's metropolitan markets to develop rural areas. As developing countries are observing greater economic growth on the national scale, poorer regions are observing seemingly fewer benefits compared to what governments promised would occur with increased access. Therefore, governments need to carefully assess what technologies to support and to bring into their societies first, usually through step-by-step intervention measures in the private sector like in developed nations.

Some scholars have run comparisons between areas with higher and lower economic growth to gain an understanding of the Internet's role in poverty alleviation. In China, the world's second largest economy, positive impacts suggest that more interventions or policy programs are needed to boost Internet service and telecommunication infrastructure, because there is a higher ratio of return on investment for rural households in the upper distributions of income and expenditure (Ma et al., 2020). Similarly, in the United States the digital divide persists even as lower-income Americans make gains in technology adoption, with roughly 26% of adults being entirely smartphone-dependent as opposed to owning laptops or desktops used by higher-income groups (Anderson & Kumar, 2019). Therefore, the inability for initiatives to sufficiently benefit people in lower distributions of income needs to be addressed to ensure the integrity of Internet investments.

## Conceptual Framework

An actor-network framework is useful in analyzing systems, such as with Internet Service Providers in developing countries versus developed countries, because it can help model the interdependence of entities under the broad categories of location, industrial growth, social status, and education. Latour, Callon and Law developed the Actor-Network theory (ANT) as a sociological theory that attempts to examine heterogeneous networks composed of actors or actants, which could be either humans or technological agents (Latour, 1998). In many cases, ANT can be used to analyze coexistent entities that maintain ever changing relationships over one another. Many actors at times are locked into networks of which certain elements reside outside of the focal organization, which allows the study of the assembling and stabilizing of diverse human and non-human entities within diffuse socio-material systems (Alcadipani & Hassard, 2010). Critics such as Langdon Winner maintain that properties such as intentionality fundamentally distinguish humans from animals or from objects that are included as "actors" in ANT (Winner, 1993). Moreover, the potential for networks to intermingle and devolve into infinite branches of connections may be considered a criticism of ANT. In this thesis networks will be carefully chosen and limited by levels to avoid endless connections. A final point to note is that ANT should not be used for policy prescriptions due to its neutral stance towards actors and actants.

A utilitarian ethics perspective is useful in analyzing the consequences of traditionally providing Internet access through government or commercial investment, because it focuses on the choice that yields the greatest benefit to the most people. For this reason, utilitarian analysis can be used for compelling policy prescriptions that weigh the costs and benefits of increased access, which is in contrast to the neutral stance of ANT. John Stuart Mill argued that the creed which accepts as the foundation of morals, Utility, or the Greatest Happiness Principle, holds that actions are right in proportion as they tend to promote happiness, wrong as they tend to produce the reverse of happiness (Mill, 1859). A criticism to note when applying a utilitarian framework is that the topic analyzed should be thoroughly researched, since a more informed choice predicts whether an action is right or wrong accurately. In the context of this thesis, on the surface it seems that the topic of increased Internet access in the developing world requires a higher level of research, but each year the number of studies on Internet technologies multiplies as commercial interests take hold. Moreover, the inclusion of a utilitarianism perspective is validated by the number of resources provided in this thesis.

**Case of Scientific Collaboration: "Kerala Model"**

The current rate of Internet access proliferation in developing countries affects many groups, the global research community being one of primary importance in this case. Scientists, as part of the professional elite in developing areas, have been projected as early and extensive users of Internet technology, just as in Western countries. Yet many scientists in the developing world are falling behind technologically, without the basic connectivity and the bandwidth that are taken for granted in developed countries (Davidson et al., 2002). While an increased rate of Internet connectivity measures implemented by national or commercial interests are beneficial to the scientific community, constraints associated with gender biases and localism have resulted in career differences between the developed and developing world. Kerala, a state in India known for its model of development, has joined this bandwagon by selecting the Internet and information communication technologies to improve its present economic position (Sooryamurthy et al., 2007).

While most growth models have been understudied in the developing world, Kerala has stood out in demonstrating through democratic means that radical improvements in the quality of life of ordinary citizens are possible without high economic growth and governmental difficulty (Parayil, 1996). Defining an actor network framework can highlight certain dimensions of interest in the "Kerala model." The methodology presented below splits the model into general levels that are applicable towards similar national contexts. The base level actors in this case are the research populace of developing nations: male and female scientists. The next level would encompass the institution or organization that the scientists are representing, regardless of size or structure, which are then split between scientific organizations which engage in international collaboration and those which are restricted to domestic collaboration. A network would then link the levels through research that is either exiting the country for collaboration, or that persists in the country. A utilitarian ethics framework will finally analyze and predict the result of further increasing Internet access, motivated the question posed by Sooryamurthy: are the institutions of Kerala equipped to meet the challenges posed by the new path of development? (Sooryamoorthy et al., 2007)

Paige Miller et al. note that an actor's location in a social network influences the resources he or she can draw on. In the case of the network's base level actors, scientists, relatively little is known about the careers of female scientists in the developing world. Although it is acknowledged that females fall behind their male counterparts on such dimensions as prestige, rank, and salary, there are few empirical studies examining the processes contributing to such outcomes (Paige Miller et al., 2006). However, men and women do differ on dimensions of career attainment, specifically in human and social capital. First, there are significant differences in educational attainment, with fewer women possessing a doctoral degree. Second, women display more localism in educational and career choices (Paige Miller et al., 2006). A utilitarian ethics perspective on male and female scientists in Kerala supports that increased Internet access results in a greater output of research nationally. However, a key point to consider is that if governmental or commercial interests inject funds into this model without stressing gender gap initiatives within the scientific community, then human and social capital differences will likely still exist, which are workplace inequalities. If new development proceeds in the Internet and communication technology sector in regions such as Kerala, a utilitarian ethics friendly approach would tackle the problem head on by promoting opportunities for female scientists to achieve higher degrees and travel given the sociological contexts of the developing area.

On the institutional level, underdeveloped areas have smaller research communities, and fewer scientists are often dispersed over long distances. When separated geographically, scientists are unable to maintain regular communication with others in their field, nor can they benefit from the intellectual stimulation that accompanies contact. Isolation can exist locally as well as internationally (Davidson et al., 2002). However, the split between scientific organizations which engage in international collaboration and those which are restricted to domestic collaboration still has variable effects when Internet proliferation is increased. Wagner notes that an increase in information and communications technology can be enormously helpful in driving scientific efforts for third world countries, but it does not in itself motivate or enable collaboration (Wagner et al., 2001). For a social utilitarian ethics perspective, if funding without greater purpose were injected into the research community, the growth of national scientific output would still be a main benefit to consider. In fact, the most tangible benefit to society would be to introduce measures to motivate collaboration with international scientific communities. To avoid a top-down development strategy trap, scientists could be asked what they want developed first and what their main policy concerns are to achieve a more productive outcome in society. A utilitarian approach supports that if there are good effects which are, on balance, better than the effects of any alternative course of action, then the action is the right one (Driver, 2014).

The Kerala case of Internet adoption can be applied to the general population in developing nations, since scientists are a professional group, and many other professional groups rely on networks like the one presented to reap a form of a national economic benefit. Most modern-day methods of injecting money from governmental or commercial interests into such countries ignore the given predicaments of society, whether it be gender biases or isolation. Internet technology access programs that are centered around an agenda which ignores a utilitarian framework will continue to neglect suitable practices.

**Case of Commercialization Culture**

With the rapid dissemination of Internet technologies in the developing world, consumerism culture has been introduced into areas which are still unable to keep up with the demand. In Western and early Internet-adopting countries, the economic boom introduced by the Internet in terms of flow of money, job creation and increased efficiency has given industries and business a competitive advantage in the regional and global marketplace (Albirini, 2008). Similarly, in the developing world Internet access marks only the initial concern about the digital divide, because the rate at which technology is adopted could affect the populace in unexpected ways. According to Robinson, a potential issue with access is that the populace who are already well informed about the Internet could not only gain access to new technology but could use it to increase their advantages over those less well informed (Robinson, 2003). Furthermore, the point serves as a cautionary example of what the rapid commercialization of the Internet in developing nations could result in.

Like with the previous case, defining an actor network framework can be used to highlight certain dimensions of interest in the case of commercialization. The methodology presented below splits the model into general levels that can be applicable towards similar national contexts. The base level actors in this case are the people who are uninformed about increased Internet access measures that may be separated from the general population geographically. The next level actors are the people who are informed about increased Internet access measures. An intermediary network will link the two levels by economic resources through the flow of money, which measures the impact of Internet access. A utilitarian ethics framework will finally analyze and predict the result of further increasing Internet access to critique the question arising from Robinson's point: can the well-informed population increase their advantages over the uninformed? (Robinson, 2003).

Kirkpatrick notes that the overall goal of Internet providers is to give people who have never used the Internet a taste of the features and benefits of Internet access, so that it becomes a "must-have" in their lives, rather than a "nice-to-have." In Kirkpatrick's interview with Darrell West, vice president of governance studies at the Brookings Institution, West notes that "the key barrier is the initial deployment—once people start using the Internet, they generally want to use it more, and it becomes a higher financial priority for them" (Kirkpatrick, 2018). From the lens of the uninformed populace who are unaware of Internet access measures in their developing nation, human capital is largely measured on providing a non-digitized service or labor in an area of occupation. On the other hand, for the informed populace that restriction does not need to be made; the informed can provide human capital through digital and physical means alike, because being informed about Internet access allows for more choices to be made.

Using the General Social Survey (GSS) evidence from the years 2000 and 2002, Robinson finds that college educated individuals demonstrate more advantage over the less educated on aspects of sophistication, such as knowledge particularly in terms of the types of Internet sites visited. The college educated user is significantly more likely to visit sites that build on their human capital or enhance their life chances, such as sites related to work, education, or health (Robinson, 2003). A utilitarian ethics perspective supports the approach of educating individuals about the Internet in that it produces the greatest benefit for groups who know about Internet access. However, for an entire developing nation, if the benefits of the Internet are not actively communicated to the digitally disadvantaged, the digital divide remains to only grow further. The most tangible benefit to society would be to spread Internet resources extensively to areas that are known to have populations unaware of the Internet, so users of the Internet can get educated to reap the benefits without any overlooked limitations.

A potential limitation of the chosen actor-network model is that it applies to countries in which most denizens are separated geographically. However, even in most geographically separated areas of the developing world, the general population is aware of the existence of the Internet but still does not possess the knowledge to use it effectively. In this case Internet education measures would still be applicable because an increased availability of access does not always guarantee successful adoption. While the current spread of Internet resources benefits only those who are aware of its access, Internet education is still a prerequisite. We can apply the case of commercialization to the adoption of the Internet for reducing the digital divide. For those who still need to be introduced and educated about the Internet, a utilitarian ethics framework ensures equity in the opportunities provided with Internet access. If Internet resources are propagated without accommodating reasonable access to people who are unaware of the technology, the digital divide will continue to grow.

### Counterarguments

The main argument of this thesis is that the costs of Internet accessibility measures in developing areas must not be discounted under economic growth. A major counterargument that could be made about the research analysis is that increased Internet access in poorer regions still results in a net positive for the whole nation. Unfortunately, that view through a utilitarian framework masks the negative consequences of Internet access, whether it be complex societal problems like gender biases or human capital issues like non-digitized occupations. According to a study by Galperin and Viecens, while the evidence indicates that advanced economies are reaping significant benefits from internet investments, the returns for less advanced economies, and in particular for the fight against poverty in these regions, remain uncertain. (Galperin & Viecens, 2017). This thesis argues that evidence of economic growth through increased Internet access should not discount a solution that minimizes negative outcomes. A second counterargument that could be made about the analysis is that Internet accessibility prices in third world countries are currently reducing with the modernization of technology, which can tackle issues of the digital divide. However, since the population distribution is relatively disproportionate for developing regions of the world with an urban centralization, measures must be put in place so that Internet technology access does not become unequitable. Ynalnez et al. notes that research institutions are generally concentrated in urban centers, which results in capital cities to be chosen as a base for Internet data collection (et al., 2005). A final counterargument that could be made is that applying a utilitarian ethics framework for the topic of increased Internet access in the developing world requires a higher level of research. However, each year the number of studies on Internet technologies multiplies as commercial interests take hold. Moreover, the inclusion of a utilitarianism perspective is validated by the number of resources provided in this thesis.

## Conclusion

Given recent technological advancements in Internet technologies for developing countries, worldwide initiatives have been put in place to counter the divide between access in impoverished and prosperous areas. However, while the Internet is often portrayed as an empowering tool with the potential of ushering in a new era of development, it hastens unanticipated consequences to impoverished areas already burdened with hardship. Many factors, such as the average level of education and income in impoverished regions, were contextualized to illustrate how increased Internet access masks systematic issues under the guise of economic development. In order for the Internet to alleviate issues of poverty and hardship in developing regions of the world the most positively, governmental interests should step through systemic issues addressing which public and private initiatives achieve the greatest benefit to society. This thesis detailed various networks and their actors found from research on the determinants of Internet access in developing countries and used utilitarian ethics to examine the consequences of traditional efforts of providing Internet access through government or commercial investment.

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**Smart Medication Organizer**
(Technical Paper)

**The Internet as a Social Artifact: How Widespread Internet Access May Hinder Developing Nations**

(STS Paper)

A Thesis Prospectus Submitted to the

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Fall, 2020

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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**

## Introduction

Between 1986 and 2002, Americans aged 45 and older reported that their regular use of prescription drugs increased from 52% to 75%. On average, the same groups say they take an average of four different prescription drugs daily (Barrett, 2005). It may be difficult and burdensome to keep track of several medications which must be taken at certain times throughout the day, and there can be serious health consequences if a medication is neglected. The National Institute on Aging recommends that older adults be “careful to keep track of medicines and use them safely” by maintaining “consistent medicine scheduling” (“Safe Use of Medicines for Older Adults,” n.d.). The consistent tracking of prescriptions can be achieved by the creation of a medication tracker to store user medication information in a single device. The final technical deliverable, an embedded smart medication organizer, tracks medication dosage through convenient organization and timed reminders to signal which medications to take consistently.

On a similar note of technical dependence, the advent of wireless technologies and the Internet has fostered social implications worldwide that must be carefully examined and researched. The World Bank Group notes that Internet access is not a luxury, but a basic necessity for economic and human development in both developed and developing countries (Daly & Miller, 2020). Yet, in developing countries, even when there are Internet connections available, many people in regions simply cannot afford either the devices required or account access (Kirkpatrick, 2018). With the role of recent technological advancements in satellite-based internet, it is vital to explore how widespread internet access may help or hinder third world countries. The final topic deliverable explores the effects of internet connectivity in developing areas of society and explains the impact of recent advancements in Internet technology.

**Technical**

The average American over 45 takes an average of four different prescription drugs daily (Barrett, 2005). It can be difficult and cumbersome to keep track of several medications that must be taken at certain times throughout the day, and there can be health consequences if a medication is neglected. The Smart Medication Organizer aims to alleviate these issues by providing a simple and reliable solution that stores all of a user's medications in a single device that provides consistent reminders, ensuring that the user never forgets taking their medication and spends less time thinking about which medication to take. A few similar products have been attempted commercially. Most notable are the MedMinder and Hero pill dispensers ("Safe and Automated Medication Dispenser", 2020; "Automatic Pill Dispenser & Medication Manager: Hero", n.d.). These products have been produced by large engineering teams so they have a few useful features that are out of the scope of our project, including automatic dispensing, compartment locking, and email and text message reminders.

Our project, however, will introduce some valuable features that these products lack. Our pill dispenser will be compact, compared to the Hero automatic pill dispenser which is an unwieldy device that cannot be taken travelling. Our product will be smaller than a lunch box, compared to the MedaCube which is as large as a coffee machine ("Automatic Pill Dispenser for Seniors & Loved Ones", n.d.). Our project will also be substantially easier to prepare compared to its counterparts. The MedMinder pill dispenser has 28 compartments that must be carefully filled with the correct medications for each day, and there is no separation of the medications based on time. The Smart Medication Organizer has compartments for up to 6 types of medication, and the user is notified by the LEDs and screen to take from the given compartments at a given time. Moreover, the value of the safe use of medicines for older adults is shown by the National Institute on Aging which recommends that older adults must be "careful to keep track of [their] medicines and use them safely" by maintaining "consistent medicine scheduling" ("Safe Use of Medicines for Older Adults," n.d.). Our smart medication organizer box will deliver on these promises and therefore be as reliable as our commercial counterparts. Finally, our project will save our customers money because there is no subscription-based service for the reminders and notifications. Both the MedMinder and the Hero charge monthly subscriptions to use the applications that control their devices ("Safe and Automated Medication Dispenser", 2020; "Automatic Pill Dispenser & Medication Manager: Hero", n.d.). MedaCube requires an outrageous $1,500 investment upfront ("Automatic Pill Dispenser for Seniors & Loved Ones", n.d.). Our device will be affordable and the user application will come paired with our device for free.

The implementation of our project will draw heavily from the Computer Engineering curriculum. We will use knowledge from the Fundamentals of Electrical Engineering series (ECE 2630, ECE 2660, ECE 3750) by designing a PCB to connect our hardware elements of our device to the microcontroller. The hardware elements will include an LCD screen, a power supply, a piezoelectric buzzer, LEDs, MOSFETs, and other basic circuit components. Our project will use an embedded microcontroller (ECE 3430) to drive the screen, LEDs, and buzzer. We will use software development skills (CS 2150, CS 3240) to design a user application to configure the types of medications and the time of their delivery. We will also use our knowledge of computer networks (CS 4457) to create a wireless link between our device and the user application.

Responsibilities for the project will be divided as follows. Forrest will lead the networking for the device, as well as the embedded software, with a secondary focus on the user facing software. Sean will be responsible for designing the enclosure for the device and integrating it with the PCB design, as well as additional work on the software. Sai will primarily focus on the user application for the device, and will provide assistance with the embedded programming and design of the PCB. Quin will prioritize designing the PCB and utilization of the FPGA, and assist with software development as needed. We plan to finish the Smart Medication tracker by the end of the Fall 2020 semester.

**STS Topic**

For decades, wireless technologies in developed nations such as the United States have been readily available for public and private use. Yet in developing regions of the world, which include but are not limited to parts of Africa, Asia, and Latin America, there is relatively sparse infrastructure in place to allow citizens of these areas to access the Internet (Kirkpatrick, 2018). Given recent technological advancements in connectivity to developing countries, worldwide initiatives have been put in place to counter the divide between Internet access in impoverished and prosperous areas. However, while the Internet is often portrayed as an empowering tool with the potential of ushering in a new era of development, it could actually hasten unanticipated consequences to impoverished areas already burdened with hardship.

Starting as a small, closed, text-based computer network of a few thousand scientific and government users in the early 1980, the Internet rapidly grew to an open global network of an estimated 150 million users in early 1999 (Petrazzini & Kibati, 1999). Over the past decade, governments and donors have invested heavily in Internet connectivity projects across the world, based on the assumption that increased access to internet services and applications will boost economic growth and improve the well-being of the poor (Galperin & Viecens, 2017). However, impact evaluations of Internet access in developing areas have not necessarily found the link between expectations of increased Internet access and evidence in societal change. A factor worth considering is that higher costs for Internet services in developing countries dissuade connectivity for the general population. Most countries cannot go beyond the small group constituting the professional class for Internet development—in Tanzania, a computer costs three times an average professional's monthly salary (Petrazzini & Kibati, 1999). Furthermore, in developing countries, income by itself is not probably the sole, overwhelming determinant of Internet access (Chaudhuri et al., 2005). In a survey on the impact of Internet use on income and expenditure in rural China households, education had a positive and statistically significant coefficient, suggesting that better-educated household heads are more likely to use the Internet (Ma et al., 2020). In developing areas, where illiteracy and poverty run rampant, it can be argued that the image of the Internet as a benefactor to developing countries has been propagated throughout the globe mainly for industrial and corporate profit (Albirini, 2008). The merit of Internet connectivity is therefore reliant on a variety of factors that differ from each developing country.

Given that education may be a notable factor in wireless technology usage in developing areas, case studies on the impact of the Internet on third world research communities can be analyzed. In order to use the Internet, one must first garner the skills necessary for its effective use. Ynalvez, et al. (2005), observe that the distribution and variation in Internet practice and experience, together with measures of ready access and current use, provide more reliable indicators of digital inequality in the developing world. Another point of analysis outlined by research communities in developing areas is the impact of gender and science on Internet disparities. Paige Miller et al. (2006), note that gender gaps in educational and organizational localism became more pronounced among scientists in Ghana, Kenya, and the State of Kerala in southwestern India. Such indicators show that Internet disparity is not only dependent on the level of Internet proliferation, but also the specific people to whom it is introduced.

With the variety of unique factors surrounding the proliferation of Internet access in the developing world, Actor Network theory (ANT) will primarily be used to pursue the research problem. Latour, Callon and Law developed the ANT as a sociological theory that attempts to examine heterogeneous networks comprised of actors or actants, which could be either humans or technological agents (Latour, 1998). In many cases, ANT can be used to analyze coexistent entities that maintain everchanging relationships over one other. Many actors at times are locked into networks of which certain elements reside outside of the focal organization, which allows the study of the assembling and stabilizing of diverse human and non-human entities within diffuse socio-material systems (Alcadipani & Hassard, 2010). Critics such as Langdon Winner maintain that properties such as intentionality fundamentally distinguish humans from animals or from objects that are included as "actors" in ANT (Winner, 1993). Moreover, the potential for networks to intermingle and devolve into infinite branches of connections may be considered a criticism of ANT.

**Research Question and Methods**

The research question being attempted to answer is: to what extent does the societal spread of internet connectivity and access help or hinder third world countries?

To answer my research question, I will use Actor Network Theory and Scientific Case study methodologies. Beginning with the background section, I will detail various networks and their actors found from research on the determinants of Internet access in developing countries. For example, an examination of an Internet issue can be modelled using traditionally developed ANT actors and depicting their relationships, while allowing for real, actual and empirical realities (Balock & Cusack, 2011). The division of the ANT network into layers allows for problem areas to be examined from a variety of perspectives. In terms of research collection, I have organized my sources with the aim of balancing data driven research with analytical work. Using keywords such as "Internet statistics in Developing Countries" on research collection websites handles the data driven research side of my collection methodology— keywords such as "analysis on ISPs in Developing Countries" handles the analytical side of my research.

My method consists of a thorough exploration of the effects of the spread of internet connectivity in developing areas of society, as described above. It also includes an explanation of the impacts of recent advancements in providing internet access across the world. It will foster a discussion on the topic of increased Internet access for all, and how researching Internet connectivity in developing countries has merit in present society.

**Conclusion**

This paper covers the development of a Smart Medication Organizer to provide a simple and reliable embedded solution that stores all of a user's medications in a single device. The device provides consistent reminders, ensuring that the user never forgets taking their medication and spends less time thinking about which medication to take. The paper additionally covers a sociotechnical analysis on the costs and benefits of Internet access in developing countries, using Actor Network theory as a means to analyze the research problem.

The technical deliverable, once completed, will solve the issue of keeping track of several medications which must be taken at certain times throughout the day, given that there can be serious health consequences if a medication is neglected. The sociotechnical deliverable, once completed, will foster a discussion on the topic of increased Internet access for all, and how researching Internet connectivity in developing countries has merit in present society.

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