CprE491 Senior Design
Project Plan 10/2/14
Group: May1525

Advisor: Lee Harkin
Client: Lee Harkin / Department of Electrical and Computer Engineering
Project Title: CyLocker Access System

Group Roles

Team Leader -> Nathan Castek
Team WebMaster -> Corey Coazzato
Team Communicator -> Nathan Lafferty
Team Key Concept -> Priyank Patel
Team Technical Leader -> Mohammad Syazwan

Revision History

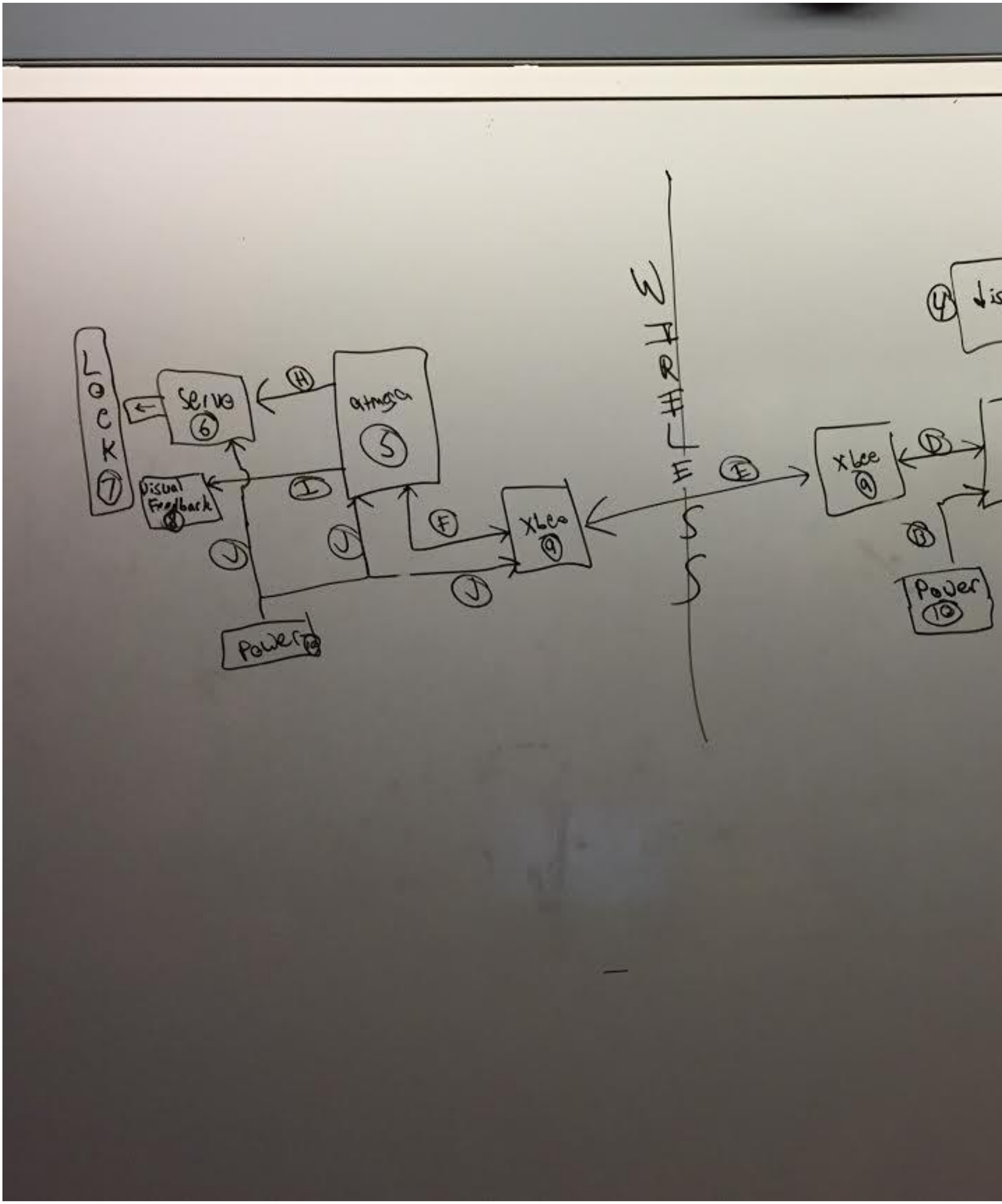
Date	**Revision**	**Description**
10/2/2014	1.0	Initial Plan
11/5/2014	1.1	Revised with feedback from instructions
11/12/2014	1.2	Additional revisions, added testing section

Problem Statement

This project is to solve the problem of security and management of the storage and lockers in the senior design lab in Coover 1301. Currently, the lockers are being secured by padlocks, where the same locks are reused semester after semester. This is an issue as previous students may tamper with current student's projects, as well as having the maintenance overhead of manually assigning lockers to students, or removing identifying information on the physical locks to attempt to prevent the security issues.

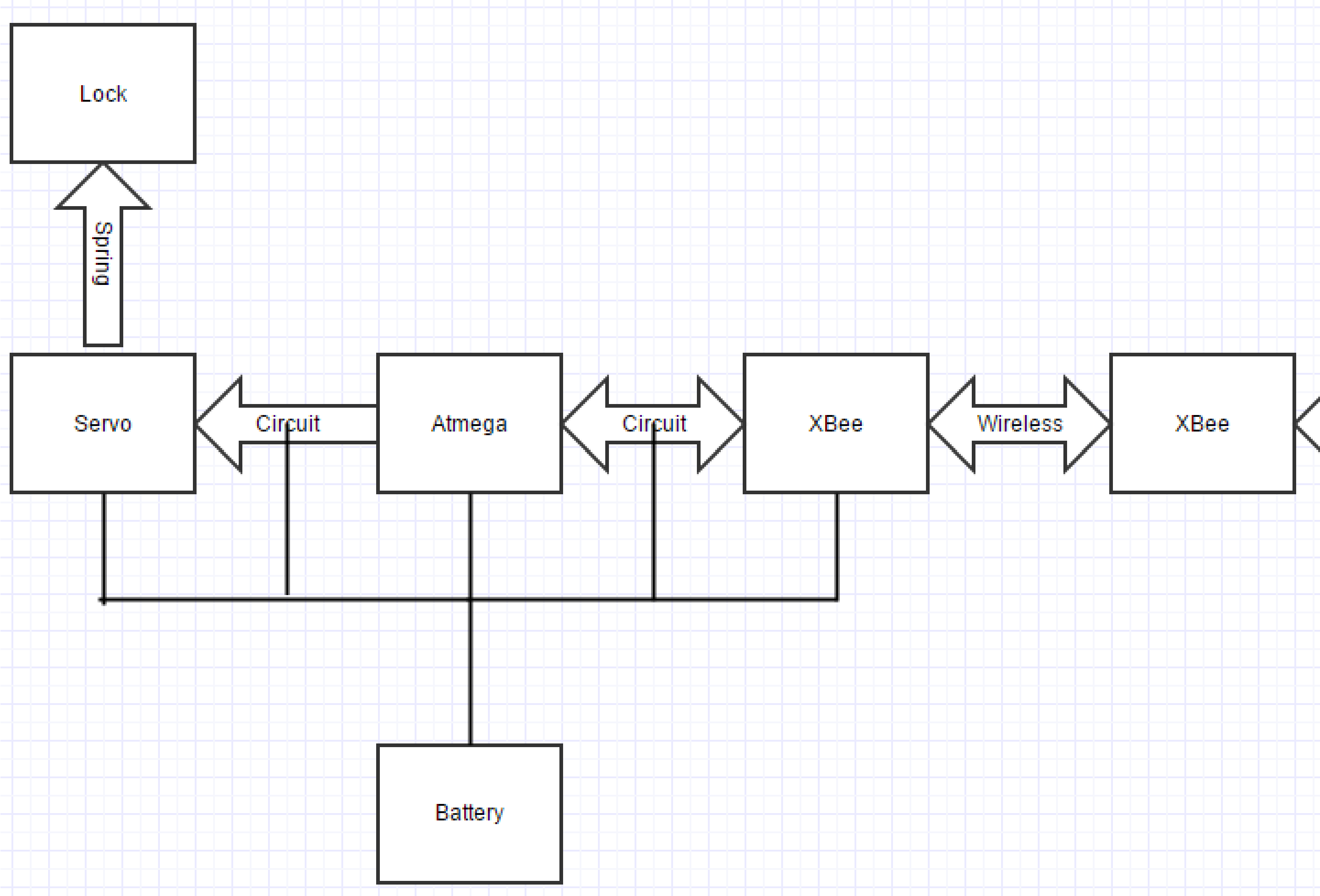
Our proposed solution, which is extensible, reliable, and affordable, is to reprise the current system to include electronic lockers, complete with remote-management. These lockers will be battery-powered, and access will be provided using current student's ISU ID cards. By having remote management and having access on a per-student level (instead of a per-lock level), our project is a valid solution to the problem stated above.

Concept Sketch/Mockup



LOCK
7
servo
6
H
atmega
5
I
Visual Feedback
8
J
F
xbee
9
J
Power
10
WIRELESS
E
xbee
9
D
B
Power
10
4

Concept Sketch of components



Block diagram of components

<u>System Requirements</u>

Projects Requirements

- Students are able to access their locker by using their ISU card or by entering group credentials into a QWERTY-keyboard
- The LCU (“Locker Control Unit”) must have a battery life for at least two semesters
- The MCU (“Main Control Unit”) shall display when battery life is low and critically low
- The MCU must be able to control multiple LCU’s (minimum of 50), and all LCU’s must be tied to a single MCU
- The SD card must be able to read and store a database of names and locker numbers so administrators can update all the names and numbers each year
- The LCU and MCU must be able to securely transmit data
- The wireless data transmission need to be transmit data at the longest distance from the LCU
- Management tools and scripts must be available remotely
- The MCU must be able to be configured over SSH, wirelessly, and must connect to Iowa State public Wifi

- The lockers must be physically secure

Operating Environment

The operating environment of the LCU and the locker units would be a type of classroom or workplace. Users would be able to safely store personal items in a designated locker with an automated lock. This lock would be controlled by the swipe of an id card. The user would be able to either swipe their personal card or type their group credentials into a corresponding keyboard. This control of access to the lockers is determined by the credentials stored on the MCU located in the room. Additionally, we are assuming a stable operating environment in a temperature-controller room, and we are already assuming physical security. As such, no physical security shall be implemented to the controlling units beyond a standard casing unit and standard bolt-lock. Additionally, we are assuming the environment will be weather-controlled and will not be exposed to the elements.

Risk Assessment of Solution

- Public wifi may be a security hazard
- Finding a low-cost high-yield battery option may be difficult
- The cost of the project will be more than the budget provided if the components of the project are not selected carefully
- Physical damage to the components may compromise security
- Transmissions over wireless may be intercepted
- Transmissions over wireless may degrade signal-quality over a large enough distance
- Electrical equipment may be subject to failure, which may compromise security

Validation and Acceptance Test

Electrical Systems

All of the components used, such as the Xbee, Atmega and Servo, need to be tested whether the components can be powered at a certain voltage levels. The voltage levels can be tested by supplying a range of voltage through the components and then they are ensured to be operating correctly by performing a certain task for each component. For example, when a range of voltage is supplied to the Xbee, the Xbee can be ensured to be working by sending and receiving data to or from another Xbee. As for the servo, when a range of voltage is supplied, the servo needs to be rotated according to the angle and direction of rotation entered through the Atmega. Verifying that the angle and direction of rotation is correct will yield a valid test. The most important part to test is the Atmega. When the atmega is powered, we can test it's GPIO pins to verify that it is receiving data properly, processing data properly, and outputting data properly. This component may be tested in parallel with the other components. Something else that will be tested are the "neutral" zones of the equipment. We must verify that if the Atmega is asleep, that the other components are still receiving proper data and correct functionality is maintained. Proper acceptance of the electrical systems is that all systems operate correctly in every legally-defined state of the system, and that they operate correctly for a valid amount of time.

Power Systems

The LCU is powered by four AA batteries each with 1.5 V with total power input of 6 V. The system needs to be operated from the batteries for at least two semesters. For that reason our batteries will need to be chosen carefully. At first we need to figure out how much current draw will each device drain, so four scenarios were chosen. The first scenario is that the lockers are never open, the LCU looks for open call every 5 seconds, and it sends battery status to the control panel every two hours. The second scenario is that the lockers are opened once per week, the LCU looks for open call every 5 seconds, and it sends battery status to the control panel every two hours. The third scenario is that the lockers are opened twice per week, the LCU looks for open call every 5 seconds, and it sends battery status to the control panel every two hours. The fourth and final scenario is that the lockers are opened once per day, the LCU looks for open call every 5 seconds, and it sends battery status to control panel every two hours. For each scenarios we then calculated how much voltage it takes to turn on a device and how much current it will need for the device to be running or asleep. Below is our calculations from each scenarios.

	Scenario Calculations		
	Current Draw (mA)	Time (hours)	Electric Power Over Time (mAh)
Scenario 1	20.0657901	2688	53936.84378
Scenario 2	20.07625212	2688	53964.96571
Scenario 3	20.09723107	2688	54021.35712
Scenario 4	20.10770194	2688	54049.50282
Scenario 5	20.13911456	2688	54133.93995
Scenario 6	20.21248508	2688	54331.1599

Taking these calculations, we are then capable of making testing assumptions by measuring the current draws of a final circuit to verify that our math is correct and, additionally, that there is no power leakage. The power system is accepted when we can verify that we can power the system for two consecutive semesters, using the scenarios above to extrapolate data.

LCU

The LCU will be validated by ensuring that it meets all requirements in its intended environment. All testing will be performed in the senior design room to ensure all acceptance tests will work in the intended environment of the system. First, the LCU will be sent a wireless signal from the MCU and one will ensure that the correct locker unlocks. One will then test a different locker and ensure that the correct locker unlocks again. Next, one will test the furthest LCU from the MCU to ensure that the LCU is able to receive the wireless signal at its longest distance. Furthermore, one will validate that the green LED turns on when the locker is unlocked and no erratic behavior occurs. Lastly, one will ensure that the LCU can notify the MCU when its battery status is below 20%. This will be tested by draining the batteries from one LCU and seeing if it sends the correct “battery low” message to the MCU.

MCU

The MCU will be validated to meet all the requirements for the intended use of the system. All the specific functionality of the MCU will be tested apart and then finally tested as a system as a whole. First, the Atmega328 processor will be tested to ensure the functionality of a servo and an LED. Next, the servo is ensured that it has enough strength to pull and hold a lock open. Then, the wireless communication between the Xbees are tested. After all the proceeding have been tested and functionable, the MCU system as a whole is assembled as a prototype. In this prototype testing is done to ensure all communication works. The xbee receives a signal from the LCU to tell the servo to open the lock and turn on the green LED. The Atmega328 performs a power check to then have the Xbee send a signal to the LCU and turn on the red LED if power is low.

Another important part to test in the MCU are the software components. We must test to verify that the datafiles in the system may not be corrupted, and that correct functionality is maintained during edge cases. As such, the MCU software components will be tested using edge-cases of input, and that proper checking occurs for errors. Ultimately, an acceptance of the software system requires no erroneous data will corrupt or crash the system, and that all edge-cases are accounted for.

System Description

Technical Specifications

Power System

The power system plays an important role in this project, in that the LCU needs continuous power to properly function. Without power the system won't run and administrators would have to manually open the locker to repair or replace equipment, or even to provide access to students. The power system will be powered using 4 AA batteries to supply the required voltage to each of the individual components of the LCU. The power system must stay above the operating threshold for at least a single student-year, and must also be affordable.

Communication

The locker system requires wireless communication in order to send the data from the controller unit, where the input is inserted through ISU student card or student ID number, to the locking system of the locker. The wireless communication device used is XBee 1mW Trace Antenna – Series 1 (802.15.4). The XBee is manufactured by Digi. The range of the communication system must be able to reasonably reach all of the lockers in the room. The XBee can be programmed easily by using the X-CTU software. The Xbee can and will be able to be put to sleep in order to preserve power.

LCU

The LCU is the “Locker Control Unit”. Formally, it is the Arduino microcontroller that is responsible for communicating with the MCU and the hardware on the locker itself. It is running on the “Atmega328” microcontroller. The LCU will communicate with the physical components (Locker status LEDs, Servo Locking Mechanism, LCU XBee) to achieve proper functionality. The LCU will be in sleep mode to conserve power unless a battery-request or locker-request is retrieved from the MCU.

MCU

The MCU is an acronym for “Main Controlling Unit”, and it is the primary interface with the user and the various LCU’s. It is in control over all LCU’s, and is capable of telling them to lock/unlock their doors, as well as requesting status updates. It interfaces with the user through the use of a card-reader, as well as a keyboard (should a student forget their ISU card). A display will render battery status, and remote management software shall be included.

User Interface

The user interface will be in four key parts:

1. The MCU keyboard
2. The MCU keypad
3. The MCU display (optional)
4. Interaction with the locker itself

The keyboard shall be used when a user forgets their ISU ID card, and users will be able to enter group credentials to unlock their lockers. These credentials will be generated by an administrator, and provided to the students at the beginning of senior design. The credentials shall include both a username and a password pair, which shall be auto-generated at the administrator's request.

The Locker shall include a dual-colored LED, which shall display battery and lock status. Additionally, the locker shall open and close, and the lock component shall be spring-loaded for ease-of-design.

The display will primarily be used to display the input of the user (and standard asterisk format) and to render feedback (AUTH_SUCCESSFUL, AUTH_FAILURE). Additionally, an administrator mode will be enabled, such that administrators can see the status of all of the lockers currently in the system. Remote-access will be enabled through the use of SSH, such that admins may replace locker permissions at-will from editing configuration files on the controller itself.

Process Details

Stage 1: Research System

- Perform background research on each major system component

Stage 2: Proof of Concept

- Apply background research to practical application
- Design and test circuitry on breadboards
- Perform power calculations to ensure battery life
- Interface magnetic card reader, keyboard, and display with rasberry pi and send wireless signal when card is swiped
- Ensure locker control unit receives signal and controls servo and LED
- Perform full system level test to provide proof of concept to client

Stage 3: Verification Testing

- Test MCU can recognize different card swipes
- MCU has a user interface display

- LCU can receive signal at desired range limit
- Batteries will last the desired amount of time

Stage 4: Produce System

- Fabricate PCB from circuitry designs
- Encase MCU hardware
- Create docking station for keyboard
- Encase LCU hardware and battery pack

Stage 5: Document System

- Finalize project plan and design document
- Create specification sheet for system
- Create instruction manual for installing system

Scheduling

Deliverables

First Semester

1. Project Plan Draft
2. Design Document Draft
3. Project Website Draft
4. Main Control Unit Prototype
5. Locker Control Unit Prototype

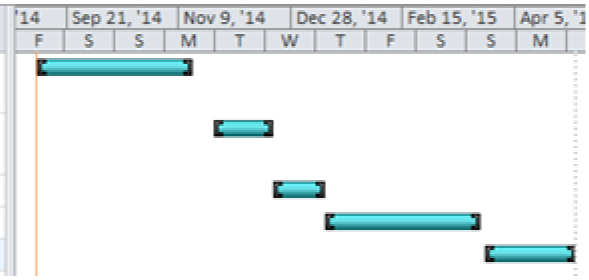
Second Semester

1. Final Project Plan
2. Final Design Document
3. Project Website
4. Completed Main Control Unit
    a. Numeric Keypad
    b. Magnetic Card Reader
    c. I/O Display
    d. Wireless Transmit Ability
    e. Extensible Desi
5. Completed Locker Control Units

. Three Completed Locker Control Units
a. Locking Mechanism
b. Monitoring Status of Locker
c. Wireless Receive Ability
d. Battery-Powered for a single student-year

Project Schedule

Task Name	Duration	Start	Finish
Research and Design System	50 days	Mon 9/8/14	Fri 11/14/14
Prove System will Function	20 days	Mon 11/24/14	Fri 12/19/14
Order Parts	17 days	Sat 12/20/14	Sun 1/11/15
Verification Testing	50 days	Mon 1/12/15	Fri 3/20/15
System Documentation	30 days	Mon 3/23/15	Fri 5/1/15



Work Breakdown Structure

The work shall be broken down into the following areas and assigned accordingly:

1. PCB Fabrication / Design

a. Includes Mockups, Sketches, and actual Fabrication

2. Power Systems

. Includes battery selection and maintenance

a. Includes delivering of power to the rest of the circuit

3. General Electrical Design

. Design interconnection circuitry

a. Perform mathematical calculations as necessary

b. Determine electrical components as necessary (Resistors, Capacitors, etc.)

4. Communication System

. Communication between MCU and LCU

5. MCU - Pi Control Unit

. Includes card reader, numpad entry, display, and the Pi board itself

a. Includes all software running on the Pi

6. LCU - Locker Control Unit

. Houses PCB, mechanical lock, batteries

a. Includes Arduino Microcontroller

7. Mechanical Design

. Design of the locking mechanism

Market Survey

This project is being designed strictly for use with Iowa State University, and as such we have no plans to market this product. None-the-less, we have researched alternatives to our design to provide the best coverage and to understand current best practices.

The Smart Locker System manufactured by Genesys is the best example for our project. It has a similar functionality such as automated keyless access, with the only required item to access the locker is an ID card. Additionally, the Smart Locker controller unit consists of a LCD screen and a scanner. The information from the ID card, such as name and locker number, will be presented on the LCD screen for the user. Additionally, the locker has a bi-colored LED which will turn provide feedback into the locker-status (again, similar to our design). Inside the locker, there are two A/C power sockets which enables the user to charge electrical devices when being stored in the locker. Ultimately, the major differences between our design and the Genesys system, is that the genesys system is not battery-powered, nor does it have a fallback if the ID card is lost. Additionally, our design does not provide A/C power inside of the locker.

Ultimately, we have assessed that our design falls outside of current technology, and should not risk infringement on existing patents or trademarks. Additionally, we have determined that our system is a better-fit for the ECpE department at Iowa State University, and as such we shall continue our design.

Genesys Smart Locker System

Conclusion

This design, the CyLocker access system, will provide a significant improvement to the current physical lockers. It will be both easier to manage and easier to access. We hope to overcome the risks and challenges of building this system and, by doing so, achieve a project that is both extensible and reliable. Ultimately, this system can only benefit the Electrical and Computer Engineering Senior Design Program at Iowa State University.