Smart IoT Alarm Clock

ECE 4011 Senior Design Project

Section A05, Smart IoT Alarm Clock Team

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Executive Summary

It is common knowledge that waking up with a personalized morning routine is a vital key to having a productive day. Many morning routines begin with similar tasks such as turning on the lights and starting a pot of coffee. These two activities can easily be automated by utilizing IoT devices. The team will design and prototype a Smart IoT Alarm Clock (SITAC) that connects wirelessly with a modified coffee maker and smart light bulbs combining these morning tasks into one of setting the alarm the night before. By using the SITAC, users will have a more productive morning routine with less menial tasks to accomplish. The SITAC will be built using an mbed development board, Wi-Fi module, Bluetooth module, LCD screen, push buttons, speaker, and two power supplies. An off the shelf coffee maker will be modified to include IoT support necessary to be controlled by the SITAC. Commercially available smart light bulbs with a Bluetooth connection will be used. To interface with the SITAC, there will be an on-device interface composed of an LCD screen and pushbuttons, and a phone app for the remote interface. The phone app will connect to the SITAC through Wi-Fi, enabling control of the device from anywhere in the world. To power the device there will be a power cord that connects to a standard wall outlet, along with a battery power supply for portability or backup power during outages. The SITAC team expects to build a working prototype that costs less than $500 with the inclusion of the modified coffee maker and smart light bulbs.

1. Introduction

The Smart IoT Alarm Clock group will design an alarm clock that can control smart home devices, such as lights and a coffee maker, and be controlled by a phone app or by the alarm clock interface itself. The team is requesting $500 to fund the development of the SITAC prototype.

1.1 Objective

The team's objective is to create an alarm clock that can control in-home devices that the consumer uses every morning. The consumer will then be able to control the whole system from their phone. The prototype will showcase its ability to control these devices by operating a coffee maker and lighting a light bulb. **Figure 1** shows the sequence of events that are completed when the user sets an alarm and requests that the lights be turned on and coffee maker started.

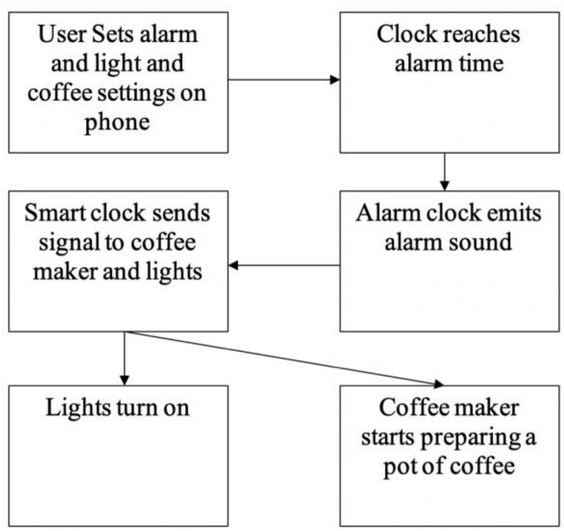

Figure 1. Flow chart for use of alarm clock and home device system.

1.2 Motivation

The motivation for this project is to generate a more efficient and convenient morning experience for the user. Making the coffee for the user before they go to the kitchen will save them time by cutting coffee preparation from their routine. On the market today, to get an alarm clock that works with your coffee maker, the devices are sometimes sold as a combined unit. This project will allow control over a coffee maker in another room instead of bringing the coffee maker into the bedroom. Turning the lights on when it is time to wake up will help the user get out of bed on the first alarm instead of snoozing and rolling over. The light feature will also appeal to deaf users, providing an alternative stimulus for waking the user.

1.3 Background

Home automation is becoming more common. The IoT industry is a rapidly-growing field with increasing prevalence in businesses and industry today [1]. The goal of IoT is to connect all of the devices a consumer might interact with. In today's fast-paced world, staying connected is incredibly important, and this desire to stay connected is the driving force behind the rapid growth of the IoT field in industry [1]. There are a number of different IoT alarm clocks on the market today with a variety of features, but it is rare to find one that does everything. Some alarm clocks that start your coffee maker are sold as one unit where the coffee maker also plays the alarm tone, such as the Barisieur, but these products require the user to move their coffee maker into their bedroom [2]. There are also programmable products where a time is set on the coffee maker, and the coffee maker will begin brewing at the desired time. However, these products, like the Cuisinart Automatic Grind and Brew, require the user to program their alarm clock and coffee maker separately [3]. The Google Assistant can turn lights on, starting a coffee maker, and reading the weather forecast to users, but can only be used on Android phones and in some cases, only on the Pixel 3 [4]. The best way for the alarm clock to connect to the other in-home devices (the coffee pot and the lights) is via Wi-Fi and the Internet [1]. According to many sources, the ESP8266 is the best Wi-Fi module on the market [5, 6]. This will be used, with its microcontroller capabilities, to connect to the Internet and to communicate with other devices.

2. Project Description and Goals

The team will design a Smart IoT Alarm Clock which will be able to turn a coffee maker and a light source on/off when the alarm sounds. Pushbuttons and an LCD will be used for the on-device interface, while a phone app is used for the remote interface. The device will be composed of a microcontroller, Wi-Fi module, Bluetooth module, LCD screen, push buttons, speaker, and two power supplies. A standard coffee maker will be modified to add IoT functionality allowing the SITAC to turn it on and off. A modified lamp will be connected to the SITAC through Bluetooth, enabling light-control via the device. The device will have the following features:

- Alarm clock functionality
- LCD display
- Internet connection via Wi-Fi
- Starts smart coffee maker
- Controls smart lights
- Configurable through on-device interface and phone app
- Wall power and battery power for ease of use, portability, and outages

3. Technical Specifications

Table 1. Alarm Clock Specifications

Feature	Specification
Maximum Dimensions	12”x12”x6”
Accuracy	±1 second
Backup Battery Life	1 week
Power Supply	5V
Alarm Volume	70 dBm
Buttons	4 buttons
Weight	< 4 lbs

Table 2. Coffee Pot and Lamp Specifications

Feature	Specification
Coffee Pot Volume	4 cups
Lamp Power Supply	5V
Lamp Brightness	600 lumens
Lamp Power Consumption	60W

4. Design Approach and Details

4.1 Design Approach

System Overview

The SITAC will consist of a microcontroller, touchscreen LCD, Wi-Fi module, speaker, push buttons, and backup power system. Wi-Fi modules will also be connected to the coffee maker and lights. **Figure 2** shows a block diagram of the system.

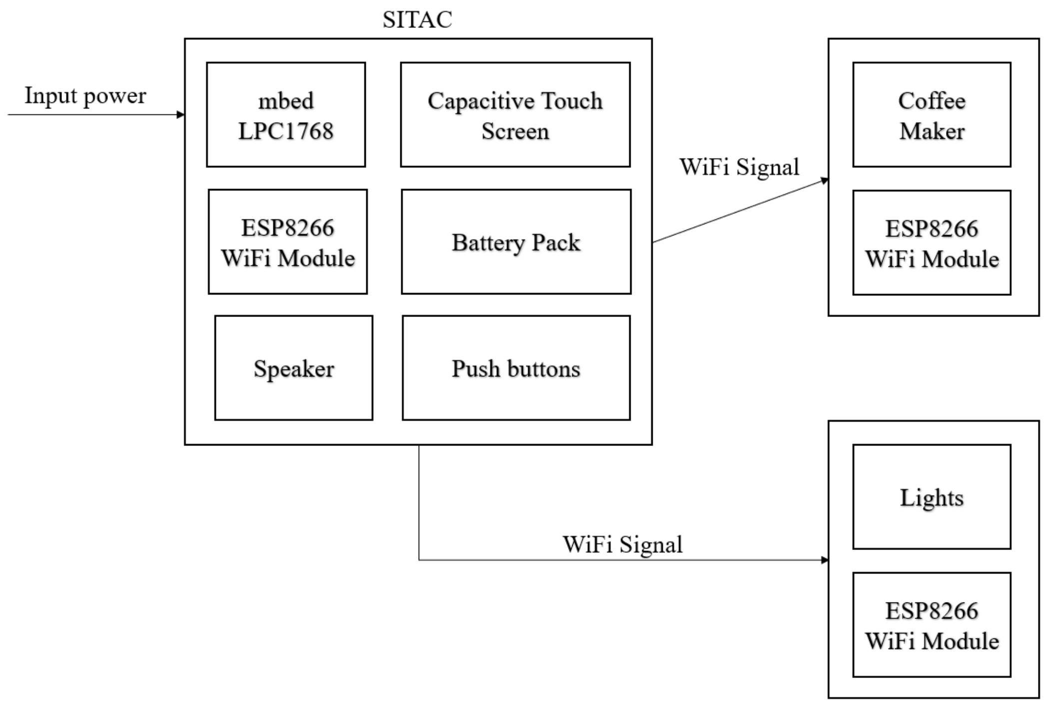

Figure 2. Block diagram of the SITAC system.

The mbed LPC1768 has been chosen as the platform for this project for two reasons. First, the mbed has extensive software support for hardware commonly used in IoT projects. Second, the team is most familiar with this platform, which will focus development on features instead of learning the platform. The Wi-Fi module which will be used in this project is the ESP8266, which is a low-cost module with GPIO support. Presently, no display has been selected for the project.

The SITAC will be connected to a power outlet independently of the coffee maker and lights. Development of the system will begin with basic clock features, followed by integration of the coffee maker and lights into the clock's functionality.

Basic Clock Features

The SITAC will function as an alarm clock independently of any smart features. Basic alarm clock functions will include:

- Internet-controlled timekeeping
- Multiple alarms
- Adjustable alarm volume
- Customizable alarm tone
- Variable brightness

Internet-controlled timekeeping will be accomplished through a Wi-Fi connection. If no connection is available, the user will be able to manually adjust the time. Customizable alarm tones will be generated as they are played, though audio file playback is a possibility. Alarm volume will be adjusted through the touch screen interface. Variable brightness may be achieved through user control or by syncing with the lights. There are currently no plans for a hard cap on the number of alarms the user may save.

Coffee Maker and Light Integration

The coffee maker and lights will each be connected to the SITAC through Wi-Fi using an ESP8266 module. Alarm information will be stored on the SITAC and wirelessly sent to the coffee maker and lights. When the user sets an alarm on the SITAC, there will be several options available for the alarm. Among these, the user may choose to have the alarm brew coffee or trigger any connected lights. If the brew option is selected, the coffee maker will be switched on when the alarm sounds. Similarly, when the light option is selected and the alarm sounds, the lights are turned on.

Backup Power Source

Five AA batteries and a 5V regulator will be used as backup power. The batteries will be connected to the mbed through a 2.1mm barrel plug, which is shown in **Figure 3**.

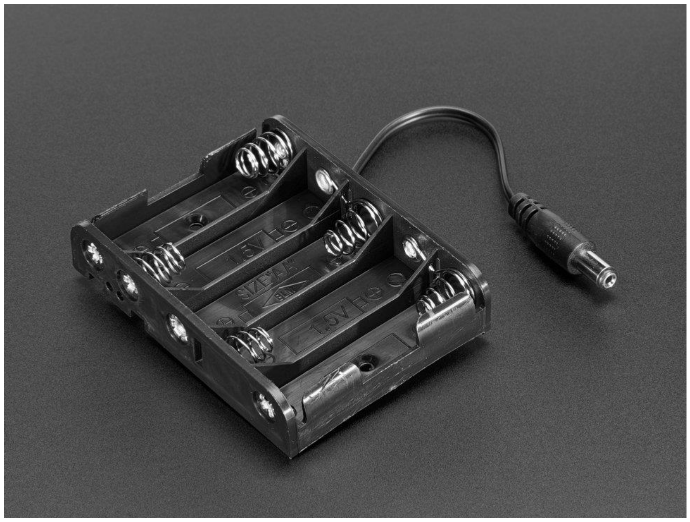

Figure 3. 5 x AA Battery Holder with 2.1mm DC Jack [7].

Battery power will only be triggered when outlet power is removed from the SITAC. While rechargeable AA batteries may be used with this holder, rechargeable battery packs have been considered as backup power sources. If a rechargeable battery pack with the correct specifications is found, it may be used instead of the AA battery holder.

GUI Layout

Because a display has not yet been selected, no GUI layouts have been finalized. However, current plans include displaying the current time, the time of the next enabled alarm, and its settings on the home screen. This is shown in **Figure 4**.

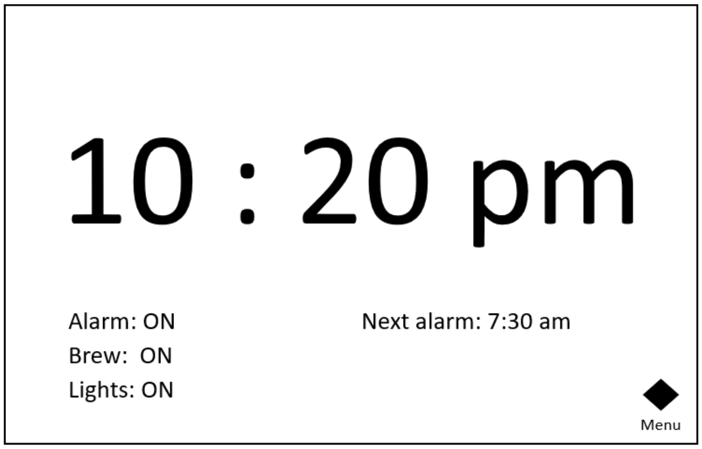

Figure 4. Home screen display prototype.

The clock's settings will be accessed through the menu icon on the bottom right. Here, the user can set alarms and change their settings, manage connected devices, and adjust screen brightness. Settings such as alarm volume and tone will be managed by each individual alarm and will not be included in the menu for the clock's general settings. A potential interface for alarm settings is shown in **Figure 5**.

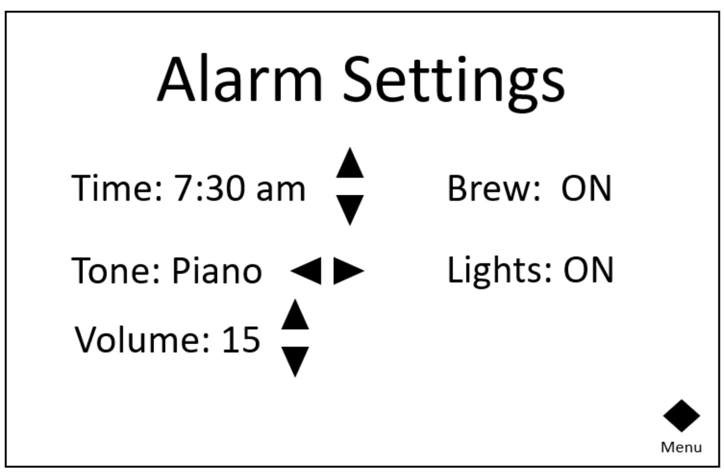

Figure 5. Alarm settings prototype.

Design Process

The critical path in this project is dominated by the development of the phone app. This will be addressed by laying out the requirements for the app as soon as the basic clock functionality is completed and work on coffee maker and light connectivity has begun. The phone app will be developed alongside connectivity of the coffee maker and lights. However, development of these modules is not strictly bound together. Certain elements of connection with the coffee maker, such as the settings and timing, can be developed independently of the app. Development of these features will not severely interrupt or hinder progress on the app, nor will development of the app impact progress on integration features.

Other aspects of this project's design include code management. A GitHub repository will be created to host the source code for this project. The team will meet and agree upon coding guidelines, which will make it easier to maintain the repository as the project evolves. Because this project involves complex software systems, the team will devise a software architecture for the project after initial hardware prototyping is finished. Architecture will *not* be developed until after the hardware is confirmed because the software running the SITAC is dependent on the hardware it is composed of.

Contingency Plans

Because development of the phone app dominates the critical path of this project, contingencies will be put in place in case significant roadblocks are encountered. If development of an app is not possible, then features of the alarm clock will be extended to include connectivity to other devices, weather display information, and other common "smart" features. If progress on the app is too slow, then the team members who were not originally working on the app will begin to help. If it is found that the hardware selected for this project is inadequate, then new components will be selected and rapidly integrated into the project.

4.2 Codes and Standards

The most significant protocols that apply to this project are Wi-Fi, I^2C, and SPI.

1. Wi-Fi is a wireless communication technology based on IEEE wireless communication standard 802.11 [8]. There are several specifications for Wi-Fi. This project will use 802.11n because it is supported by most devices and has a sufficient data transfer rate for this project. The 802.11n standard features:
   - 2.4 or 5 GHz operating frequency
   - 20, 40 MHz channel width
   - 450 Mbps data transfer rate
2. Inter-Integrated Circuit (I^2C) is a two-wire serial protocol mainly used for microcontrollers and peripherals [9]. It allows for multiple master devices. Data transfer between slave and master is split into 8-bit packets. The I^2C protocol features:
   - 7-bit address for each slave device; some devices with 10-bit addresses permitted
   - Data transfer rates between 100 kHz and 5 MHz
   - Serial clock and serial data pulled up to power
3. Serial Peripheral Interface (SPI) is a bus commonly used to transmit data between microcontrollers and peripherals [10]. SPI uses separate buses for sending data and clock information, keeping the two synchronized. The mbed LPC1768 and ESP8266 have built-in support for SPI, allowing this standard to be used to for communication between the two devices. It features:
   - Master-slave device relationship
   - Adjustable data transfer rate

- Simple shift register interface

Because of the adjustable data transfer rate and shift register interface, SPI is faster and easier to use than I^2C.

4.3 Constraints, Alternatives, and Tradeoffs

Constraints

Limitations of the current approach include the creation of a phone application to interface with the SITAC. Presently, no one involved with the project has experience creating apps. Because of the lack of experience in this area, alternatives to the phone app, such as extending the SITAC's functionality, may be better options instead Another constraint of this project is an enclosure for the SITAC. Specifications for an enclosure cannot be drafted until a prototype SITAC is created. Until then the components will be assembled on a breadboard, which is not representative of the final product. Furthermore, no one involved with this project has experience with CAD or 3D printing. This means that an enclosure will have to be constructed manually or the team will learn to use 3D printing technology during this project.

Alternatives and Tradeoffs

For the platform, a Raspberry Pi or other ARM-based microcontroller could be used instead of the mbed LPC1768. While the mbed has lower performance than many affordable Raspberry Pis, such as the Pi Zero, it has extensive library support for web interfaces and supplementary hardware. A Raspberry Pi would provide lower-level hardware support at the register level, but the Pi’s libraries would make software maintenance more difficult. The mbed was chosen for this project because its libraries are easier to use and has broad hardware support.

The ESP8266 was chosen because it is a low-cost Wi-Fi module with I2C and SPI functionality. Other Wi-Fi modules considered were the SimpleLink Wi-Fi CC3000 and Roving Networks WiFly RN-171-XV. They were much more expensive than the ESP8266, costing over twice as much. Because the ESP8266 has the features required for this project, including onboard power regulation and GPIO, it was selected for its lower cost.

Bluetooth was considered over Wi-Fi to connect the SITAC to the lights and coffee maker, but was ultimately rejected for three reasons. First, the number of devices that may be interconnected with Bluetooth is limited. Second, Bluetooth is more limited in range than Wi-Fi, which would cap the distance the SITAC could be from the lights and coffee maker. Third, Bluetooth has a slower data transfer rate. While initial plans involve sending only limited information from the SITAC to the lights and coffee maker, data bandwidth could be an unforeseen constraint in the future if other features are implemented.

5. Schedule, Tasks, and Milestones

The PERT Chart in **Appendix A** shows all of the specific tasks and milestones of the project. The three values separated by dashes in the bottom right of each node represent fastest, expected, and worst-case times for each task, respectively. A large time range represents a high estimated degree of difficulty and risk, while a low time range shows that the team is more confident in their ability to complete the goal in the expected time. The values below each node are the weighted expected times based on the fastest and worst-case possible times. The critical path is shown by the bolded arrows between nodes.

The GANTT Chart in **Appendix B** shows all specific tasks and which team member is responsible for each. It also shows a specific, detailed timeline (numbers 1-16 represent weeks of the semester). Critical paths are color coded, and details on how to follow them are in the key.

6. Project Demonstration

The SITAC prototype will be set up with the coffee maker and light bulb. Five areas of the prototype will be tested:

1. The SITAC's ability to check the Internet to get the most accurate time of day.
2. The SITAC phone app's ability to set an alarm.
3. The SITAC's ability to turn on the coffee maker.
4. The SITAC's ability to turn on the light.
5. The SITAC's on-device interface's ability to set an alarm.

To confirm the successful implementation of each aspect of the SITAC, the following tests will be conducted:

1. The SITAC clock will be powered on from a powerless state and allowed time to check the Internet and display a time on the LCD.
2. The SITAC app will be used to set an alarm (coffee and light preferences will be set to ON) for one minute in the future. After the minute has passed, the system will confirm its success by playing the alarm.

3. When the alarm sounds from test two, the coffee maker will be turned on automatically via signals from the SITAC, confirming the successful implementation of the feature.
4. When the alarm sounds from test two, the light will be turned on automatically via signals from the SITAC, confirming the successful implementation of the feature.
5. The SITAC clock's on-device interface will be used to set an alarm for one minute in the future (coffee and light preferences can be set to either setting). After the passing of the minute, an alarm will sound to confirm the successful implementation of the feature.

These tests will be run during the design process as well, every time a new feature has been added to the SITAC system. This will allow the team to track the projects progress during the early stages of design.

7. Marketing and Cost Analysis

7.1 Marketing Analysis

The target market consists of individuals who want to improve their alarm clock experience. Alarm clocks today have generic sounds that abruptly wake up their customer from their much-needed rest. Professionals have discovered that sound is crucial to starting the day off right, "As sleep expert Michael J. Decker told the Huffington Post in a 2014 interview, the study suggested that 'sensory input does create a physiologic response,'" which indicates that customers need to have a therapeutic noise to awaken them from their slumber [11]. The SITAC offers customers the choice to pick from an assorted collection of alarm sounds that they desire to use for their alarm clock. The SITAC will also have backup batteries so that if the alarm clock does not have a wall outlet or the primary power source is shut off, then the alarm clock will not be reset.

7.2 Cost Analysis

The total cost for a development of a prototype is $9,371.00. **Table 3** shows the breakdown of project components with labor hours, labor costs, and those combined with parts cost. **Table 4** shows the breakdown of the costs of each hardware part. The labor costs are calculated with an assumed cost of $30 per hour. Wi-Fi programming and testing/debugging are essential components to the project because the heart of the project involves connecting the alarm clock to the Internet and have it interacting with other smart devices.

Project Component	Labor Hours	Labor Cost	Parts Cost	Total Cost
Hardware Design	40	$1200.00	$36.00	$1236.00
Wi-Fi Programming	70	$2100.00	$35.00	$2135.00
Sound Modulation	20	$600.00		$600.00
Group Meetings	80	$2400.00		$2400.00
Testing/Debugging	100	$3000.00		$3000.00
Total Labor	310	$9300.00		$9300.00
Total Parts			$71.00	
Project Total				$9371.00

Table 3. Total Cost of Labor and Parts combined

Hardware Part	Price	Quantity	Total Cost
Mbed microcontroller - LPC1768 (Cortex-M3)	$55.00	1	$55.00
Wi-Fi Module – ESP8266	$7.00	3	$21.00
Bluefruit LE - Bluetooth Low Energy (BLE 4.0)	$18.00	1	$18.00
Speaker – PCB mount	$2.00	1	$2.00
128x64 SPI Graphic LCD Display	$18.00	1	$18.00
Coffee Maker	$20.00	1	$20.00
Smart Light Bulb	$18.00	1	$8.00
Wall Adapter Power Supply - 5V DC 2A	$6.00	1	$6.00
Battery Holder - 4xAA	$2.00	1	$2.00
DC Barrel Jack Adapter	$1.00	1	$1.00
Jumper Wires	$2.00	1 (30 pack)	$2.00

Table 4. Total Cost of Hardware Parts

The production will consist of 10,000 units sold over a 5-year period at a price of $175. **Table 5** shows the expected profit and selling price. Fringe benefits are assumed at 30%, overhead at 120%, and sales expense at 10%. At $175 for each product, the expected total profit is $5,266.95.

Based on:	10,000 units
Parts Cost	710000
Labor Cost	8433.9
Fringe Benefits, % of Labor	2530.17
Subtotal	720964.07
Overhead, % of Materials, Labor & Fringe	865156.88
Subtotal, Input Costs	1586120.95
Sales Expense	158612.10
Amortized Development Costs	10
Subtotal, All costs	1744733.05
Profit	5266.95
Selling Price	175

Table 5. Determination of the Selling Price

8. Current Status

The team has a solid foundation of the parts, components, and design features that need to be implemented, but they have not been tested. At the moment, the type of LCD screen needs to be determined and the Wi-Fi modules must be tested to verify that they can connect to a coffee pot or other smart devices. The first step to setting up the alarm clock is to connect the clock itself to the Internet and make sure that the clock can display the correct time. The next step is to connect the smart alarm clock to other smart devices and ensure that the connection is stable and functional. Afterwards, cosmetic changes can be implemented to give the clock a desirable appearance and sound can be adjusted to give a delightful experience.

9. References

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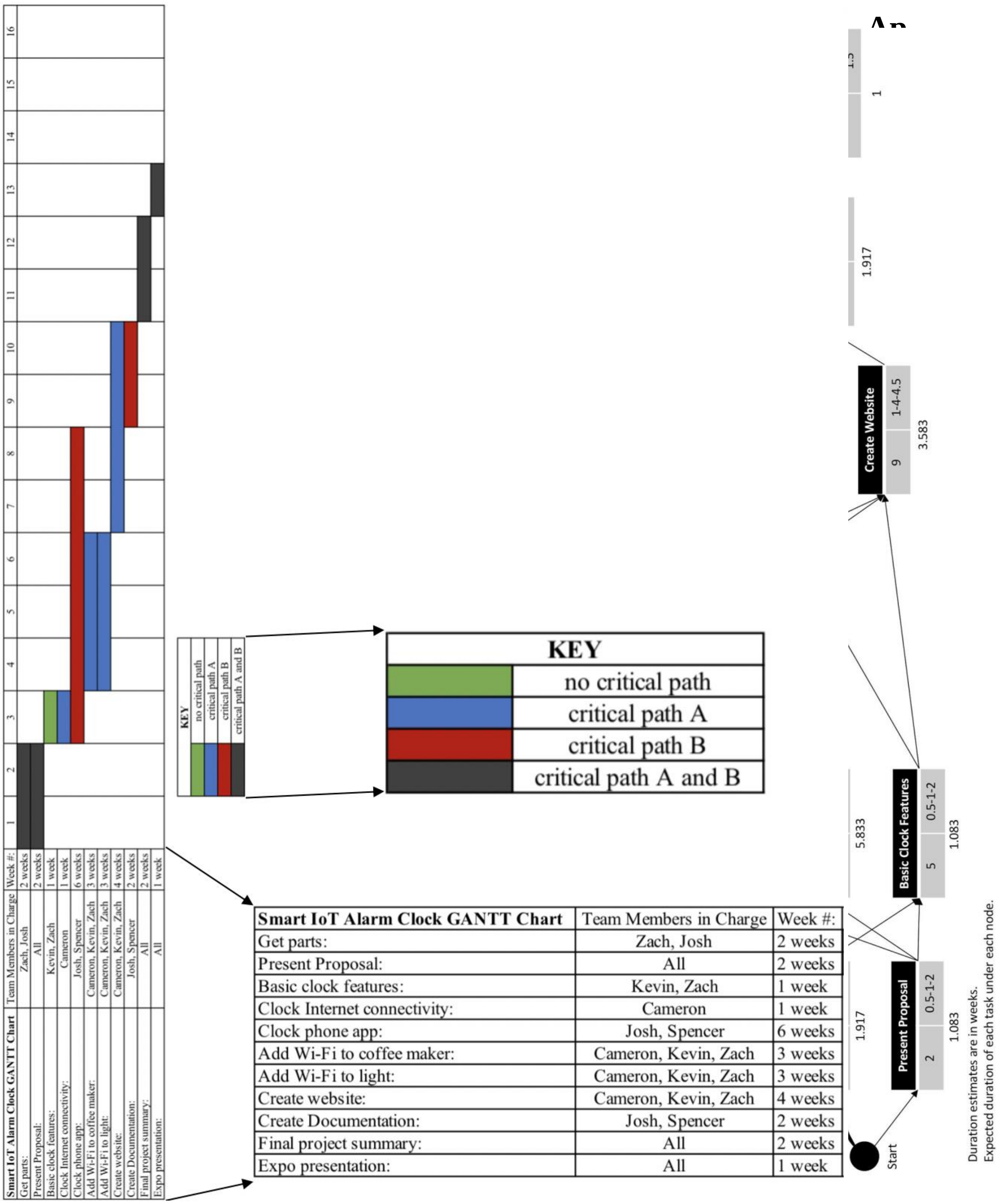
Appendix A: PERT Chart



Smart IoT Alarm Clock GANTT Chart	Team Members in Charge	Week #:
Get parts:	Zach, Josh	2 weeks
Present Proposal:	All	2 weeks
Basic clock features:	Kevin, Zach	1 week
Clock Internet connectivity:	Cameron	1 week
Clock phone app:	Josh, Spencer	6 weeks
Add Wi-Fi to coffee maker:	Cameron, Kevin, Zach	3 weeks
Add Wi-Fi to light:	Cameron, Kevin, Zach	3 weeks
Create website:	Cameron, Kevin, Zach	4 weeks
Create Documentation:	Josh, Spencer	2 weeks
Final project summary:	All	2 weeks
Expo presentation:	All	1 week

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