Small Equipment Checkout System

PROJECT PLAN

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List of Definitions

- **A-Track system:** It is a powerful database that manages ISU students' personal information.
- **CRUD:** An acronym for Create Read Update Delete. This acronym is typically used to describe software functionality.
- **ETG:** An acronym for Electronics and Technology Group.
- **ECpE:** Electrical and Computer Engineering department of Iowa State University
- **OWFS:** An acronym for 1-Wire Filesystem.
- **1-Wire® Device:** 1-Wire is a device communications bus system that provides low-speed data, signaling, and power over a single conductor. It is designed by the Dallas Semiconductor Corp and trademarked by Maxim.
- PCB: An acronym for Printed Circuit Board
- **ISU:** An acronym for Iowa State University
- **Identity Provider:** An identity provider is a system entity that creates, maintains, and manages identity information while providing authentication services to applications.
- **Shibboleth:** Shibboleth is a single sign-on system for computer networks and the internet. It allows people to sign in using just one identity to various systems run by federations of different organizations or institutions.

1 Introductory Material

1.1 Acknowledgement

This senior design team, sdmay19-13, would like to thank Iowa State University(ISU), and college of Electrical and Computer Engineering(ECpE) for providing the excellent opportunity for students to form teams and to work on the professional design process. Especially, we want to thank the Electronic Technology Group(ETG), and our client and advisor, Lee Harker, for all the guidance and technical support. We have also appreciated all the contribution from the team, sdmay18-01, who has worked on this project before. Their design shows us many possibilities for this project.

1.2 Problem Statement

Electrical and Computer Engineering are subjects rely heavily on experimental experience, and students will utilize various components and equipment throughout their learning process. Currently, the most common way for students to checkout equipment is borrow directly from Electronic and Technology Group (ETG)'s part shop. However, this checkout procedure has its own limitations in working time and efficiency.

The current checkout system requires ETG faculty spending time in part shop to process students' requirement, preparing demanding equipment, and recording manually. This is not just inefficient in time, but also a waste in human resource. Also, many students likely to do the experiments after school or during weekends. In this situation, the ETG's limited working time, which is weekdays from 7am to 5pm, becomes a hinder for students to get necessary resources.

Overall, the final goal of this project is designing a feasible and reliable equipment checkout system that can solve the problems listed above by simplifying faculty's maintain process, and providing more availability for students.

1.3 Operating Environment

The accomplished design will be placed outside the ETG's part shop in Coover Hall. The whole system is supposed to work under room temperature for all times. The system can be divided into two parts, one is the locker used for storing equipment, the other one is a touchscreen monitor for users to interact with. The shelf is made of metal and will be fixed to the wall, so its stability is the most important concern and will be tested carefully. The touchscreen monitor should have quick and accurate feedback to the user's operations.

Since the system will be placed in the public environment, some students may forget to close the doors of locker units. Therefore, it is necessary to have a function for our system to detect if the doors are closed after use.

1.4 Intended Users and Intended Uses

There are two kinds of intended users, students and administrators. Students should be currently enrolled at Iowa State University(ISU), so, they will have authentication credentials to ISU's Shibboleth Identity Provider, and be permitted to access the system. Administrators should be employed at ISU under the ETG department to have authenticated access to the checkout system's website.

In order to have needed equipment in time, plenty of students have to schedule their experiences during weekdays, and this may cause the shortage in both laboratory space and equipment. Small Equipment Checkout System will allow students to borrow equipment by all day and all hours. As the result, students will have more flexible studying time by using this system.

This system will only require administrators to do the maintenance at a very specific time, so administrators will be released from fixed daily office hour. Then, they can focus more on technical support for the ECpE department and improving our lab experience.

1.5 Assumptions and Limitations

Assumptions:

- All ISU students and ETG staffs will have authentication credentials to Iowa State University's Identity Provider, Shibboleth.
- The checkout system's website will not be able to be accessed outside of Iowa State University's Internet.
- Students and administrators will be able to use a touchscreen attached to the locker to interact with the checkout system.
- The system can be used all the time except it is in maintenance.
- The system will be displayed in the English language.
- One locker unit will be used to store the Raspberry Pi.

Limitations:

- There will be 34 locker units in the checkout system.
- The size of PCB should be smaller than 3.2cm*2.5cm*1.2cm (Appendix 1).
- The output voltage of Raspberry Pi's pin is 3.3V(Clifford, Paul.).
- ISU staffs who are in other departments cannot access the administrator website.

1.6 Expected End Product and Other Deliverables

The Small Equipment Checkout System can be divided into software and hardware system. And the project delivery will include prototype and final product.

1. Prototype - December 3, 2018

At the end of the first semester, we should have at least one locker with circuit successfully controlled by the software.

- Hardware
  We should design a new circuit to control the lock in the box. The circuit should be powered and connected to Raspberry Pi, and can be controlled through the website. A sensor should also be placed on the circuit to check if the door is closed after use, or the alarm will be activated.
- Software
  The software includes website application, 1-Wire® System, MySQL database and Android application. For the prototype, the website application should be able to have the ability to control 1-Wire® System and manage data in the MySQL database.

2. Final product - April 28, 2019

At the end of the second semester, we should have a perfect and functional small equipment checkout system for the ECpE students and ETG staffs to use in a real operating environment.

- Integrated System
  For the final product, all of the aimed functionalities that we need to achieve should be finished. The locks and LEDs inside boxes are able to control by the software system. All locker units have corresponding PCB implemented. The PCB implemented in the locker units should be wired to the Raspberry PI. The web application should be able to control all units of the locker.
- Final Design Document
  The final delivery should include the detailed design documents. Followed the documents, ETG staffs should be able to maintain and manage the checkout system.
- Code
  Both frontend and backend code will be available for ETG to access in ISU's GItlab.
- Software Manual
  This manual will serve as a guide to the checkout system's software implementation. It will be available for ETG to access in ISU's Gitlab.
- Hardware Manual
  This manual will serve as a guide to the checkout system's hardware implementation. It will be available for ETG to access in ISU's Gitlab.

2 Proposed Approach and Statement of Work

2.1 Objective of the Task

Since the equipment checkout system, E-Clerk, made by the previous team, only has three working locker units, and there are 34 available locker units in the current equipment checkout system. The primary goal of our project is making all locker units work. For the hardware, we will design and place new PCBs in all 34 locker units and have an appropriate wiring plan between every locker units. For the software, we will extend the functionality of the web application to allow it to control all 34 locker units and implement the functionality which did not implement by the previous team, such as allowing students to receive email reminders.

2.2 Functional Requirements

1. Optimize the functionality implemented by the previous team and implement the functions that they did not finish.
   For students:
   - Log in and out
   - View available equipment
   - Select an equipment item to checkout
   - Turn on the LED to check equipment
   - Determine checkout duration
   - View currently checked out equipment (personal)
   - Return equipment, close checkout record
   - Report system misuse or broken items
   - Receive Email Reminder

   For Administrators:
   - Log in and out
   - CRUD available equipment
   - Determine max checkout durations for items
   - CRUD student users, records, and user privileges
   - Receive email status reports
   - Create update, remove locker units
   - Add new Administrators
2. Design a new smaller PCB to fit into the locker units of the checkout system by detecting the door of the locker units is closed or not after using it.
3. Enable the web application to control all 34 locker units in the checkout system.

2.3 Constraints Considerations

Non-functional requirements of the project:

- Maintainability:
  Our product could be maintained by ETG for future usage. ETG will have documents and resources to access the whole system and add more locker units.
- Security:
  Our web application has the access restriction for people outside of ISU to prevent our checkout system from unnecessary data losing.

Constraints:

The main constraint of our project is the limitation of choices of extended software and hardware. Because what we are working on is the prototype finished by the previous team. If we want to implement more functionalities, we have to choose the software and hardware can work together with software and hardware chosen by the previous team.

Standards:

Since we are inheriting the main implementation of the previous team, the standards we are planning to use is quite the same as their work. We are using the standards pre-built into the servers such as HTTP with Node.js server and MySQL connected with Sequelize.
What's more, our project implementation will be conforming to the 1-Wire® protocols for 1-Wire® devices and to the OWFS (1-Wire Filesystem) standards.

2.4 Previous Work And Literature

The small equipment checkout system that we are working on has a finished prototype made by the previous team. The previous team has made three locker units work correctly. For the software design, they have a web application implemented with the basic functionality described in their design document. What's more, they have implemented For the hardware design, they used a 5 V and a 12 V voltage sources to power the circuits inside the locker units. And they used PMOS as a switch to control the lock and LED ("Project E-Clerk" Design Document).
The advantages of their project are:

1. Implement the website with the latest website implementation skill React.JS and Node.JS.
2. Use powerfully embedded system 1-Wire® Device to control the locker with requests of users.
3. Use Shibboleth to prohibit people outside of ISU to access the checkout system.

The shortcomings of their project are:

1. Does not include a smaller enough PCBs to fit into the locker units.
2. Current wire design cannot control all locker units of the checkout system.
3. Does not have the function to detect or alarm when the door is not closed after usage.
4. The web application cannot control all 34 locker units.

2.5 Proposed Design

The picture below is our proposed design for the whole project. Based on that, we will design new and smaller PCBs to control the communication between locker units and 1 wire device. What's more, we will extend the current web application to control all 34 locker units and be able to send email reminders to students.

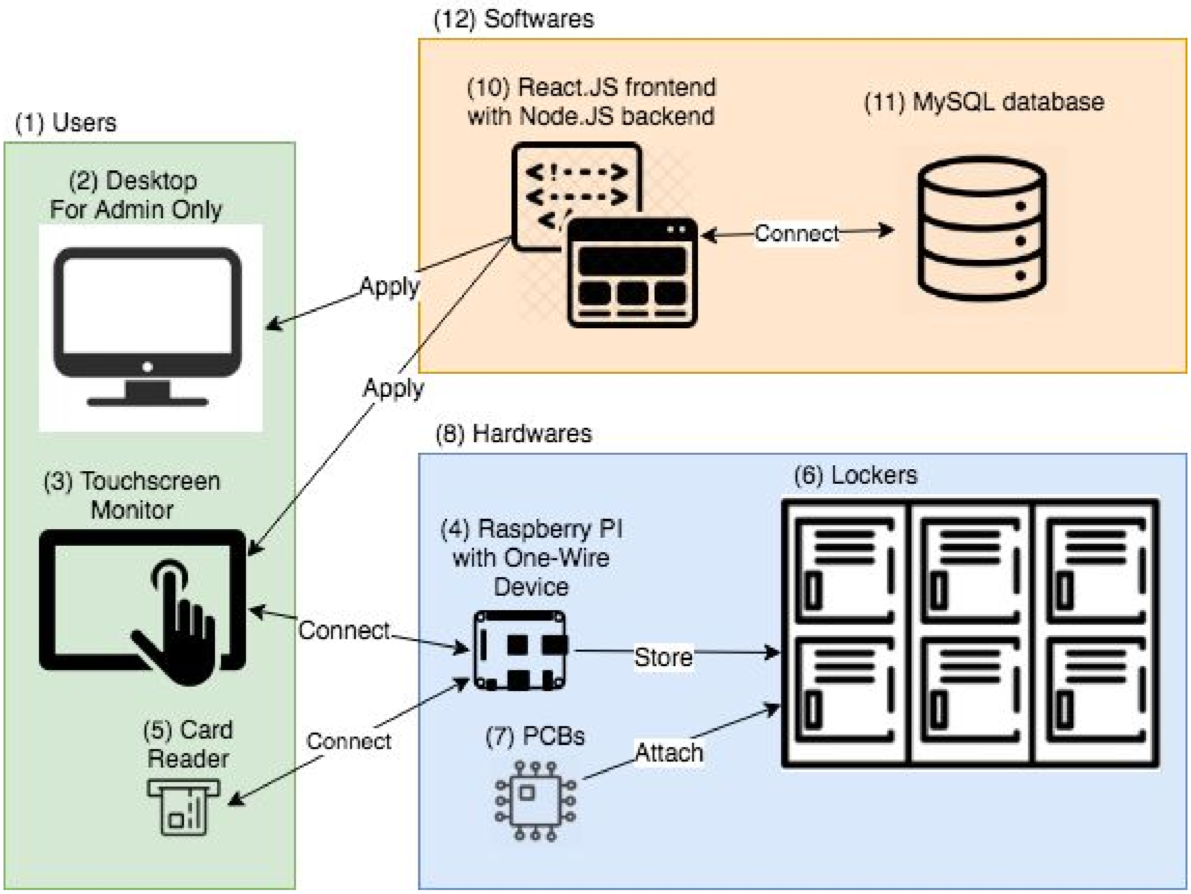


Figure 1: Proposed system design

We will have 3 major components, users (1), software(12), hardware(8). For the users (1) part, it has a Touchscreen(3) for borrowers to operate. It has a card reader (5), which will be used when borrowers want to check out or return equipment. It will read ISU ID from ISU card to identify the borrowers and check if he/she is an ISU student or an ETG staff through the A-track system which is our university's self-designed attendance tracking system. The ETG staffs can access the checkout system through any computers(2) which connected to the ISU network.

For the software(12), we will have a web application which has a frontend implemented by React.JS, a backend implemented by Node.JS(10) and a MySQL database(11).

For the hardware(8), we will have the main control board with a Raspberry Pi and a One-Wire device(4) on it. The Raspberry Pi is a microcontroller, and we will install Raspbian on it as the operating system. The One-Wire device will be used to connect Raspberry Pi and all PCBs(7) in locker units(6). The PCB(7) will have a one-wire chip, which assigns a unique address for each locker, and can control the electromagnetic lock and the LED. PCB(7) will also have a buzzer to make noise when the sensor detected the door is not closed for a long time. In the locker(6), each unit will have an item for borrow.

2.6 Technology Considerations

The primary technology consideration of our project is to successfully control all 34 locker units. The previous group has only made 3 locker units working, so, we have to improve the wiring design and build more PCBs.

The second consideration is the size of the new designed PCBs. Based on our client, Mr. Harker's requirement, our PCB should have an appropriate size to be placed into a plastic cover on the locker's door. So, we should design the circuit and choose the components carefully to reduce the area cost.

The third consideration is some students may forget to close the door after they borrow the equipment. Therefore, we need to add a new function to detect whether the door is closed or not after users' usage.

The last consideration is current web application cannot control all 34 locker units and send email reminders to users about the equipment's status. Therefore, we need to extend the functionality of the current web application to control all 34 locker units and send email reminders to students.

2.7 Safety Considerations

There are potential risks in this project. One is the security of personal information. We need to collect information from students who borrow equipment from us, which include the name and email address. So, protecting that information is an extremely important task that we need to work with.

The other one is the possible physical damage. The shelf which is used for stored electrical equipment is heavy and will be fixed on the wall, and it is possible to fall down if students pull it too hard. We will do the strengthening and test before the product is put in work.

2.8 Task Approach

Since the project has developed by the previous senior design team, the first thing we need to do is to analyze what exactly they have done and how to improve their design. The previous team used the website application as their user interface. We need to spend a lot of time analyzing it. After that, we will be able to extend its functionality.

Another task is to connect all 34 locker units to the one wire device, which only have 3 locker units connected at this time. So, we need to be familiar with the 1-Wire system that our client suggested using. By using the 1-wire system, we could achieve controlling multiple units by just using a single bus line. Then we can build a modularized system, and easily connect more units to the system.

Besides, we need to design a new circuit with door detecting function. We plan to use the Hall Effect Sensor, which can change the output status based on the magnetic flux density. Then, we can place a magnet inside the locker to trigger the sensor according to the door's position. A buzzer will also connect to the sensor's output.

Finally, the PCB built by the previous team is too large to fit for our project, so, we need to recreate and resize the PCBs. We plan to build the surface-mount and double sided PCB.

2.9 Possible Risks And Risk Management

Both of our software group members are not familiar web design which includes Javascript, SQL, HTML Layout, PHP, etc. It's very complex, our members may meet unexpected difficulty during the learning process.Therefore, they will begin to learn it as early as possible to get the control of the whole software system quickly.

In this project, we need to design and produce our own PCB. If there are some bugs we don't find before production or we break our PCB, it will take a long time to make a new one. So, we need to apply very detailed tests to our circuit and PCB design documents.

2.10 Project Proposed Milestones and Evaluation Criteria

There will be two project proposed milestones:

- Enable one locker unit to work appropriately with basic functionality implemented.
  Evaluation criteria:
  1. A newly designed circuit has been designed.
  2. The web application could run appropriately.
  3. The newly designed circuit could be controlled by the web application.
- Enable all locker units to work appropriately with all extended and basic functionality implemented:
  Evaluation criteria:
  1. New PCBs have been produced and are attached to every locker units.

2. The latest web application could control all locker units with all functional requirement implemented.
3. Invite students to use the system and obtain some feedback. If there are some negative feedback, we will revise the system based on their feedback

2.11 Project Tracking Procedures

We will use the weekly status report and Gantt chart to keep track of our progress. Every team member will be assigned a task with a fixed deadline. When someone is stuck on one task and spend longer time than it should be, we will hold a meeting with our client and adviser to figure out an alternative method to solve this problem.

2.12 Expected Results and Validation

The expected result is a self-service checkout system. The students are able to swipe their ISU ID cards to get verified and then use a touchscreen monitor to check the availability of the item that they want to borrow. If the item is missing or damaged, students can send out a report and the ETG staffs will get the message. If the item is ok, students can directly borrow it. And students can find the currently borrowed items, and easily return. The ETG staffs can add equipment into the locker units and manage the record of different types of equipment through the touchscreen monitor. What's more, they can also manage the database of the checkout system through the checkout system's website on any computers with ISU internet connection.

2.13 Test Plan

In the beginning, we are going to test the hardware section and software section separately. Once both the hardware section and software section pass the test, we will connect them together and test the whole system to make sure the software can control the hardware.

For hardware, we will first test our locker circuit which is controlled by OWFS server. We have to check the supply voltage of lock under both on and off status. When OWFS server sends the on command, the supply voltage of lock should rise to 12V, and when the off command is sent, the voltage should drop to 0V. Second, we will test the door detecting circuit. We will adjust the position of the door, and the buzzer should make noise when door is not completely closed. Next, we will combine the locker control circuit and door detecting circuit together, and test if they can still work or not. As soon as we have tested one single locker, we will connect all the lockers by the one-wire system and test if they can be controlled by the software. Once the whole system working well, we will create our PCBs and solder all circuit components on it.

For software, we will first test backend. We will test the connection of different servers. First, we will set the local OWFS server, then we should be able to open its homepage. If we can't, then it means we set it wrong and we will reset it until it works. Second, we will test the connection between the front end and back end. If there are connection errors or bugs, our front end will not able to access data. For example, if there are errors in accessing user data, then after we swipe the ISU card, the homepage won't jump to the next page because it cannot identify the user type through the data in the database.

After we make sure both hardware and software are working appropriately, we will do the integrated testing. In this testing, we will connect hardware, OWFS, backend, frontend together, and test if it works. Because we have already tested the connection between frontend and backend, and the OWFS server, if we cannot open the locker, it will have two major reasons. First, the connection between the OWFS server and backend has errors, and we will check the IPs and ports we used. Second, the address we declared for the locker is wrong, and we will reset the address in our database.

3 Project Timeline, Estimated Resources, and Challenges

3.1 Project Timeline

- Research
- Make plan
- Order components
- Test components/Design software
- Collecting feedback/Test software
- Design circuits/Software debug
- Test circuit
- Testing the whole system
- Improve
- Getting the final version of the project

First Semester

Our goal for the first semester of is to make sure each parts working perfectly, including the computer check-in system which belongs to the software section, and the locker circuit which belongs on the hardware section. At the end of the first semester, our two parts should be able to work separately. Bei Zhao and Caining Wang will work on building the computer check-in system. And Fengnan Yang, Jiaxin Li, and Yimin Wang will focus on the circuit design. If the group is able to achieve the milestone earlier than the plan, we will aim to build the connection between the software section and hardware section.

Second Semester

As for the second semester, our group needs to spend more time on making two system work together. We will set plenty of tests for software-hardware connection. Then we will focus on connecting multiple units (lockers) with software and make them work. And we will confirm that our whole system can work in a desired operating environment. After passing the functional test, we will spend one to two weeks to let the ECpE students using it, which can provide enough feedback to us for improving our design.

The Gantt chart below is the project timeline of our team.

First Semester:

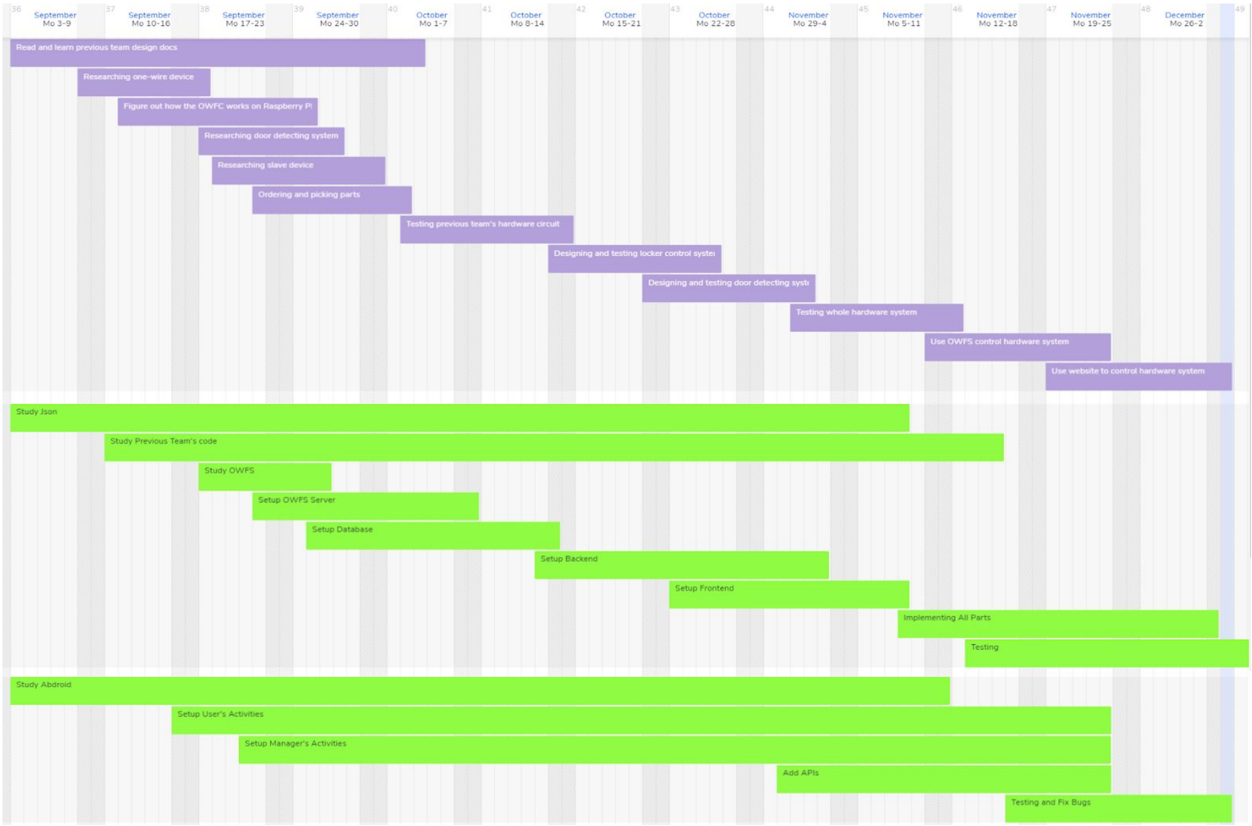


Figure 2: Gantt Chart of the first semester project timeline

Second Semester

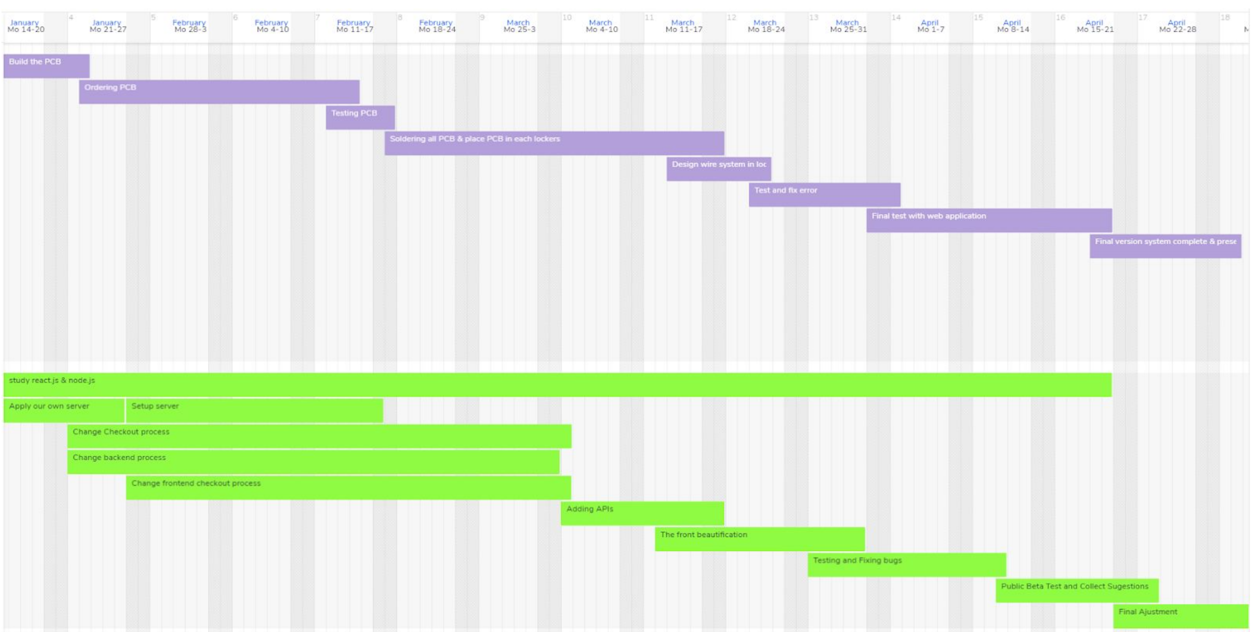


Figure 3: Gantt Chart of the second semester project timeline

3.2 Feasibility Assessment

Our project is designed to be extendable. For the software, we are able to achieve that by editing the database. The One-Wire system's address is a 16-bit number, it can generate enough different addresses for each locker. For the hardware, since our lockers are parallel connected, we can just connect more circuits and lockers to the bus line to extend the system. But the reality is that because lockers are paralleled, the currents for each locker will be added together at last. When the number of lockers is too large, it will exceed the PIN's limit, so the power supply will need to be redesigned.

Another one is that because we are using a campus server, the database could be modified on any device which is connected to the campus network. However, in the real world, after the manager modified an item in the locker, the manager still needs to go to the locker and put items in it, so this will not be a problem.

3.3 Personnel Effort Requirements

Below is the table of personnel effort requirements of our project.

Table 1: Personnel Effort Requirements

Task	Effort Level	Description
Setup locker units database	Low	Simply request a database from ETG and implement tables based on clients' requirement
Setup OWFS Server	Medium	Configure the Server based on the instruction of the OWFS website corresponding to the one-wire device.
Implement SMTP service	Medium	Setting up SMTP is not very hard, but we are not familiar with JS it could cause some trouble.
Install Raspbian on Raspberry Pi	Low	We need to install a OS on Raspberry Pi, there are guide online, it wouldn't be hard.
Setup Backend	High	The backend is based on node.js, it's a completely new thing for us, it needs a long time studying.
Implement Frontend Functions	High	The frontend is based on react.js, we haven't learned it before, we will need to learn it while implement through the whole project.
Design the door detecting circuit	High	New function. Use hall effect sensor and magnet to detect the position of the locker's door. And use a buzzer to alarm users.
Design the lock circuit	High	Main function. Use a 1-wire chip to assign an unique address for one locker, then design the voltage supply of lock, which is controlled by 1-wire system.
Combine circuits and test	Low	Connect lock and door detecting circuit and test.

3.4 Other Resource Requirements

Our project will need to apply for a campus server. It's prerequisite for accessing website on multiple devices. We also need permission to use Attendance Track, so our system can check student's identity. We also need to use power tools from ETG to cut a window on each locker.

3.5 Financial Requirements

The table below is showing the estimated cost list of our checkout system.
Table 2: Estimated Cost List

Estimated Cost List

TOTAL ESTIMATE COST VALUE: $722.99
ITEMS: 16

Manufacturer number	DESCRIPTION	REORDER QTY	COST	TOTAL COST VALUE
7.95891E+11	Mini Electromagnetic Electric Control Door Cabinet Drawer Lockers Lock	34	$2.69	$91.46
MP-3014-1100-50-80	LED COOL WHITE 5000K 80CRI	34	$0.15	$4.96
XJS 11x5.5x11mm	Metal Taper Conical Compression Spring	34	$0.18	$6.12
DS2406+-ND	One-Wire Slave Device	34	$4.10	$139.40
LM2575T	IC REG BUCK 5V 1A TO220-5	34	$2.41	$81.94
LMC662CN	IC OPAMP GP 1.4MHZ RRO 8DIP	34	$1.62	$55.08
1528-2233-ND	Jumper Wires	9	$1.95	$17.55
LM 555CN	IC OSC SINGLE TIMER 100KHZ 8-DIP	34	$1.02	$34.51
RASPBERRY PI B	Resberry Pi	1	$29.95	$29.95
DS2482S-100+T&RTR-ND	One-Wire Mater Device	1	$1.68	$1.68
DRV5023AJQLPGM	Hall Effect Senor	34	$0.79	$26.86
PS1240P02BT	AUDIO PIEZO TRANSDUCER	34	$0.48	$16.46
2197	HDMI FLAT CABLE - 1 FOOT / 30CM	1	$3.95	$3.95
U050-003	USB 2.0 A TO MICRO-USB B CABL 3'	1	$4.65	$4.65
	PCB	34	$6.08	$206.72
	Resistors and Capacitances Kits	34	$0.05	$1.70

4 Closure Materials

4.1 Conclusion

Because our group was required to continue the previous group's work, our goal is improving the old design and adding new functions to the current system, and finally achieve an all-time, self-service checkout system.

In the first semester, except we spent some time to be familiar with the project description, we also tested and evaluated previous group's work. For this semester, the hardware team focused on build locker control system and door detecting system which are able to be controlled by the Web Application at the same time. For the software team, they focused on building connection among the Web Application, OWFS, and Raspberry Pi. At the end of the first semester, we are able to connect the hardware and software systems together and control one single locker. Besides, our door detecting system is able to make noise when the door is not closed.

Looking forward to next semester, our software team needs to add more function to the Web Application. For the hardware team, they need to design and solder all PCBs and place them in 34 lockers and make sure they are able to control by our Web Application. After that, our group needs to test the entire system to make sure our design is reliable and friendly for the users. On the other hand, the client should be more involved in our project to makes sure our final design is a useful and scalable solution for the ETG.

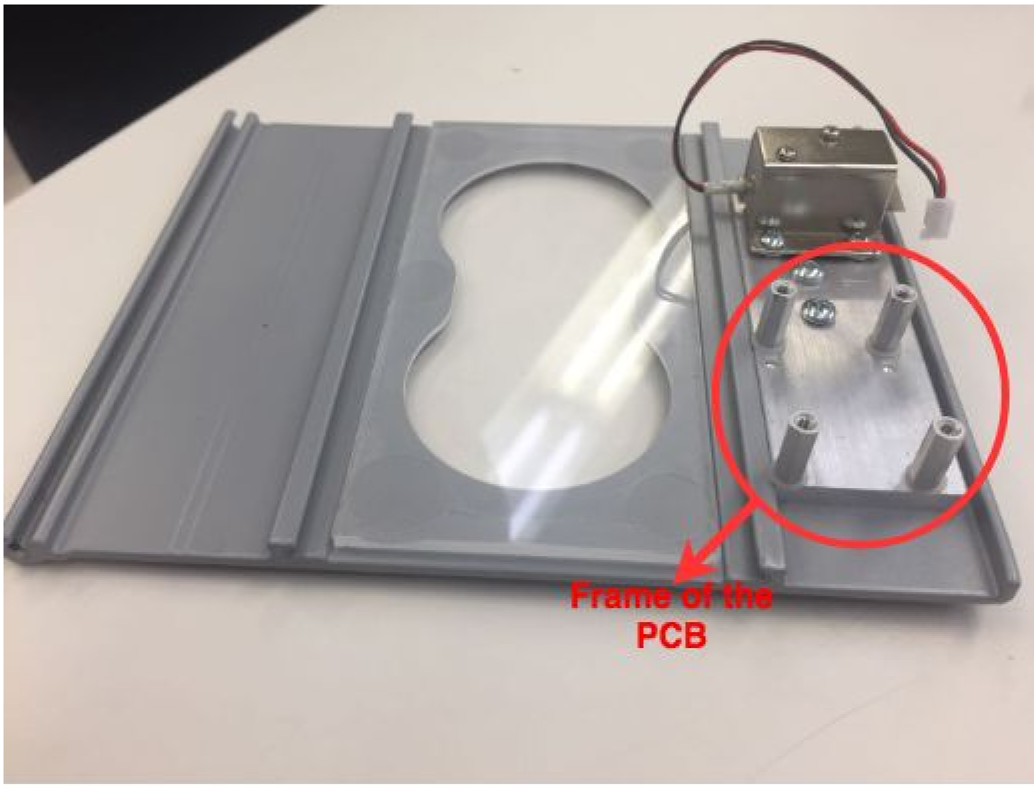
4.2 References

- Clifford, Paul. "GPIO Electrical Specifications, Raspberry Pi Input and Output Pin Voltage and Current Capability." Find Controllers for Instrumentation and Automation at the Mosaic Industries Site, Mosaic Industries, Inc., www.mosaic-industries.com/embedded-systems/microcontroller-projects/raspberry-pi/gpio-pin-electrical-specifications.
- "Owfs Development Site." Owfs Development Site - Quickstart Guide, owfs.org/index.php?page=quickstart-guide.
- "Project E-Clerk" Design Document, sdmay18-01, http://sdmay18-01.sd.ece.iastate.edu/documents/Design_Document_Final.pdf
- "Raspberry Pi 3 Model B." Rotate Display 90º - Raspberry Pi Forums, www.raspberrypi.org/products/raspberry-pi-3-model-b/.
- "React – A JavaScript Library for Building User Interfaces." – A JavaScript Library for Building User Interfaces, reactjs.org/.

- "Wiring 1-Wire Devices." Solución Domótica Loxone Smart Home ES, www.loxone.com/enen/kb/wiring-1-wire-devices/.

4.3 Appendices

1. The locker unit's door:



The measurement of the frame of the PCB is 3.2cm*2.5cm*1.2cm.