Brilliant Utility for Study Capacity App

(BUSCA)

Final Project Report

ECE4012 Senior Design Project

ECE 4012 Section A

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Executive Summary

Study space on campus is a limited resource that most students struggle with on a daily basis. Student testimonials have shown that searching for available spaces often wastes valuable study time and usually results in the student being unsuccessful in his or her search. Brilliant Utility for Study Capacity App (BUSCA) has the potential to solve this problem. Having implemented a scalable service connecting study spaces to students seeking them, the work done for this project has proved the concept viable. The project involved making an Internet of Things (IoT) low-power embedded device with a button that is capable of communicating if a table is in use. The device sends status data over Wi-Fi to a cloud server, to then be accessible through a mobile app, which displays a map showing the available tables by building and floor. With this data, along with BUSCA's scalability, students can determine which buildings, floors, and tables are available. While university and college campuses are the primary market, BUSCA can also be modified to fit other limited seating scenarios, such as casual dining or entertainment venues. A functional prototype has been developed and it successfully sends availability data to an Amazon Web Services (AWS) cloud server and updates the mobile app accordingly, all with a latency of under 10 seconds. The cost of this prototype was $179.56. The total amount needed to develop the project to completion is $133,925.22.

Brilliant Utility for Study Capacity App

1. Introduction

The Brilliant Utility for Study Capacity App (BUSCA) is study-space availability service. The service consists of small, discrete, low-power embedded devices at each study space, an app for displaying study space availability, and a cloud server. The team is requesting $79.58 to develop a working prototype.

1.1 Objective

The objective of BUSCA is to provide students with an easy and convenient way to find available study spaces on campus. The app uses a color-coded map of the study space they're interested in visiting. As seen in Figure 1, the Microcontroller Unit (MCU) is fitted in a discrete and noninvasive way under tables. The module connects via Wi-Fi to the cloud server and sends status data when a student presses the pushbutton. The server handles the data collected from all of the modules by mapping the status of each corresponding module to its location. The BUSCA app on users' phones connects with the cloud server and displays data in real-time with a user-friendly, color-coded format.

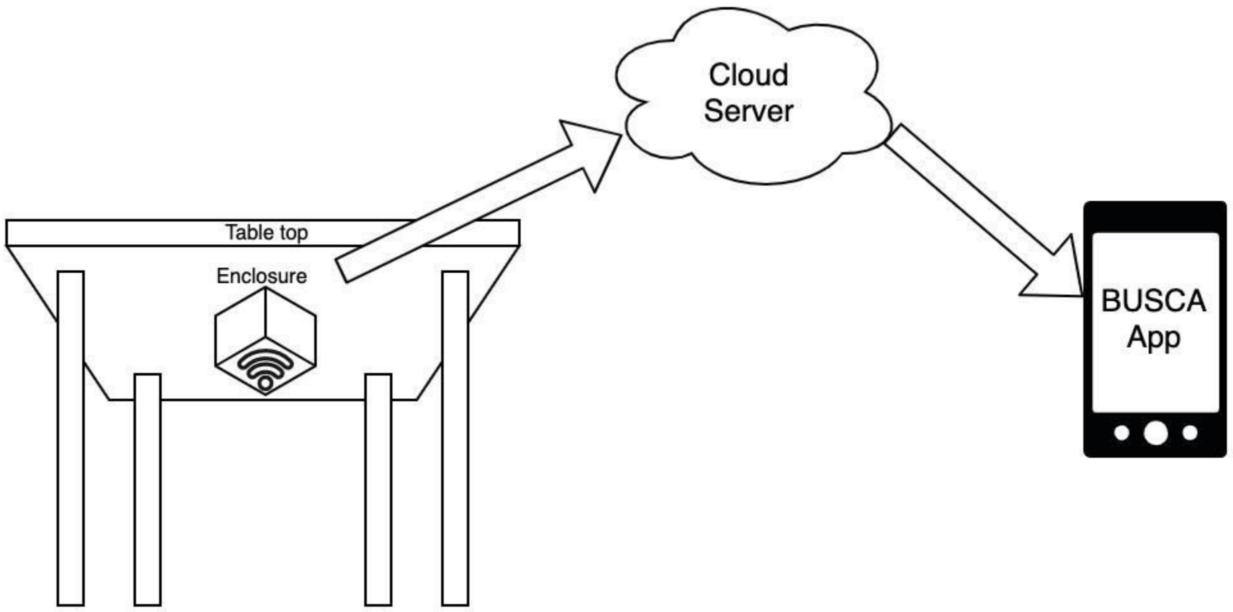

Figure 1. BUSCA components diagram.

1.2 Motivation

The motivation for this project is driven by students' frustration in searching for study spaces in popular buildings on campus. A small survey was conducted on ten random students and 100% indicated having experienced frustration when searching for study spaces. BUSCA aims to solve this by providing students with study space availability information before they spend time searching.

1.3 Background

This project involves four components: a microcontroller unit to handle processing, proximity sensors to obtain data from the environment, network connectivity to handle data transmission, and a cloud server to bridge the gap between devices and end users.

1.3.1 Microcontroller Unit

An MCU is an Integrated Circuit (IC) that contains all the components necessary for computing on a single chip. This includes one or more Central Processing Unit (CPU) cores, memory, and in some cases, a Wi-Fi module [1]. MCUs usually have a 32-bit ARM architecture, which for embedded applications offers the optimal tradeoff between power consumption and performance. The module will run on battery power; therefore, it is necessary to optimize low-power performance to reduce maintenance.

1.3.2 Proximity Sensor

A proximity sensor is able to detect the presence of an object within a range of distances. There are several types of proximity sensors in the market such as Light Detection and Ranging (LiDAR), Passive Infra-Red (PIR), and ambient-light proximity. This project will make use of ambient-light proximity sensors to detect the presence of people in a study space. The sensor detects a proximity signal which, after a burst of current pulses, is received from the infra-red photodiode [2].

1.3.3 Network Connectivity

Network connectivity between the module and the cloud server is essential in the context of this project. This involves having a reliable connection to send each module's status data to the server. The module will connect to the internet through Wi-Fi and send its data reliably using Transmission Control Protocol (TCP). This protocol establishes a connection and transmits data reliably after doing a three-way handshake with the server [3].

1.3.4 Cloud Server

A cloud server performs the function of any web server (hosting websites, storing user data, responding to user requests, etc.) [4] with the only difference being that it is hosted by a cloud service provider (i.e. Amazon Web Services or Microsoft Azure). The advantages of using a cloud server are scalability, cost efficiency, and ease of implementation. Cloud servers are scalable given the tremendous amounts of resources available that can be dynamically allocated as needed. Using a cloud server is cost-efficient because the billing system is usage-based. This means that cloud services users are only billed for the number of requests handled. Cloud service providers handle all of the maintenance and security for their clients, making implementation convenient.

2. Project Description and Goals

The original prototype design was drastically changed due to limitations of the COVID-19 health crisis. Nonetheless, a functional prototype, web server, and mobile app were successfully implemented. The team developed an app for iOS that connects with an AWS end-point and displays a dynamic icon that changes color when the prototype button is pressed. The original prototype design used sensors to gather human presence data from its surroundings, however this idea was scrapped due to the reasons stated earlier and data is gathered by a push-button instead. The module is non-invasive, as it doesn't use cameras or sensors, however it is not discrete as originally intended since it needs to be on top of the table for users to press the button and broadcast their presence. The module shows a change on the app after pressing the button in under 10 seconds 95% of the time. The original design included the module being battery powered, however this also had to be scrapped, and a USB-powered approach was taken instead. The module is able to connect to the internet and send its status data to the cloud server. It does this through the MCU's built-in Wi-Fi module and connects wirelessly to any pre-programmed Wi-Fi network. The module sends its data to the server through the MQTT protocol, which runs on top of TCP. The features of the system include:

- Reliable data transfer from module to cloud server
- At least 95% under 10 second latency in table status
- Color-coded map

3. Technical Specifications

Previously, the two major hardware components of the system were the MCU and the proximity sensors. However, due to COVID-19, the sensor implementation was not achievable. The team pivoted to a pushbutton implementation built into the MCU, with the system powered by USB cable. Table 1 displays the performance specifications of the MCU, Table 2 displays the original specifications for the proximity sensor, and Table 3 outlines the original battery specifications that were to\ be used to power these components. Since sensors and batteries were not used in the final implementation, their final technical specifications could not be updated. As shown in Table 1, the hardware specifications of the MCU were adequate to support data transmission through the network. The hibernation mode led to reduced power consumption when idle. An average network latency of 4 seconds was achieved in the end-to-end architecture.

Table 1. Microcontroller Specifications

Feature	**Proposed Specification**	**Final Specification**
Embedded Architecture	Dual-Core ARM Processor	Dual-Core ARM Processor
Clock Speed	> 10 MHz	80 MHz
RAM	128 KB	256 KB
I/O Interface	I^2C	SD, SPI, I^2C, UART
Standby Current Draw	< 10 µA	4.5 µA
Active Current Draw	< 200 µA	238 µA
Network Capabilities	Wi-Fi Network Processor	Highly Integrated Wi-Fi Network Processor
Network Latency (Round trip time) *	< 10 s	1.5 s - Fastest 4 s - Average 8 s - Slowest
Wi-Fi TX Power	18 dBm	18 dBm
Wi-Fi RX Sensitivity	-95 dBm	-96 dBm
Maximum Dimensions	15 mm x 15 mm x 2 mm	9 mm x 9 mm x 1 mm

* Time to establish a TCP connection with Cloud server, send data, and teardown

Table 2. Sensor Specifications

Feature	**Proposed Specification**	**Final Specification**
Input Voltage	3.3 V	N/A*
Current Draw	< 100 µA	N/A*
Response Time	< 5 µs	N/A*
Minimum Detection Range	50 cm	N/A*
Minimum Detection Angle	40°	N/A*
Accuracy within 50 cm	90%	N/A*

* Implementation was not achievable due to COVID-19 limitations

Table 3. Battery Specifications

Feature	**Proposed Specification**	**Final Specification**
Nominal Voltage	3.3 - 5.0 V	N/A*
Nominal Capacity	> 1 Ah	N/A*
Maximum Diameter	14.5 mm	N/A*
Maximum Length	50.5 mm	N/A*
Expected life	4 months	N/A*

* Implementation was not achievable due to COVID-19 limitations

4. Design Approach and Details

There are three main components to the design system: the data collection through sensors and MCUs, data transfer and processing on the server, and the mobile app. The sensors capture data when people are detected around the area and transmit it to the server. The server processes the data and the mobile app will display space availability.

4.1 Design Concept Ideation, Constraints, Alternatives, and Tradeoffs

4.1.1 Data Collection Through Pushbutton

Due to the fact that the sensors cannot be assembled in the lab, the team used one on-board push-button to provide proof of concept for data collection. When people come and go, the button is pressed to reflect the change in occupation. In the original plan, the sensors should be able to capture data relevant to people's presence in its vicinity. They must also have a connection to the local MCU via I^2C so multiple sensors can be handled by a single MCU. The sensors must be able to run at low power with a quick start-up time in order to prolong battery life.

4.1.2 Microcontroller Unit

The MCUs are able to connect to the server via Wi-Fi and send the data collected by the sensors. They have I^2C interfaces for data retrieval. An important constraint on the MCUs is power consumption. Since they are running on battery, the target is for the system to run for four months (approximately the length of a semester) before maintenance is needed. An alternative to having MCUs directly connecting to the server is to have an edge-device that manages a cluster of smaller, Bluetooth-capable modules in the same general area and sending the collective data from the cluster to the cloud server. Although having an edge-device locally allows processing of data before being sent to the server, its cost is much higher than the original approach and thus is not economically preferable at the current scale.

4.1.2.1 Internet Connectivity

The three main ways of connecting the MCUs to the server are Bluetooth, wired Ethernet cables or Wi-Fi through IEEE 802.11 a/b/g standards. The wireless approach is selected since it prevents having multiple wires laying on the ground and Bluetooth is not used because of its relatively short connection range. Running and processing all the data on the server provides two benefits: it provides a way for us to check and debug the sensors' conditions by analyzing the data, and it leaves more options for data processing since there are no limits on power, current or storage.

4.1.2.2 Power

There are two ways to power the MCUs using batteries: the first one is AA batteries using an off-the-shelf battery enclosure inside of the module. Alternatively, a comparable lithium-ion rechargeable battery may be used. For maintenance purposes, the AA battery enclosure approach is preferable given it's an industry standard. Due to the fact that the enclosure case could not be produced in the lab, power testing of the prototype relies on directly powering from USB cable.

4.1.3 Cloud Server

Amazon Web Services (AWS) IoT is used as the cloud service provider for this project because of its diverse functionality, programmability and accessibility. MCUs can be programmed with Amazon FreeRTOS -- an operating system that provides native integration with the services and protocols of AWS. The server will use Message Queuing Telemetry Transport (MQTT), which runs on top of TCP, to communicate with the MCUs and transfer information.

4.1.4 Mobile App

To take the social and sustainable impact into consideration, the design ideally supports both Android and iOS users. The Android Software Development Kit (SDK) is used for Android app development and Xcode is used for iOS app development in this project because they are open source and easy to use. Considering the time and labor constraints, only an iOS app will be developed.

4.1.5 Hardware/Software Interactions

The software computing part of the design is performed by analyzing and visualizing data on the server and the mobile app. The hardware component of the design focuses on data collection. The raw data is captured by each module consisting of one MCU and several sensors, transferred through a Wi-Fi connection to the server.

4.2 Preliminary Concept Selection and Justification

4.2.1 Promising Concepts

There are two promising approaches that are initially evaluated. The first is connecting the MCUs directly to the server and the second is connecting the MCUs to an edge-device and then to the server. The two approaches are evaluated by their complexity, sustainability, flexibility, relative accuracy and cost.

4.2.2 Initial Evaluation and Critical Path

The main design limitation at the initial evaluation stage is the sensors' range, accuracy and cost. Without making sure that the sensors will provide valid and accurate data, the processing and visualization part of the design cannot proceed. Although some types of sensors seem to provide a promising range and accuracy, they will be eliminated from the design if their relative cost is economically unacceptable. Therefore, at an early stage of the design, the team will buy and test different sensors and collect data via a serial port to confirm accuracy. After comparing the specifications of different sensors, the team will settle on one sensor and proceed with the design.

4.2.3 Contingency Plan and Potential Risks

If the proposed design approach doesn’t work, a wired connection via Ethernet will be considered. Although the complexity of the design will be increased, it will at least provide a stable connection for data to be transferred to the server. Potential risks of using wireless data transfer is that data packets might be intercepted or corrupted during transport. Therefore, security and checksum methods may be needed to gather reliable data from the MCUs.

4.3 Engineering Analyses and Experiment

4.3.1 Prototype and Testing

Testing of the sensors will be performed first in the lab with data collected through a serial communication with the MCU. The prototype will consist of a single MCU and several proximity sensors. Testing of the prototype will take place in Clough Undergraduate Learning Commons (CULC) due to its popularity as a study space. Then the data will be transferred and visualized on the server.

4.3.2 Analyses and Experiments to be Performed

During experiments, data will be collected by testing the combination of the MCU and different sensors. Sensor range, accuracy, and power consumption will be analyzed, and an assessment will be performed on each combination. Obstacles and interferences with the sensors will be added to mimic the real study space environment.

4.4 Codes and Standards

1. IEEE 802.11b will be used to connect the MCUs to the server [5]. It features:
   - A maximum raw data rate of 11 Mbit/s and uses the same Carrier-Sense Multiple Access with Collision Avoidance (CSMA/CA).
   - Throughput that an application can achieve is 5.9 Mbit/s using TCP and 7.1 Mbit/s using UDP.
2. Inter-Integrated Circuit (I^2C) is a serial protocol shared between MCU and sensors [6]. It features:
   - Transfer rates up to 100 Kbits/s and 7-bit addressing.
   - Clock stretching using SCL and arbitration with SDA.

5. Project Demonstration

The demonstration of the project was to take place in the CULC. However, due to COVID-19, access to school is prohibited. The hardware side of the demonstration has also been heavily impacted, due to the team's inability to collaborate in person.

5.1 Application Demonstration

The following steps demonstrate how the mobile application will be used by users to

locate the available study spaces. These simulations also demonstrate how quickly the app updates the status of the tables. In order to decrease user frustration and incorrect information, the mobile application fetches the most recent information for an accurate representation of table vacancy.

5.1.1 Demonstration Steps·

- Open the mobile application and select the CULC building
- Use the app to select a space in the building
- Press the push button -simulate occupation of a study space- and observe how the app updates within 10 seconds
- Press the push button again -simulate leaving the table- and observe how the status changes in the app to “available”.

6. Schedule, Tasks, and Milestones

The first few tasks began the Fall 2019 semester and were all on schedule. The bulk of the major milestones and scheduled deadlines were completed during the Spring 2020 semester. Appendix A groups the different tasks that were performed as well as the contingency measures that were taken due to the situation. The task leads of each section are mentioned as well. Appendix B is a Gantt Chart including the timeline and milestones. The critical path is highlighted in red.

7. Marketing and Cost Analysis

7.1 Marketing Analysis

The primary market for BUSCA is university and college campuses. Crowded study spaces can reduce the efficiency of students' studying and searching for a non-crowded area can be time consuming [7]. This makes BUSCA a great addition to any campus' study spaces that are frequently crowded. BUSCA also markets to increasingly popular counter-serve, fast-casual restaurants [8]. Like the crowded study space issue, customers are discouraged by selecting a counter-serve restaurant only to arrive with no seating being available. BUSCA has no direct competitors in either market.

7.2 Cost Analysis

The total development cost of the BUSCA prototype is approximately $179.56. Table 4 shows the component costs for this prototype. The prototype has been developed using a development kit version of the MCU.

Table 4. Equipment Costs

Product Description	Quantity	Unit Price ($)	Total Price ($)
Texas Instruments CC3220SF-LAUNCHXL MCU	3	$49.99 [9]	$149.97
SI1153-AB00-GMR Proximity Sensor	4	$2.14 [10]	$8.56
5-pack SAFT LS14250 1/2AA 3.6v Li-SOCl2 Lithium Batteries	1	$20.99 [11]	$20.99
Amazon Web Services (Usage Based Service)		~$0.0072/Month [12]	~$0.04 (5 Months)
Total Cost			$179.56

Table 5 outlines the development costs of the labor and parts required for project completion. Labor is assumed to be $33 per hour [13]. The Labor Hours column of Table 5 accounts for the number of engineers working on the project.

Table 5. Development Costs (Labor + Part)

Project Component	Labor Hours	Labor Cost ($)
Project Planning and Documentation		
Check the locations where the device will be tested	50	$1,650.00
Order sensors/MCU/batteries	10	$330.00
Test the sensors/MCU/Batteries	50	$1,650.00
Website Development	80	$2,640.00
Final Project (Review of Proposal, Presentation)	80	$2,640.00
Device Implementation (Hardware)		
Work on the device case (design)	60	$1,980.00
Assemble the case	4	$132.00
Mount the device (Sensor, MCU, Battery)	24	$792.00
Device Implementation (Software)		
Create the framework for processing sensor data		
Digitalize the analog input	42	$1,386.00
Filter the input data	130	$4,290.00
Demo with a LED	4	$132.00

Create a framework for updating the table status		
Server Creation and Management	180	$5,940.00
Send the data to the server	52	$1,716.00
Update the tables location status	8	$264.00
Phone App		
Create the building list	120	$3,960.00
Create the building space GUI	180	$5,940.00
Combine the list and the GUI	80	$2,640.00
Update the tables status (Occupied, Available)	30	$990.00
Display table status	10	$330.00
Group Meetings	225	$7,425.00
TOTAL LABOR	1419	$46,827.00
TOTAL PART COST		$179.56
Total Cost (Labor + Part)		$47,006.56

The fringe benefits are 30% of the total labor cost, and the overhead is 120% of the total labor, parts, and fringe benefits. Table 6 shows the cost breakdown of the total development costs for the BUSCA project. The total is $133,925.22.

Table 6. Total Development Costs

Parts	**$179.56**
Labor	**$47,006.56**
Fringe Benefits (% of Labor)	$14,048.10
Subtotal	$60,875.10
Overhead (% of Parts, Labor, and Fringe)	$73,050.12
Total	**$133,925.22**

Production consists of 10,000 units total with about 1,000 units being used for each client. Over the next five years, BUSCA expects to serve at least ten clients. A production version of the MCU is used instead of the development kit. Assembly and quality testing are outsourced at a rate of $20 per unit. Advertising accounts for 10% of the final selling price as a sales expense. Each device has a setup charge of $35 and a monthly operation fee of $12. Each client must sign an operation contract at a minimum of one year. This is to ensure profitability for BUSCA and to lower the initial setup cost for the client. The selling price is modeled in Table 7 as the price for a client for one year of operation. The expected revenue per unit is $179 with a profit of $34.77 per unit or 19.42%. Over the five-year production cycle assuming the worst case where each of the ten clients only fulfils the minimum one-year contract, the expected revenue is $1,790,000 with a profit of $340,770. This estimation is drastically improved if a client continues service past the one-year minimum contract length.

Table 7. Selling Price and Profit Per Unit Per Year

TI CC3220SF MCU	$7.48 [14]
SI1153-AB00-GMR Sensor	$8.56
LS14250 Li-SOCl2 Battery	$4.20
Additional Wires and Case	$5
AWS for 1 Year of Normal Operation	$0.09
Assembly Labor	$10
Testing Labor	$10
Total Labor	$20
Fringe Benefits (% of Labor)	$6
Subtotal	$51.33
Overhead (% of Parts, Labor, and Fringe)	$61.60
Subtotal (Input Costs)	$112.93

Sales Expense	$17.90
Amortized Development Costs	$13.40
Subtotal (All Costs)	$144.23
Setup Fee	$35
Operation Fees (1 Year of Operation)	$144
Profit (1 Year of Operation)	$34.77
Selling Price	**$179.00**

8. Conclusion

The project is a success based on how the final version matched the proposed technical specifications.

8.1 Current Status

Currently the project is fully functional in accordance with the proposed (revised) specifications. The project has the capacity to scale up by building more modules and providing them with an ID to be added and identified with the mobile app.

8.2 What Happened

The original design included sensors for collecting environment data and the module being battery powered. Due to the COVID-19 health crisis, the team's ability to meet these hardware goals was greatly hindered, therefore, the team has decided to move these two features out of the projected final design and into future work for this project.

8.3 Lessons Learned

Through the development of this project, the team learned that hardware orders can potentially take much longer than expected, especially in a scenario where orders need to be reviewed and approved by a separate entity (in this case, the ECE 4012 parts ordering staff). After noticing this, the team decided to make changes to the order of tasks and focused their work on the software side of the project while the parts were received.

At the beginning of the project, none of the team members had extensive experience in app development, and the team was well aware of that in the planning stage, and estimated the timeline accordingly, considering that all team members are solid programmers. However, the learning curve for app development was much higher than expected, even for experienced programmers. This led to much of the app development timeline to be taken up by one team member learning iOS app development, before any measurable progress on the app was made.

The team found itself in an unprecedented situation during a critical part of the development process, without the possibility to meet physically and make significant progress on the hardware end. This situation arose with a very short notice, and allowed very little time to prepare a remote working tactic. Although this halted hardware progress, a revision to the design was quickly drafted, and consensus was reached on workload distribution and a platform to conduct meetings and collaborate.

After testing several approaches on the hardware end, the team ran into issues with some of the microcontroller units not working as expected. At the beginning of the project, the team had ordered 3 MCUs, but by the time the final version was achieved, only one was working properly. This combined with typical delays in hardware orders, the lesson here is to always order more hardware than originally anticipated for the project.

All in all, the main skill developed through the project was the ability to change the plans quickly in light of unexpected circumstances, while maintaining efficiency, quality, and meeting the timeline.

8.4 Future Work

The future work for this project includes developing a production version. This consists of implementing sensors, battery power, design adaptability, and a data collection framework. Sensors and battery power would allow a more seamless, discrete, and low-profile approach to the problem. They allow the device to be independent of human interaction, therefore reducing potential for human error. Also, expanding the design to accommodate tables of all types would allow the customer to apply a single solution to an entire campus. The data collection framework would add a backend for extensive data collection and analysis. Using this framework the team could construct prediction models for the likelihood of a table being available, overall demand for a particular study space, and heatmaps for all study spaces across an entire campus. This data would prove invaluable for a school to work towards the goal of efficiently improving study spaces campus-wide.

9. Sustainability and Contemporary Issues

9.1 Considering Current State

The deployment of this project would involve a reasonably low amount of effort to maintain. At its current state, it requires virtually no maintenance, since modules would be powered via a continuous, reliable power source. The only ongoing cost associated with its use would be the cost of using AWS.

A foreseeable problem with the current design is that its usefulness will fully rely on users' input. This means that an uncooperative user can make the system display inaccurate data.

9.2 Considering Future Work

Deploying this project with all of the future work implementations would imply a considerably higher maintenance cost, with the need to replace the batteries approximately once every four months. All other costs would remain the same.

This design implementation would solve foreseeable problems with the current design by gathering data without the need for user input.

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Appendix A - Project Timeline and Tasks Breakdown

Task Name	Task Leads	Start date	End date
Project Planning and Documentation	All (SN*)	1/6/2020	4/23/2020
Check the locations where the device will be tested	All (SN*)	1/6/2020	1/13/2020
Order sensors/MCU/batteries	All (AR*)	01/26/2020	02/25/2020
Test the various sensors/MCU/batteries	All (JW*)	02/11/2020	3/10/2020
Website Development	JL*, NM	1/13/2020	4/12/2020
Project Progress Presentation #1	All (AR*)	1/09/2020	1/14/2020
Project Progress Presentation #2	All (AR*)	2/20/2020	2/25/2020
Final Project (Review of Proposal, Presentation #3)	All (SN*)	4/9/2020	4/16/2020
~~Expo Preparation (Oral Presentation, Participate in Expo)~~ (Check Contingency Plan Table)	All (JL*)	4/16/2020	4/23/2020
~~Device Implementation (Hardware)~~ (Cancelled)	JL*, SN, JW	3/10/2020	4/2/2020
~~Work on the device case (design)~~	JL, SN*, JW	3/23/2020	4/1/2020
~~Assemble the case~~	SN, JW*	4/1/2020	4/2/2020
~~Mount the device (Sensor, MCU, Wi-Fi, Battery)~~	SN, JW*, JL	3/10/2020	3/12/2020
Device Implementation (Software)	All	3/12/2020	4/5/2020
~~Create framework for processing sensor data~~ (Check Contingency Plan Table)	JL, SN, JW*	3/12/2020	3/26/2020
~~Digitalize the analog input~~	SN*, JL, JW	3/12/2020	3/19/2020
~~Filter the input data~~	SN, JW*, JL	3/19/2020	3/26/2020
~~Demo with a LED~~	SN*, JW	3/25/2020	3/26/2020
Create framework for updating the table status	AR*, NM	2/3/2020	4/9/2020

AWS account Creation and Management	JL, SN, JW, NM*	2/3/2020	4/9/2020
Send the data to the server	SN, JW*	2/20/2020	2/25/2020
Update the tables location status	JL, NM*	2/18/2020	3/3/2020
Mobile App	AR*, NM	1/15/2020	4/9/2020
Create the building list	AR	1/15/2020	2/22/2020
Create the building Space GUI	AR*, NM	1/15/2020	2/22/2020
Combine the list and the GUI	AR*, NM	2/22/2020	3/16/2020
Update the tables status (Occupied, available)	AR*, NM	3/3/2020	4/9/2020
Display tables status	AR	4/9/2020	4/9/2020

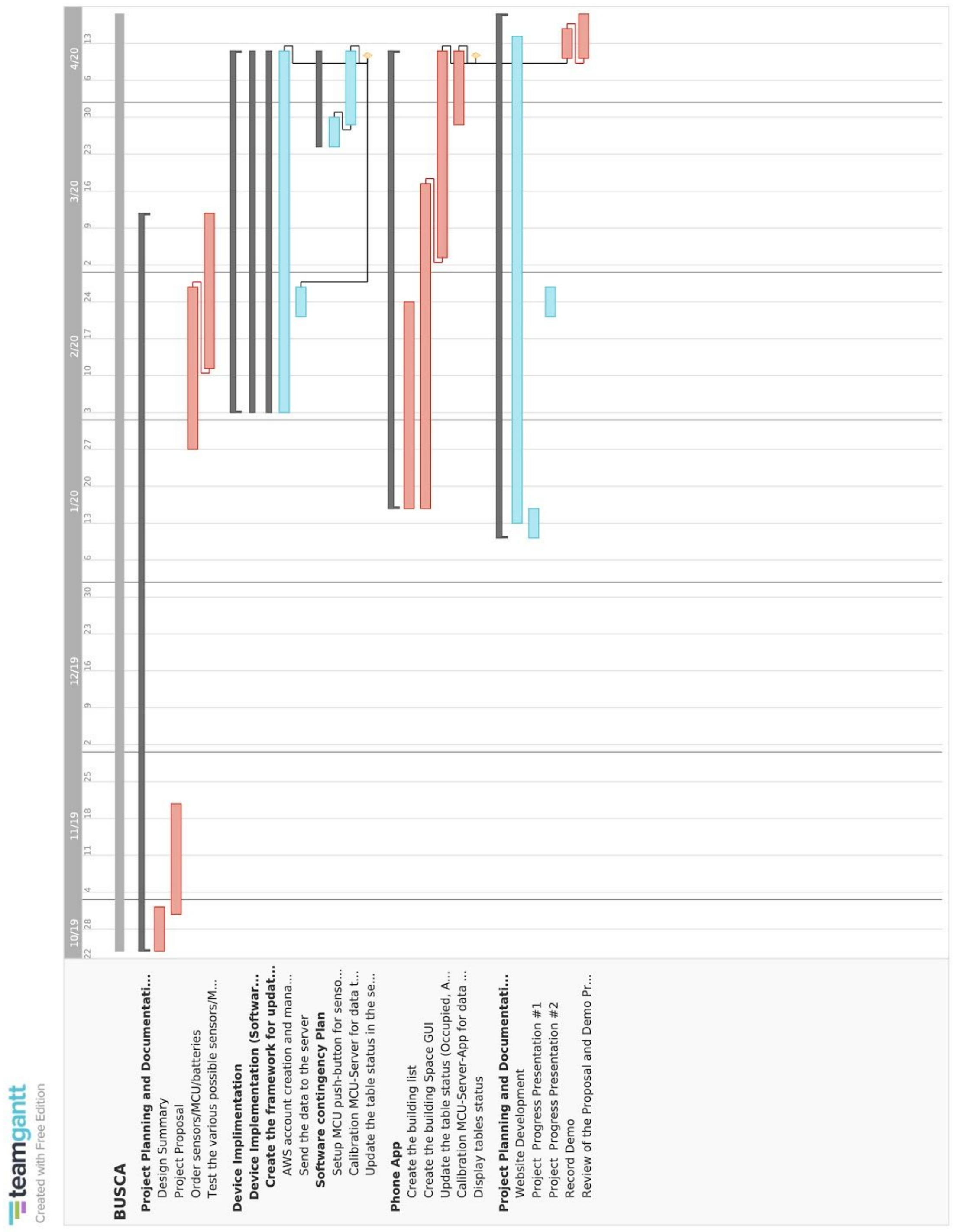
Contingency Plan Table

Software implementation	Task Leads	Start date	End date
Setup MCU push-button for sensor simulation	JW*	3/24/2020	3/27/2020
Calibration MCU-Server for data transmission	JW*, JL	3/27/2020	4/09/2020
Calibration MCU-Server-App for data transmission	JW*, AR, NM	3/27/2020	4/09/2020
Record Demo	ALL(JL*)	4/09/2020	4/14/2020

*** Denotes team lead for that task**

AR - Aldo Rogliero, NM - Nyle Malik, SN - Salomon Nabine, JW - JingXuan Wang, JL - John Lee

Appendix B – Project Gantt Chart


teamgantt
Created with Free Edition
10/19
11/19
12/19
1/20
2/20
3/20
4/20
BUSCA
Project Planning and Documentati...
Design Summary
Project Proposal
Order sensors/MCU/batteries
Test the various possible sensors/M...
Device Implimentation
Device Implementation (Softwar...
Create the framework for updat...
AWS account creation and mana...
Send the data to the server
Software contingency Plan
Setup MCU push-button for senso...
Calibration MCU-Server for data t...
Update the table status in the se...
Phone App
Create the building list
Create the building Space GUI
Update the table status (Occupied, A...
Calibration MCU-Server-App for data ...
Display tables status
Project Planning and Documentati...
Website Development
Project Progress Presentation #1
Project Progress Presentation #2
Record Demo
Review of the Proposal and Demo Pr...