Group A

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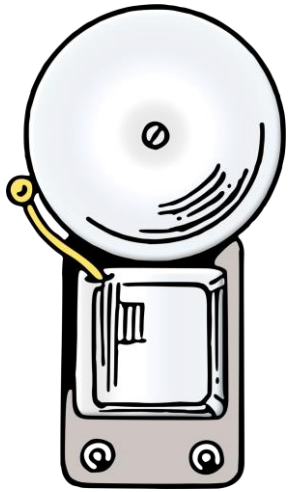
Motivation

- While technology is evolving at a rapid pace, the fire alarm has not seen any innovation.
- The smoke and fire alarm that your parents had is the same one that you have!
- These devices do not provide the user with an abundance of information.



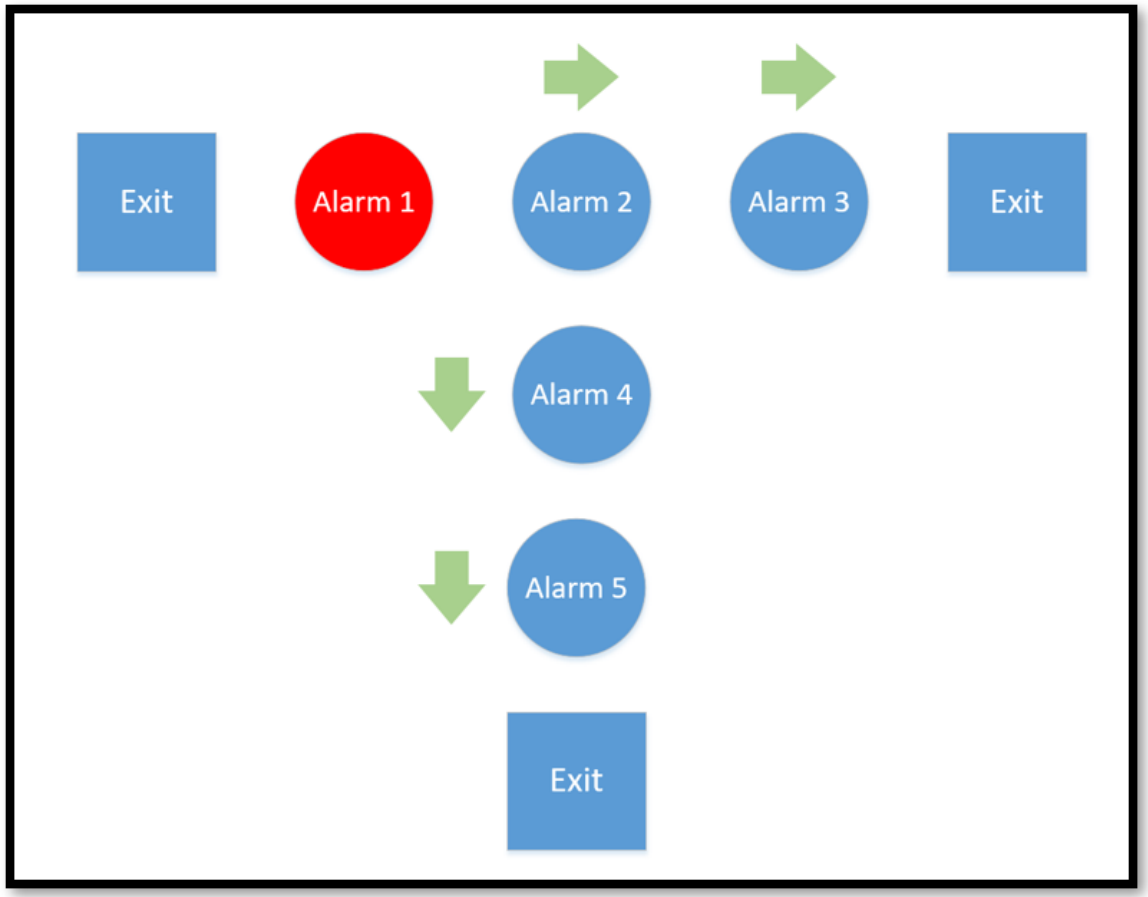
Issues with the Current System

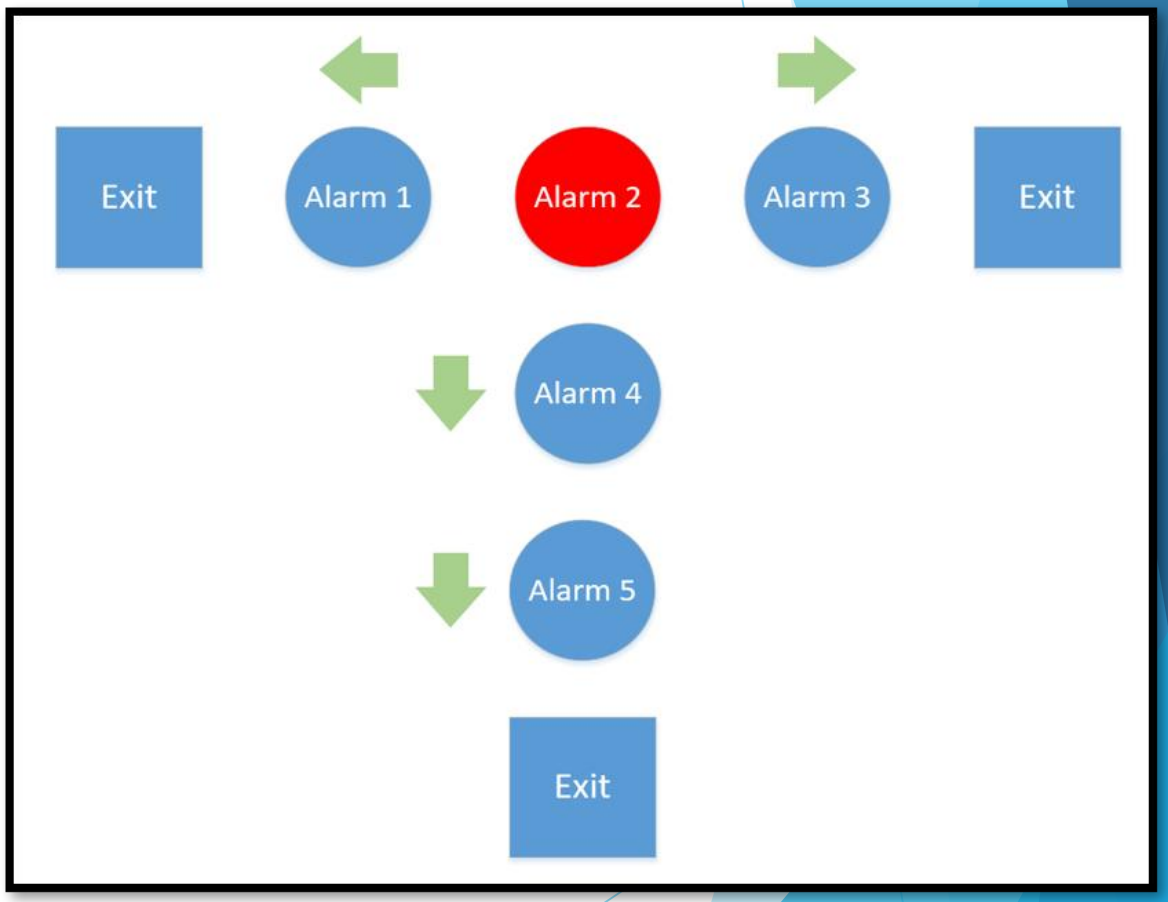
- Someone could hear the alarm go off and just frantically run to wherever they believe to be the nearest exit.
- This has the potential for disaster with multiple people inside the building who don't know their way around.
- A smoke alarm with improved functionality can help to make everyone’s lives easier, and most importantly, safer.

Project Goals and Objectives

- Alarms have ability to send a signal wirelessly to a central hub.
- Central hub can send different wireless signals to different alarms.
- System will calculate the fastest path from each alarm to an exit.
- Alarm will be able to display which direction to go on way to nearest exit.
- Smoke alarms will sound off in the order that will lead people to the nearest exit.

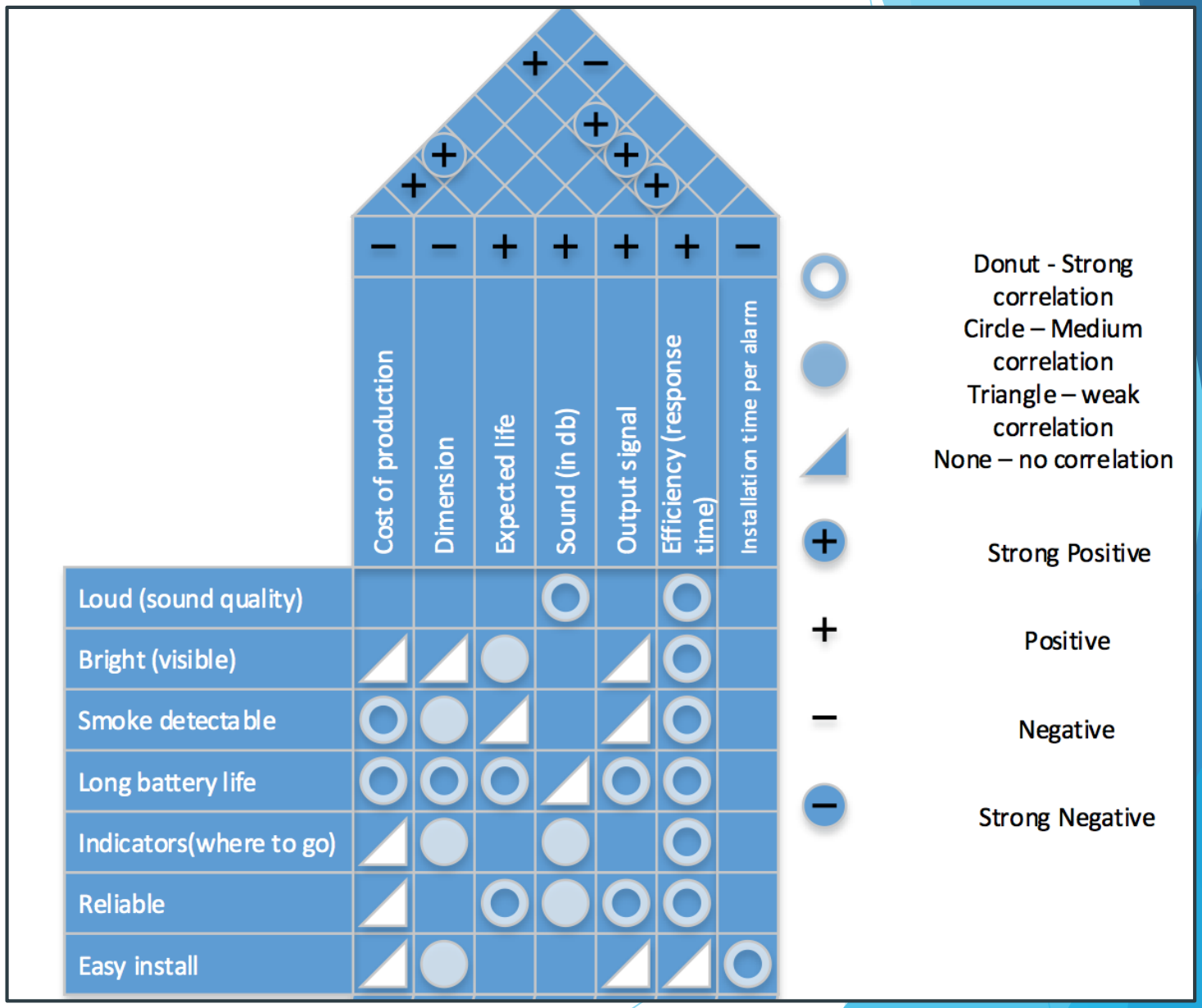
Sample Implementations





Specifications

- Low Cost
- Good Visibility and Audibility
- Reliable and Efficient
  - Fast Response Time
  - Good Life Expectancy
- Able to Detect Smoke or Gas



Requirements

- Smoke and Gas sensor to be able to detect smoke or a gas leak within the building.
- Transmitter and receiver for the wireless communication between each alarm system and the HUB.
- Indicators; such as lights and sounders to alert the building when an emergency is happening, like a detected gas leak or smoke.
- Secondary backup power supply is needed.

Project Design Approach

1. How will calculations be made?
    a. ATMEGA328PU
    b. RaspberryPi

1. How will alarms be connected?
    a. Wifi
    b. Bluetooth
    c. ZigBee

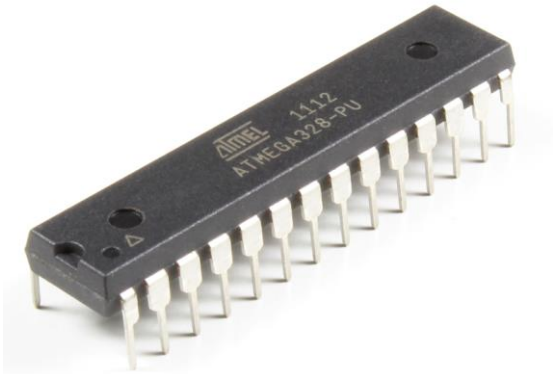
1. How will alarms be powered?
    a. AC/DC Power Converters
    b. Battery Power

1. How will alarms notify users?
    a. Smoke Sensor
    b. Buzzer/Sounders
    c. LEDs

Alarm CPUs and Main Hub CPU

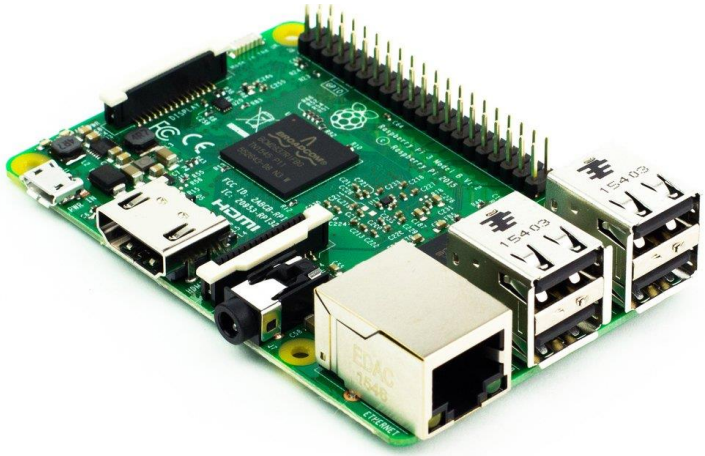
Alarms:

- ATMEGA328PU
  - Low Power
  - Adequate I/O
  - A/D Converter for Gas Sensor



Main Hub:

- Raspberry Pi 3
  - HDMI Output for Display
  - Low Cost
  - Ability for Growth



Power

- AC Power Adapter for 3.5mm 5V 2000mA Output Supply

- 9V Lithium Battery
  - Long shelf life
  - Slow self-discharge
  - Capacity: 1200mAh

Wireless Communication

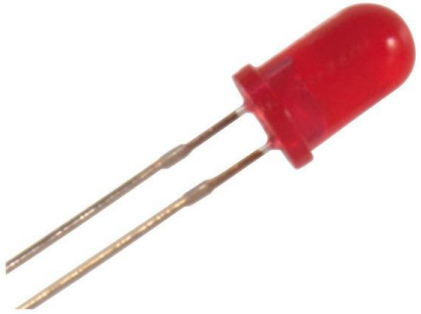
- WiFi
  - Long Range (300ft)
  - High Power Consumption
- Bluetooth
  - Short Range (30ft)
  - Low Power Consumption
- ZigBee
  - Short-Medium Range 30-100ft
  - Ultra Low Power

Alarm System

- Smoke/Gas Sensor

- Piezoelectric Buzzer

- Three Red LEDs



Component Decision: Hub Processing Unit

- Reasoning for eliminating Arduino:
  - Multicore processor is needed for calculations and receiving wireless signals at the same time
- Reasoning for eliminating BeagleBone
  - Raspberry pi is a cheaper option
  - 4gb of flash memory and 65 gpio pins are not needed

	ARDUINO UNO	RASPBERRY PI 3 MODEL B	BEAGLEBONE BLACK
PROCESSOR SPEED	16 MHz	1.2 GHz	1 GHz
DEDICATED GPU	No	Yes	Yes
GPU SPEED	N/A	400 MHz	200 MHz
MEMORY	2 KB	1GB	512 MB of DDR3L
INPUT VOLTAGE	7-12 V	5 V	5V
FLASH	32 KB	SD Card	4GB
OPERATING SYSTEM	None	Linux Distributions	Linux Distributions
MULTITASKING	None	Yes	Yes
ON BOARD WI-FI	None	Yes	No, but Ethernet port
ON BOARD BLUETOOTH	None	Yes	No
GPIO PINS	14	26 of 40 pin header	65 of 92 pins
PWM PINS	6	2	2
USB	One, input only	Two ports	Two Ports
UART	Yes	1 pin	1 pin
ON BOARD HDMI	No	Yes	Yes
PRICE	$24.95	$35	$55

Component Decisions: Smoke Sensors

- Most Commonly used sensors
- Photoelectric sensors vs Gas Sensors
- Why choose MQ-2 Sensors?

	Photoelec- tric Sensors	Ionization Sensors	Gas Sensors	Heat Sensors	Dual Sensors
Technology Used	IR LED and Photodiode	Radioac- tive Material	Ionizatio n Element	Temperat ure Sensors	Photoelectric & Ionization
False Alarm from Minor Fire (candles, etc.)	Unlikely	Likely	Unlikely	Unlikely	Likely
Smoldering Fire Detection	Fast	Slow	Fast	Slow	Fast
Flaming Fire Detection	Fast	Fast	Fast	Slow	Fast
Best Operational Use	Large Space, Smoldering Fire	Large space, Flaming fire/little smoke	Flaming Fire, Smolderi ng Fire	Small Space, rapid burning high heat fire	Large Space, Smoldering and Flaming Fire
Recommen- ded by IAFF	Yes	No	No	No	No

Component Decisions: Buzzer

Specs to consider

- Sound Pressure Level
- Cost
- Voltage
- Frequency Range

Buzzers	Max SPL (Sound Pressure Level)	Cost	Peak Voltage	Frequency
PS1927P02 Piezo Sounder	90 dBA/cm	Low	10V	2200 – 3200 Hz
PS1920P02 Piezo Sounder	80 dBA/10cm	Low	10V	2000 – 3000 Hz
PS1740P02E Piezo Sounder	85 dBA/10cm	Low	3V	1000 – 5500 Hz
PUI programmable buzzer	100 dBA/10cm	High	24V	100 – 6000 Hz

Component Decisions: Battery

Specs to consider

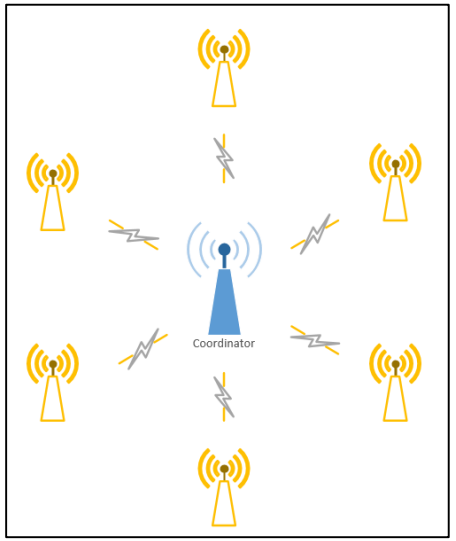
- Shelf Life
- Performance
- Cost
- Power and Capacity
- Discharge

Battery 9V	Shelf life	Performance	Cost	Discharge efficiency	Power & Capacity
Alkaline	5-7 years	Good for low drain devices and good for smoke detectors	Low	Very slow (retains 80% capacity after 5 years)	High (550 mAh)
Carbon Zinc, Zinc Chloride	3-5 years	Good for low drain devices.	Low	Slow (retains 80% capacity after 3 years)	Low (400 mAh)
Nickle-Metal Hydride (NiMH) rechargeable	3-5 years	Good for most uses for both high/low drain devices	High (highest)	Slow–Medium (retains 75% capacity after 1 years)	Low (175-300 mAh)
Lithium	10-12 years	Small risk of explosion, but great for smoke detectors	High	Very slow (loses 0.6% per year)	High (1200 mAh)

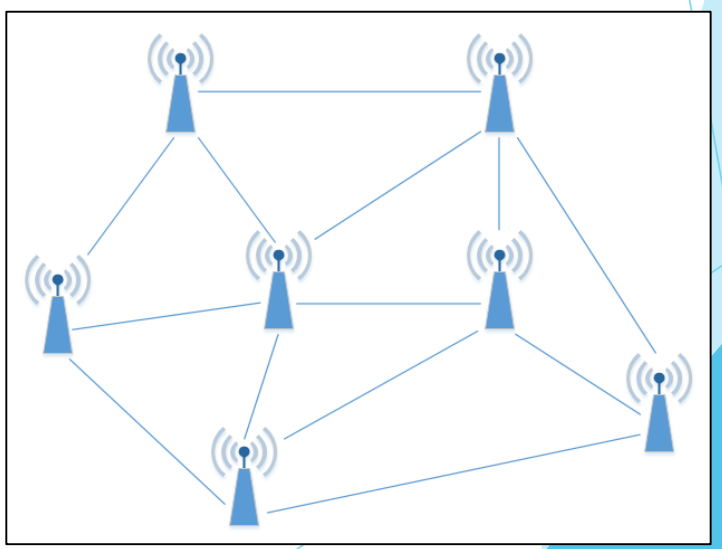
Component Decisions: Xbee Radios

- Capability of Mesh Networking
  - Allows all alarms to communicate without need for centralized network
- Ultra Low Power Consumption
  - ZigBee wireless protocol
  - Useful when battery backup is needed
- Easy to use Software Included

XBEE S2C

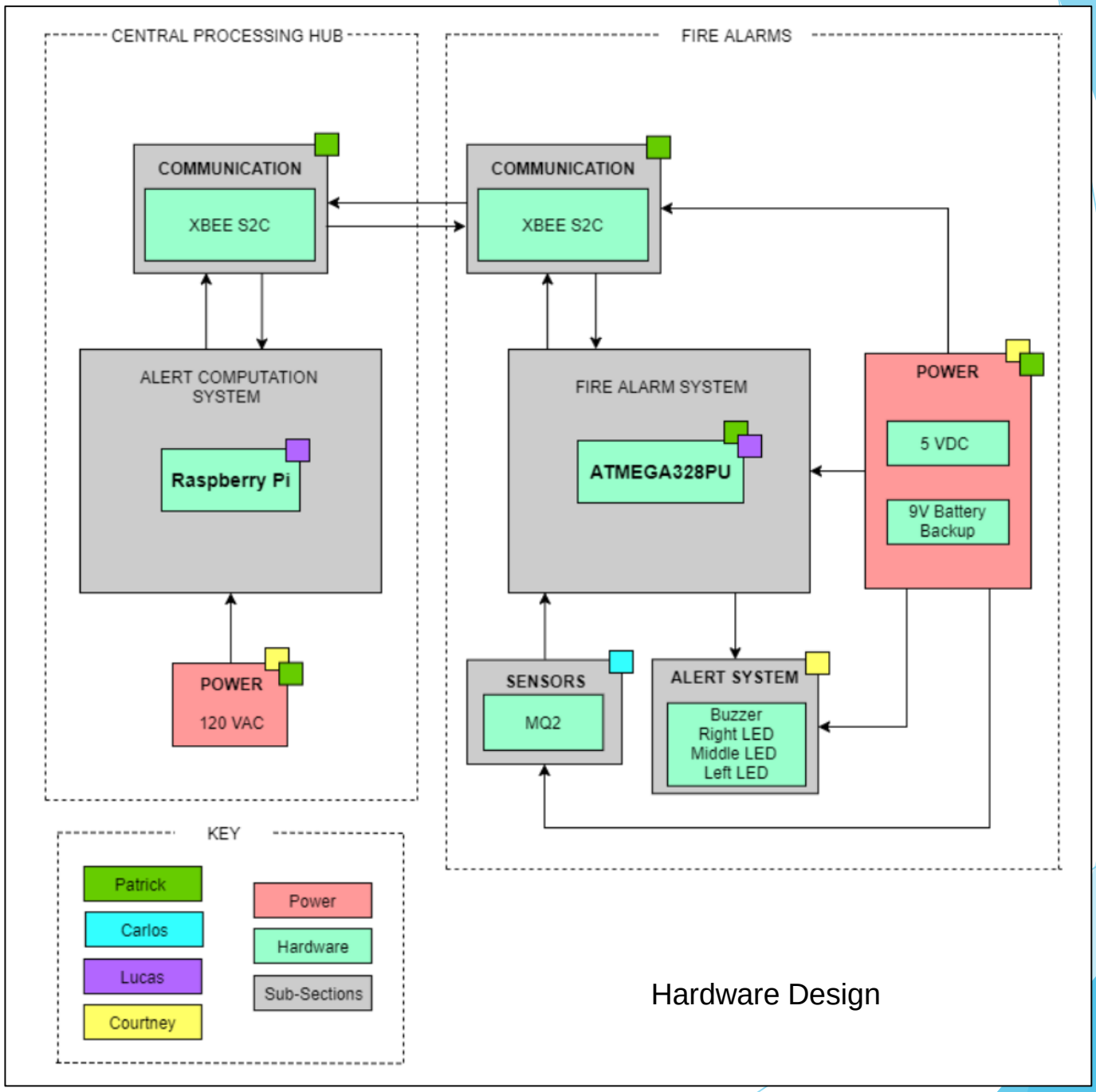


Star Network



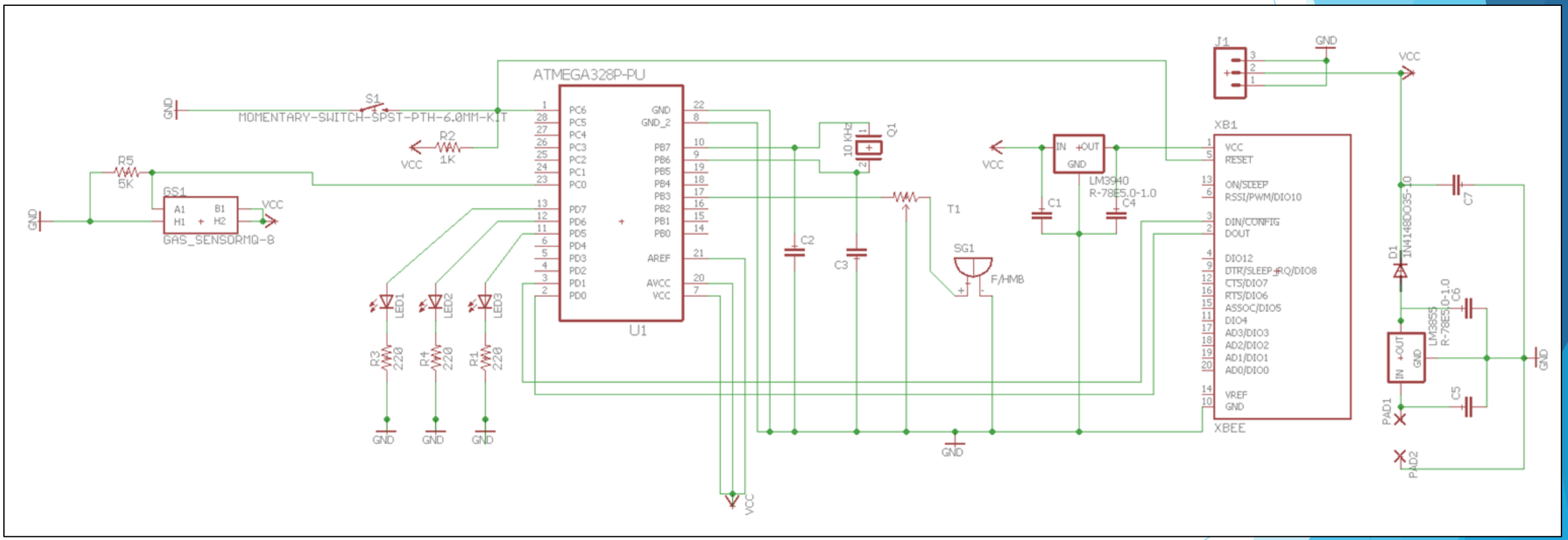
Mesh Network

System Design Diagram



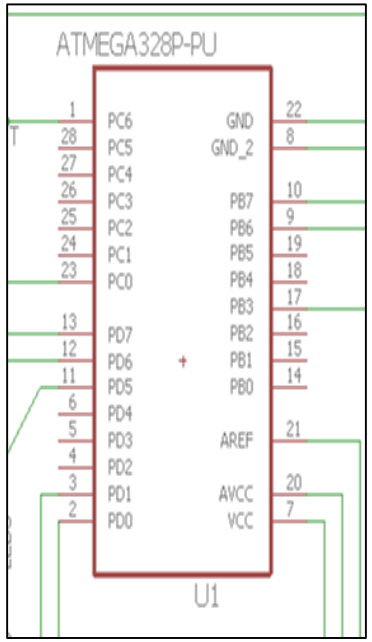
Hardware Design

Schematic

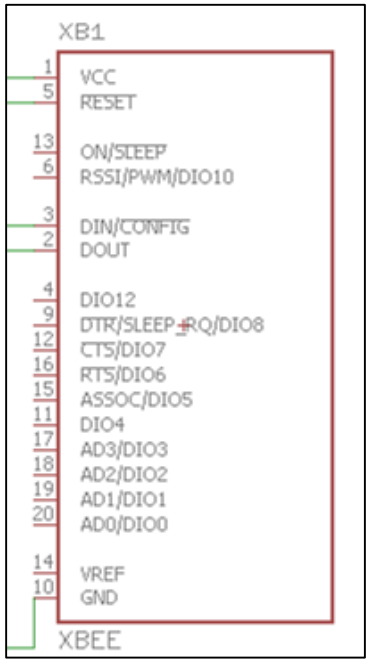


Schematic Overview

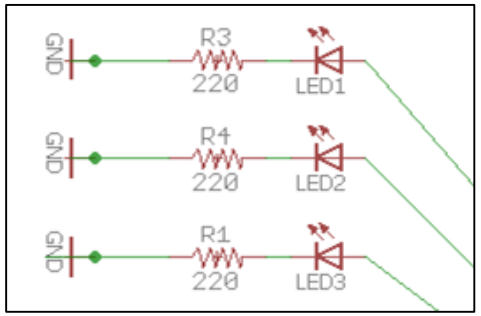
Main Components



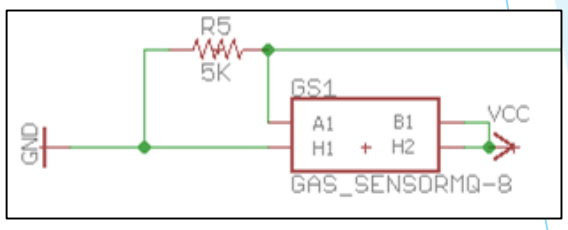
ATMEGA328PU



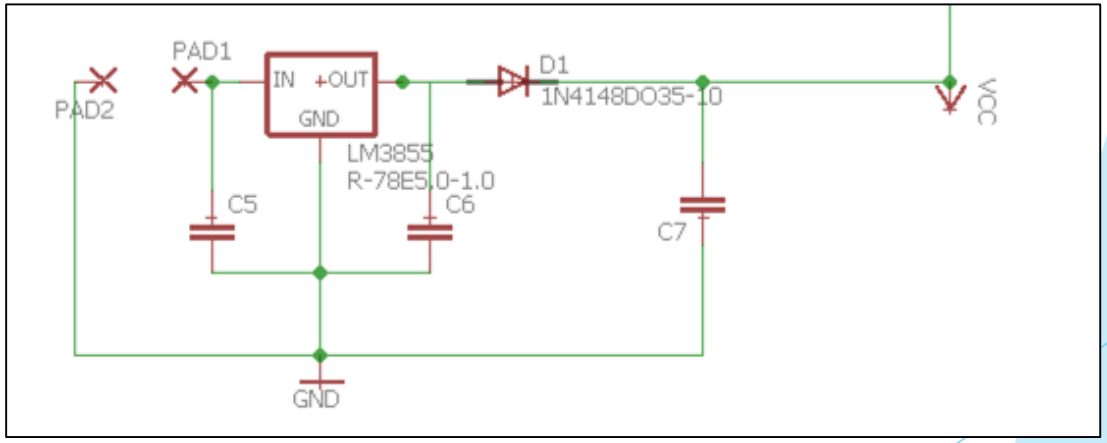
XBEE S2C



LEDs



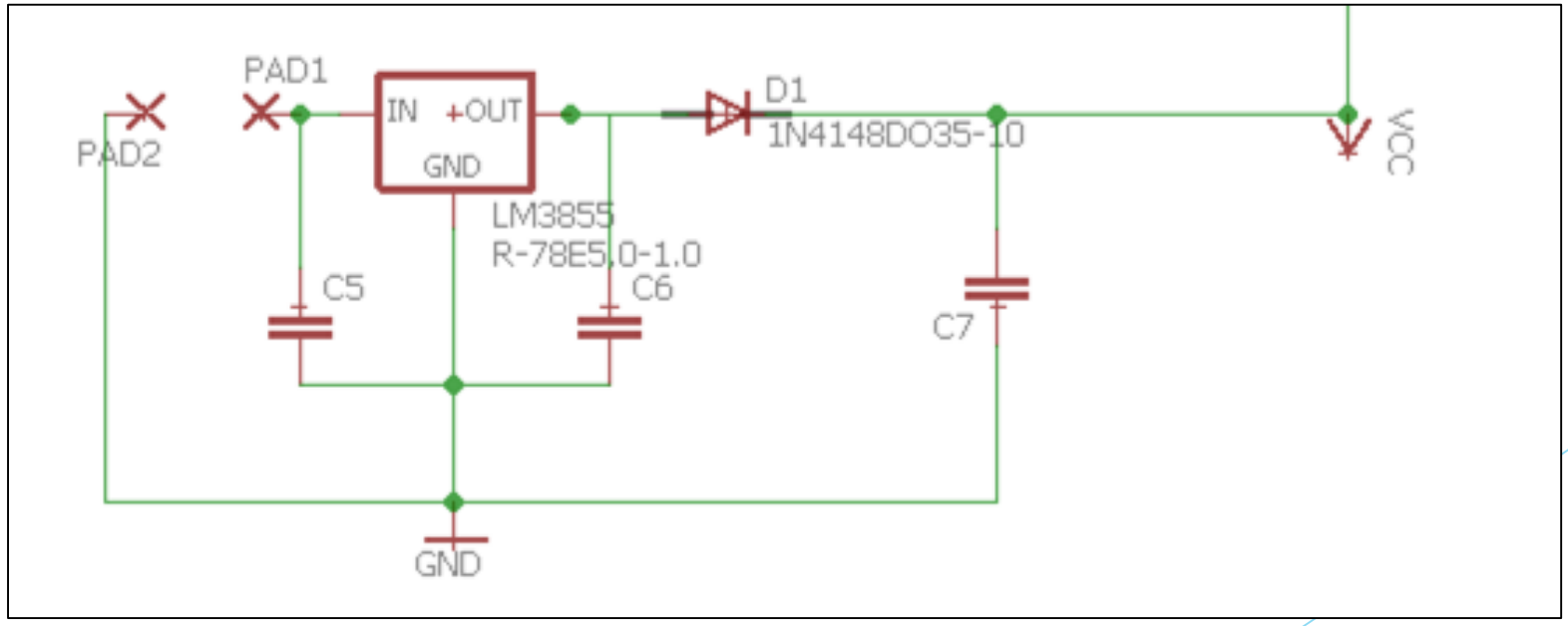
MQ-2 Gas Sensor



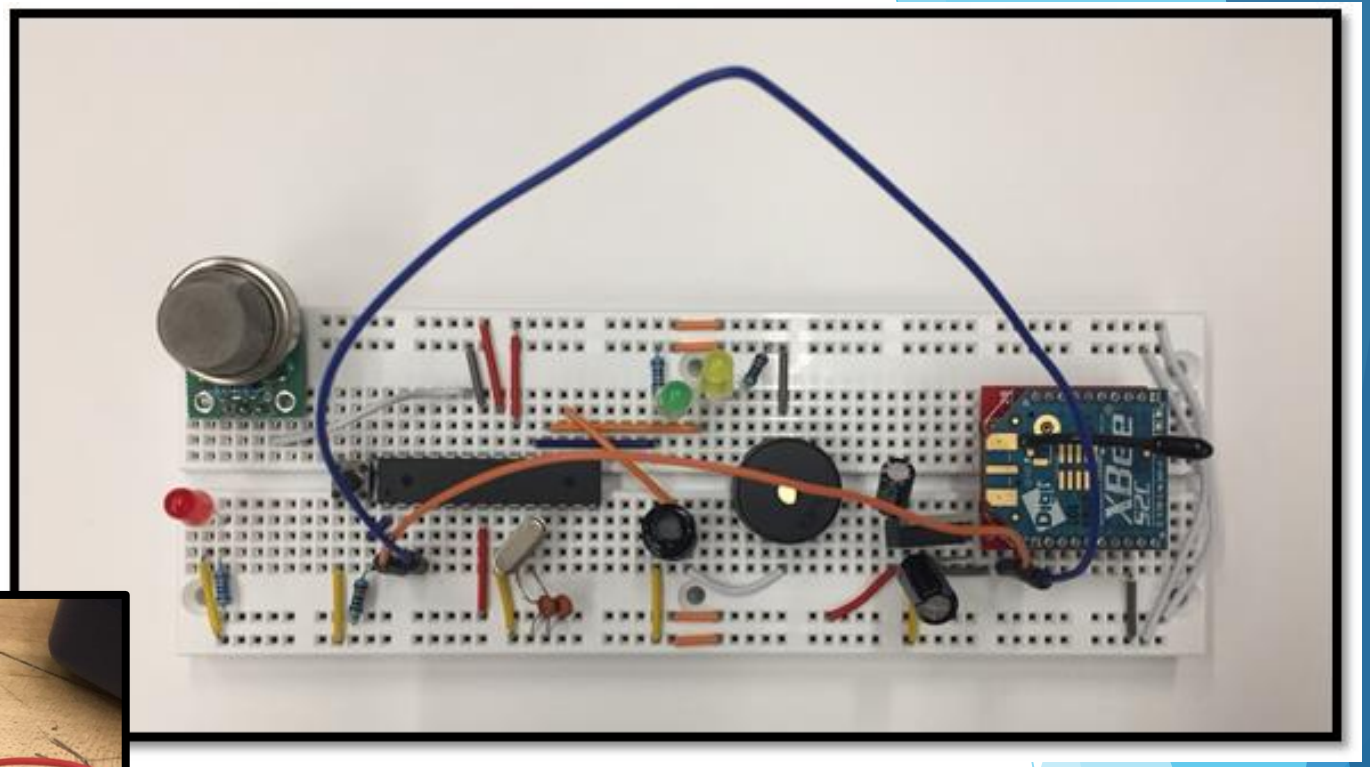
9V Battery Backup

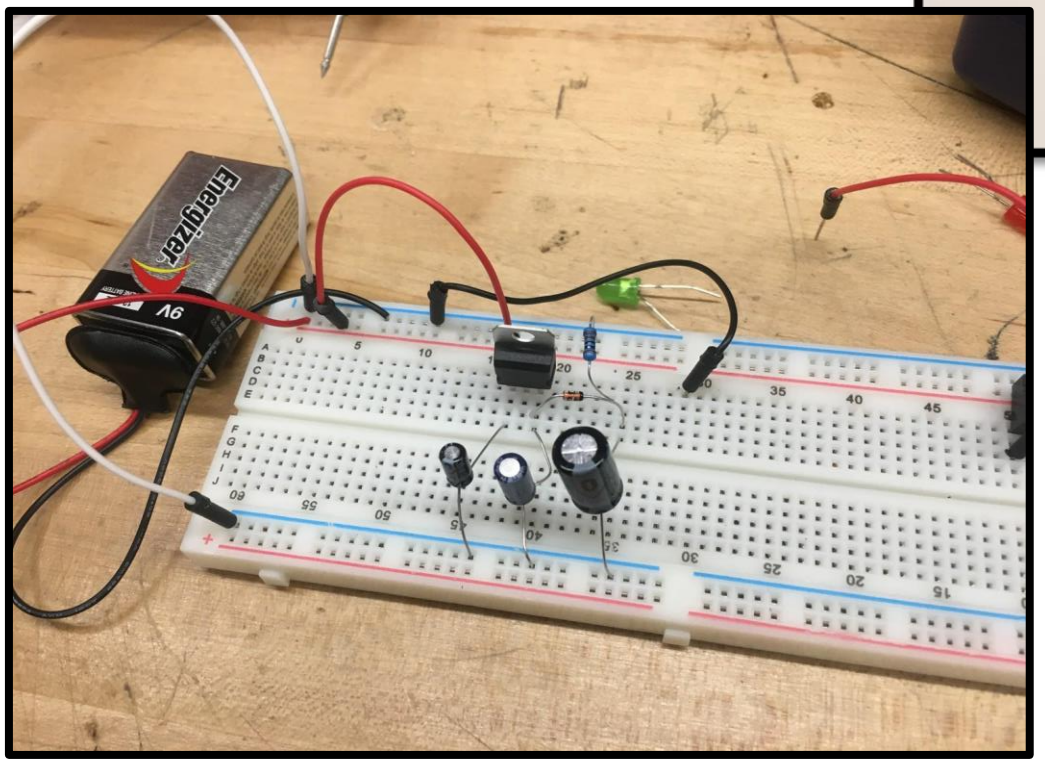
Battery Backup

- Wanted a simple design for the backup battery supply.
- Wanted switching to occur without any interruptions or delays.
- Switching happens when main power supply is cut off, and when main power is restored.

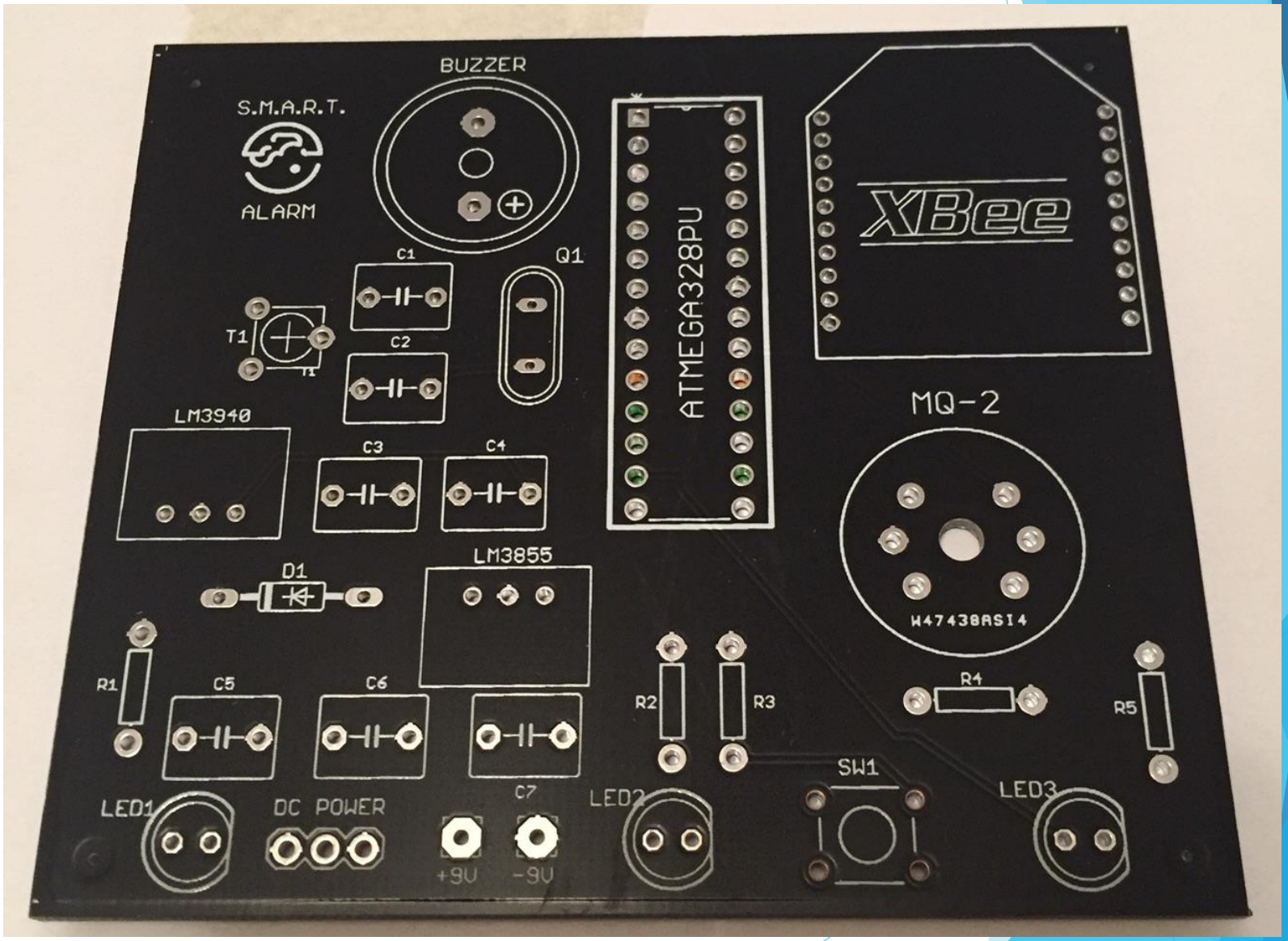


Prototyping



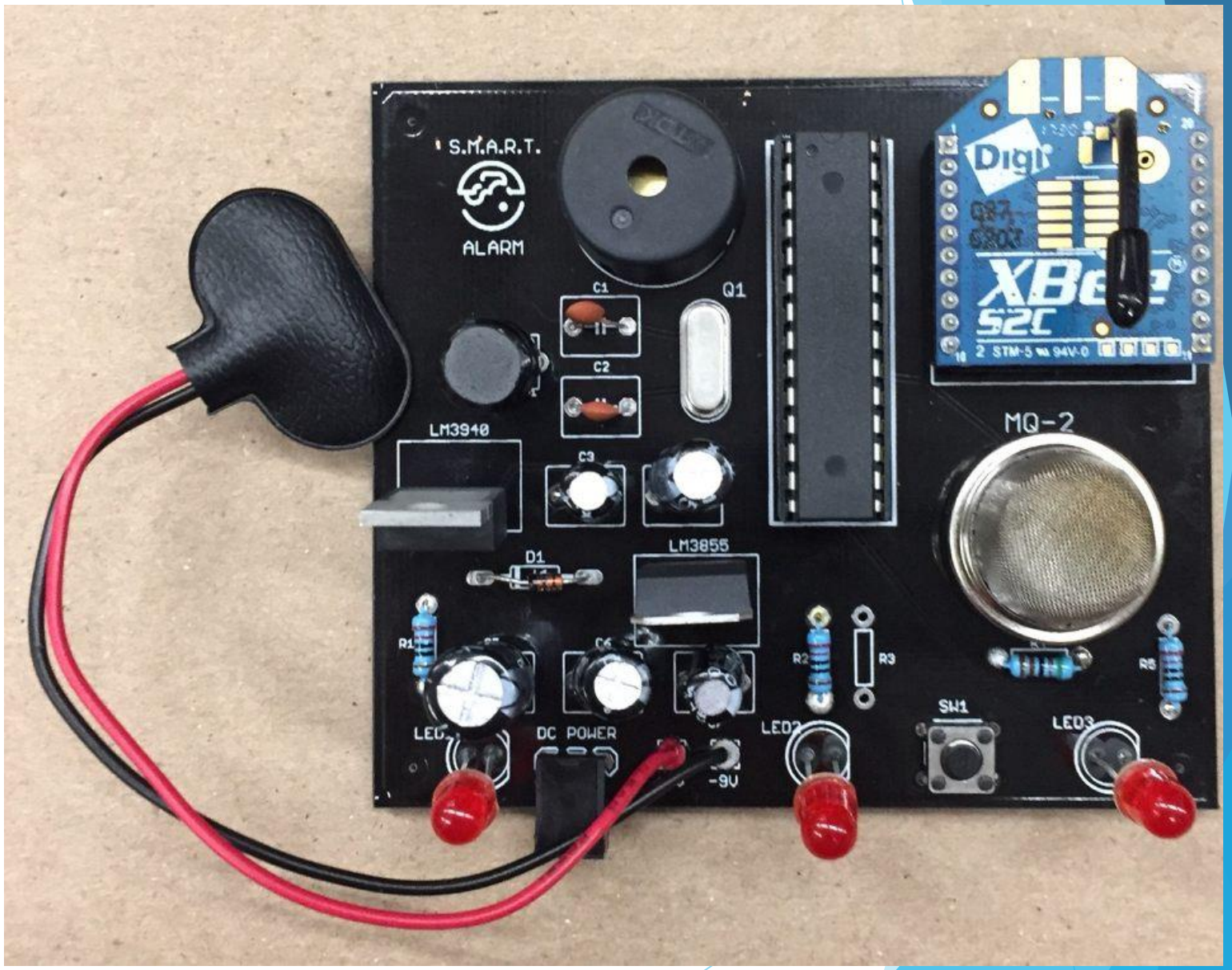


Printed PCB



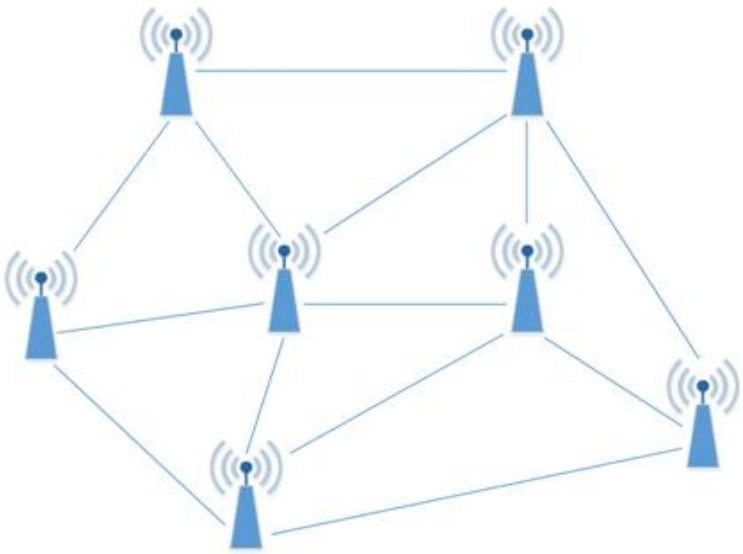
Rev A

Completed PCB



Implementation: Wireless Network

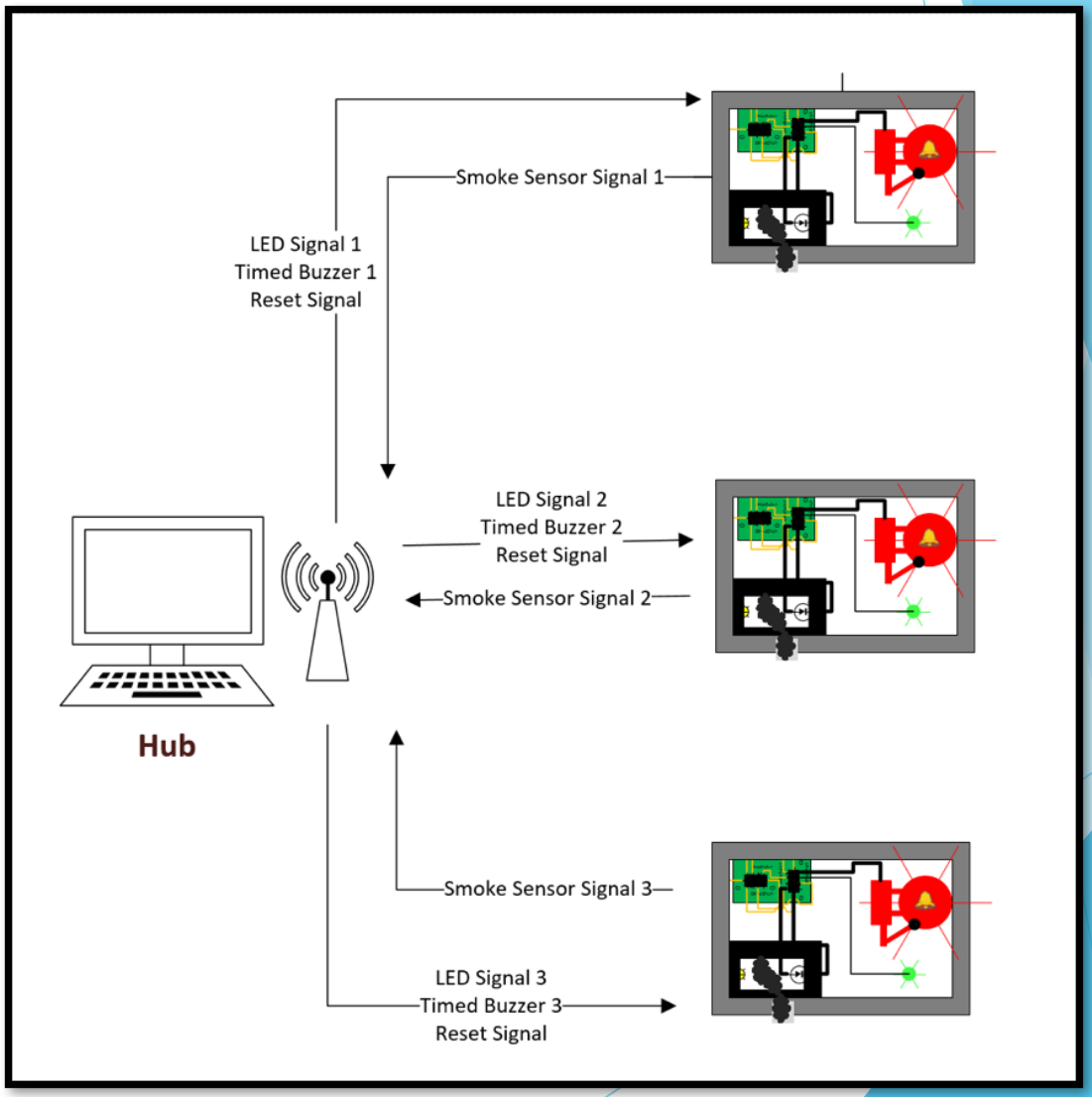
- Mesh network of xbee routers is used to facilitate messages through the system
- Each xbee router has a specific address that will be used to send messages to a specific alarm
- The hub (raspberry pi) will act as the coordinator for the xbee mesh network
- All routers (alarms) will “join” the proper network with the appropriate channel settings



Signals Sent Over the Network

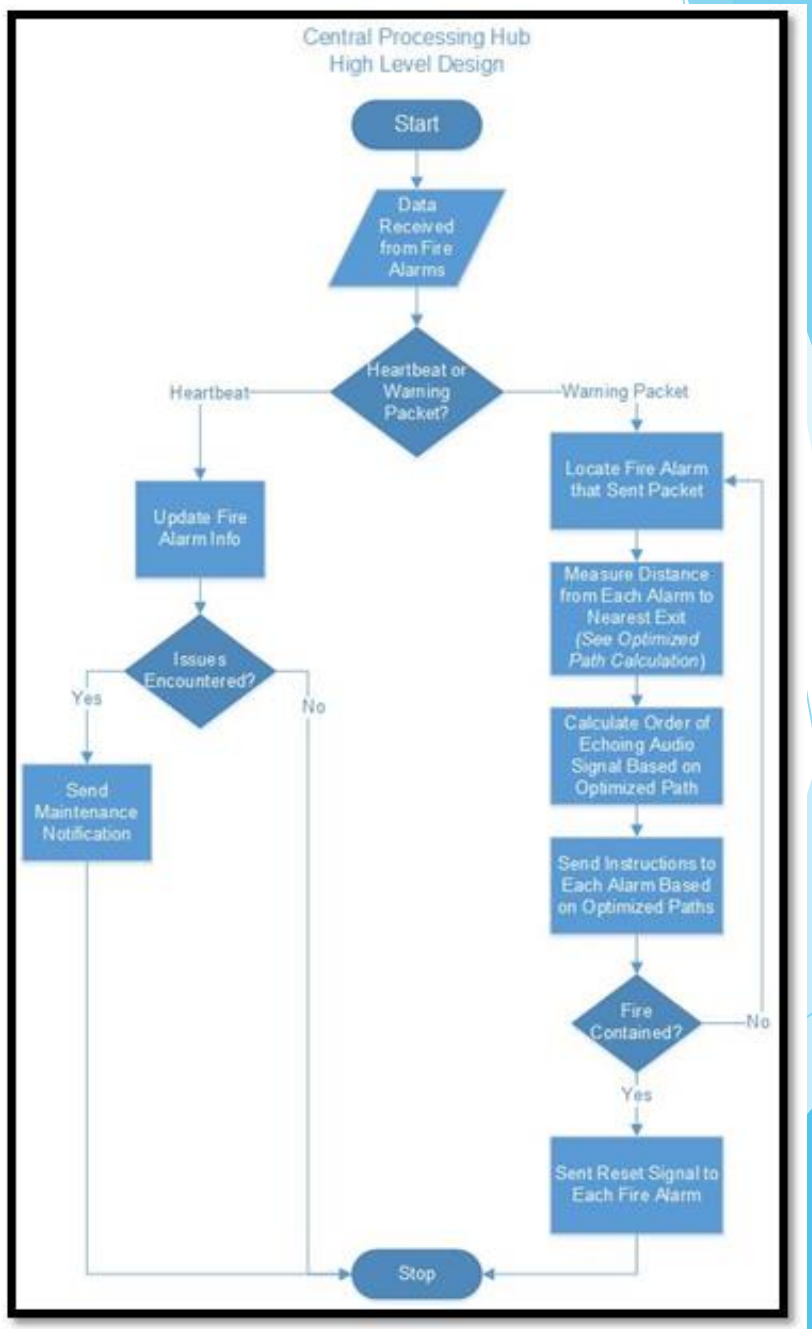
- Data packet sent to hub:
  - String: alarmMessage
  - x64XbeeAddress: alarmAddress
- Data packed sent to alarms:

  String sent to alarm will contain 3 possible signals:
  - Which direction LED to turn on
  - Whether to buzz the alarm
  - Reset the LEDs and system



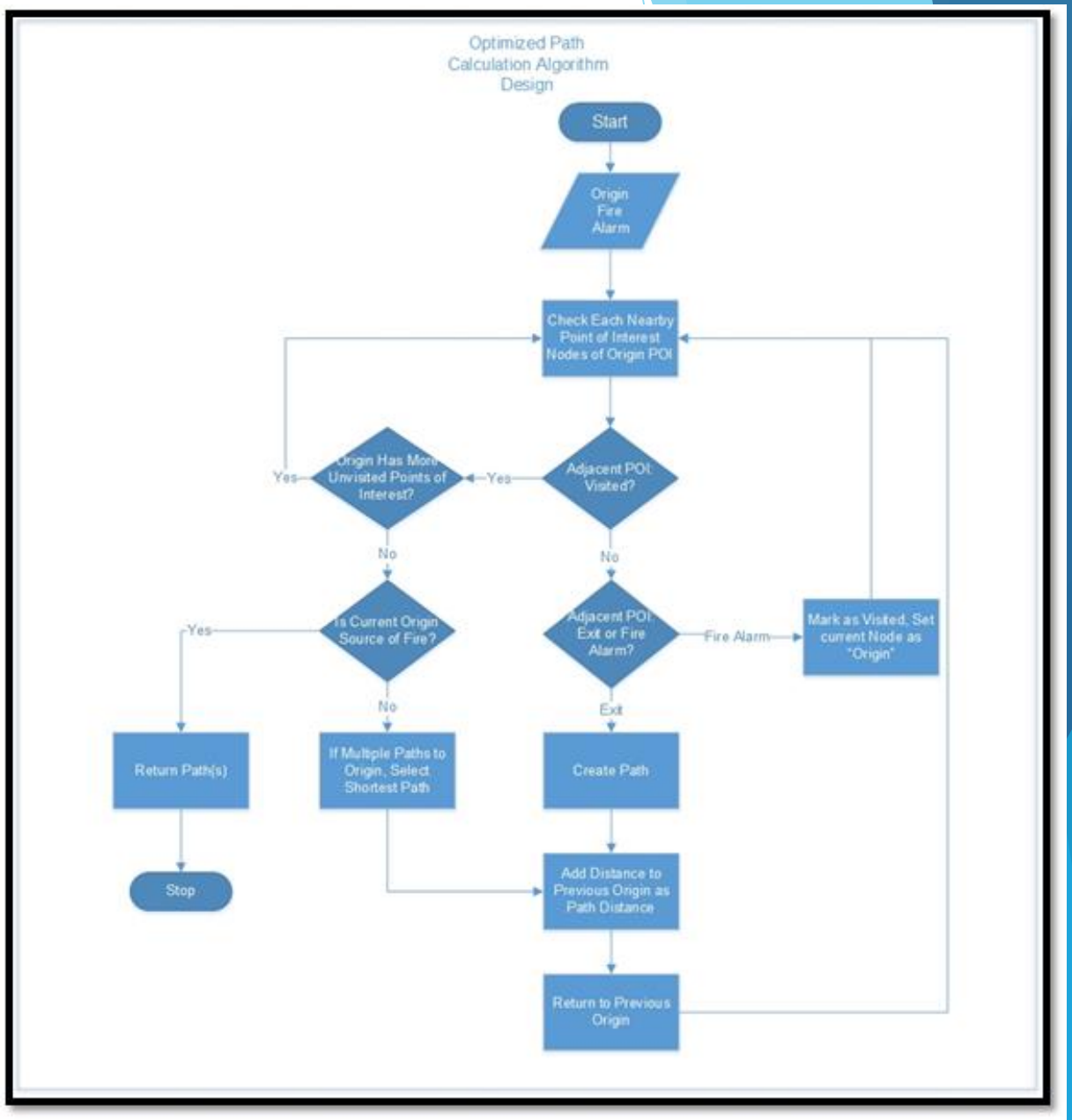
Implementation: Hub (High Level View)

- Heartbeat vs Warning Packets
- Perform path calculations
- Manage Alarms within in System



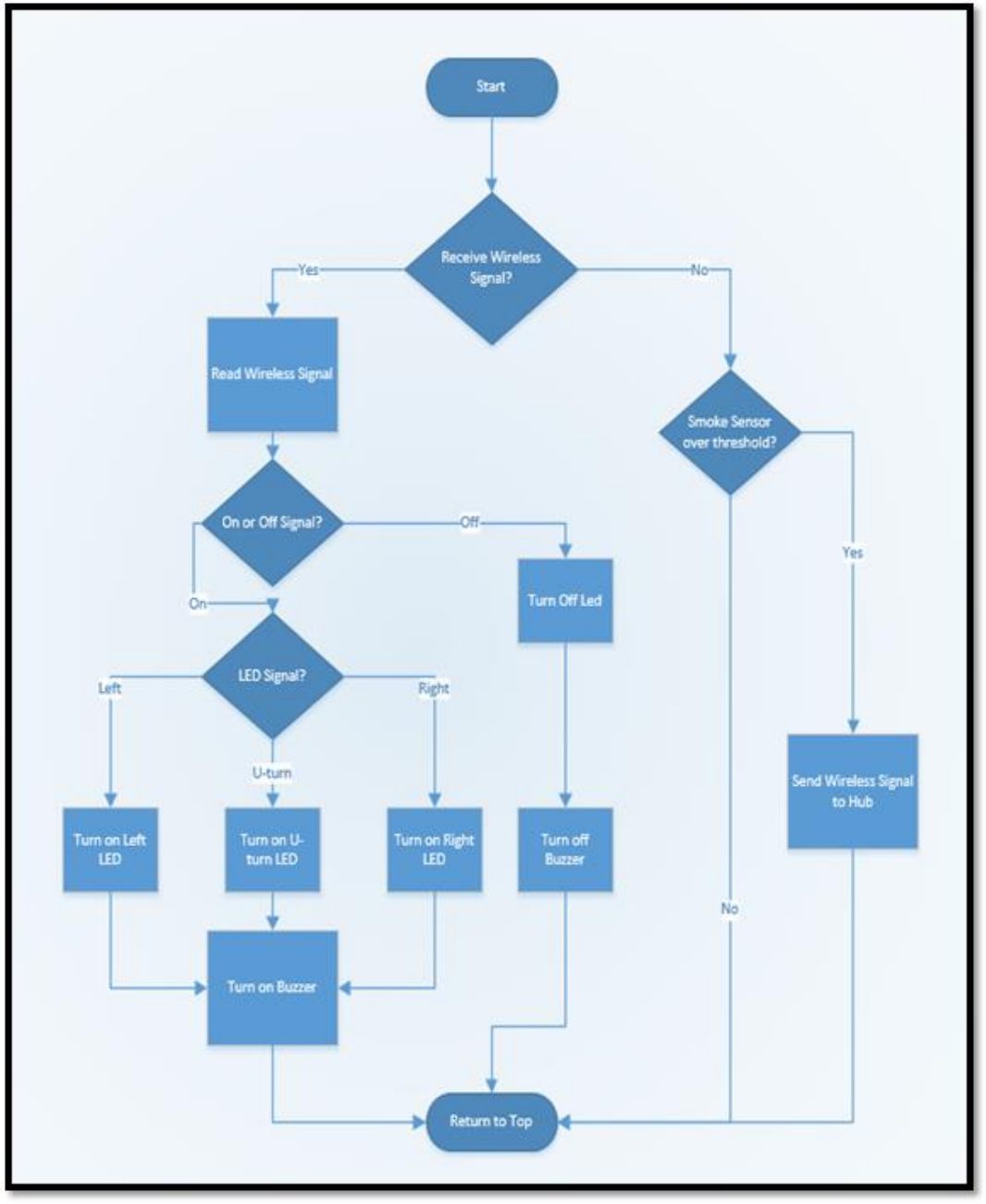
Implementation: Path Finding Algorithm

- Depth-First Based approach
- Traverse each path from exit to fire
- Each Path should find the nearest exit despite location of alarm along the path



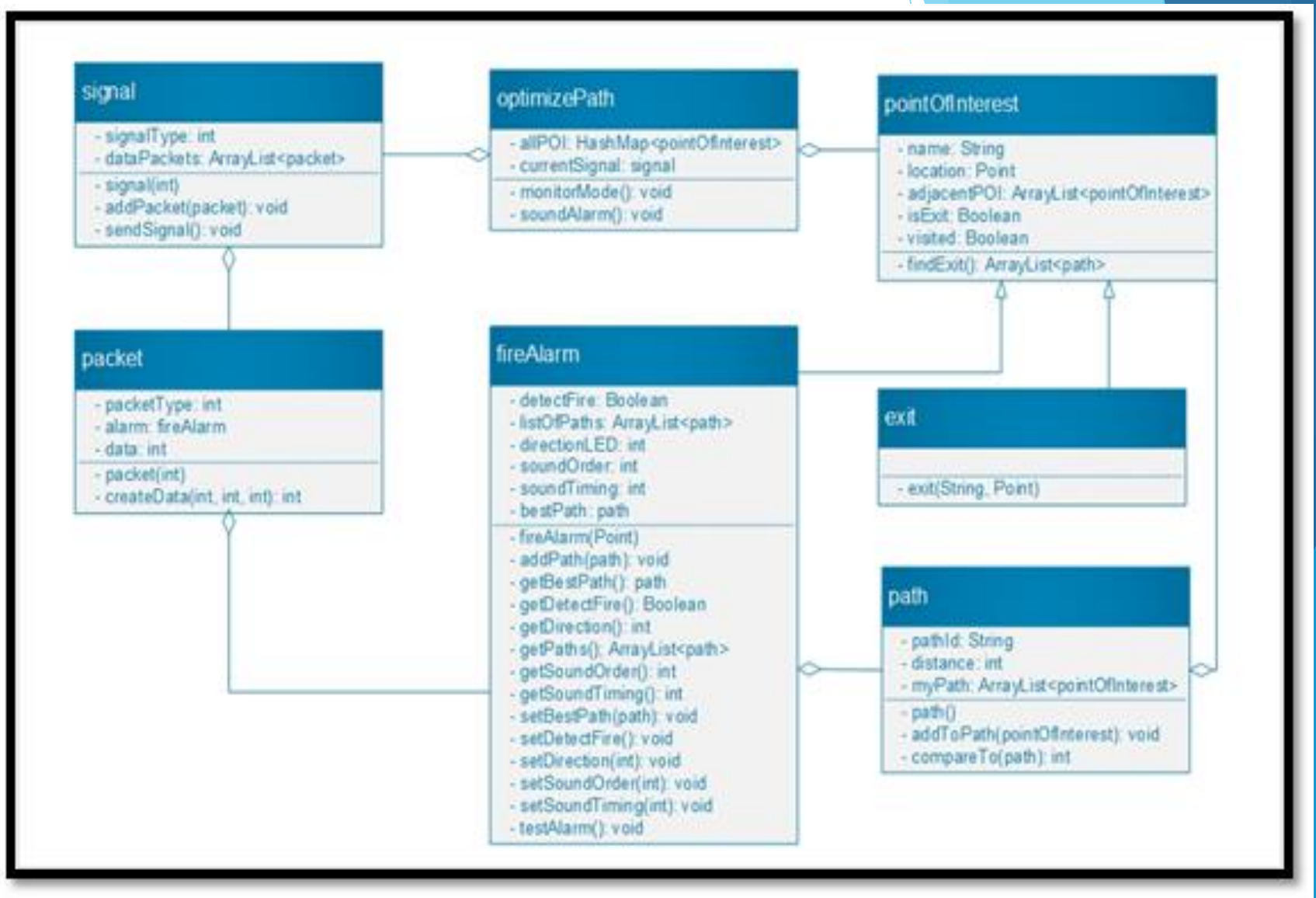
Implementation: Fire Alarm Software

- Cycling of Power
- Looping program for monitoring fires
- Receive and enact simple directions for performing duty within alarm system



Class Diagram

- Interaction of Packets with Alarm and Hub
- Using POI as parent class for exit and path classes
- Optimize path Algorithm

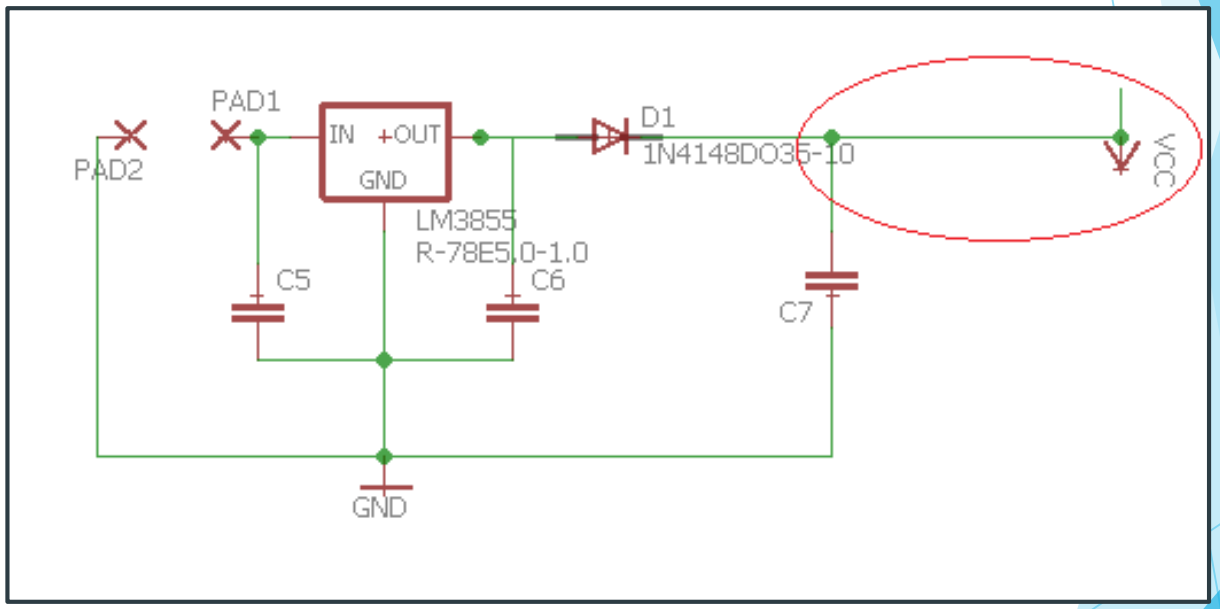


Difficulties: Xbee Communications

- Knowledge of different Xbee libraries are needed for communication between different types of devices.
- Not very much documentation for each Xbee library
- Xbee routers need to be in different configurations depending on the Xbee library (Escape characters in mode 1, not in mode 2)

Difficulties: Battery Backup

- Trouble with original design, and the voltage dropping from the main power supply.
- Making sure the correct power supply was being used.
- Making sure no discharging of the battery would happen.



Difficulties: Software/Algorithms

- Certain test cases would lead to infinite loops
- Creating test cases that would test every possible scenario
- Developing method for easy installation and management of alarm system

Administrative Content

Work Distribution

	Carlos	Courtnie	Lucas	Patrick
Fire Alarm Circuit		X		X
Battery Back-up Circuit		X		X
Fire Alarm SW			X	
Wireless Communication			X	X
Hub Software	X		X	
Administrative Duties	X			

Budget

Component	*Quantity*	*Part Cost*	*Total Cost*
Wireless Adapters	5	$10.00	$50
Battery Harness / Power Supply	5	$3.00	$15
Speaker/Alarm	5	$1.00	$5
Various Electrical Components	5	$10.00	$50
Microcontroller for Hub	1	$30.00	$30
PCB boards	5	$10.00	$50
Smoke Sensors	5	$7.00	$35
Boot flasher	1	$15.00	$15
Unexpected Costs	1	$100.00	$100
Estimated Total			$350

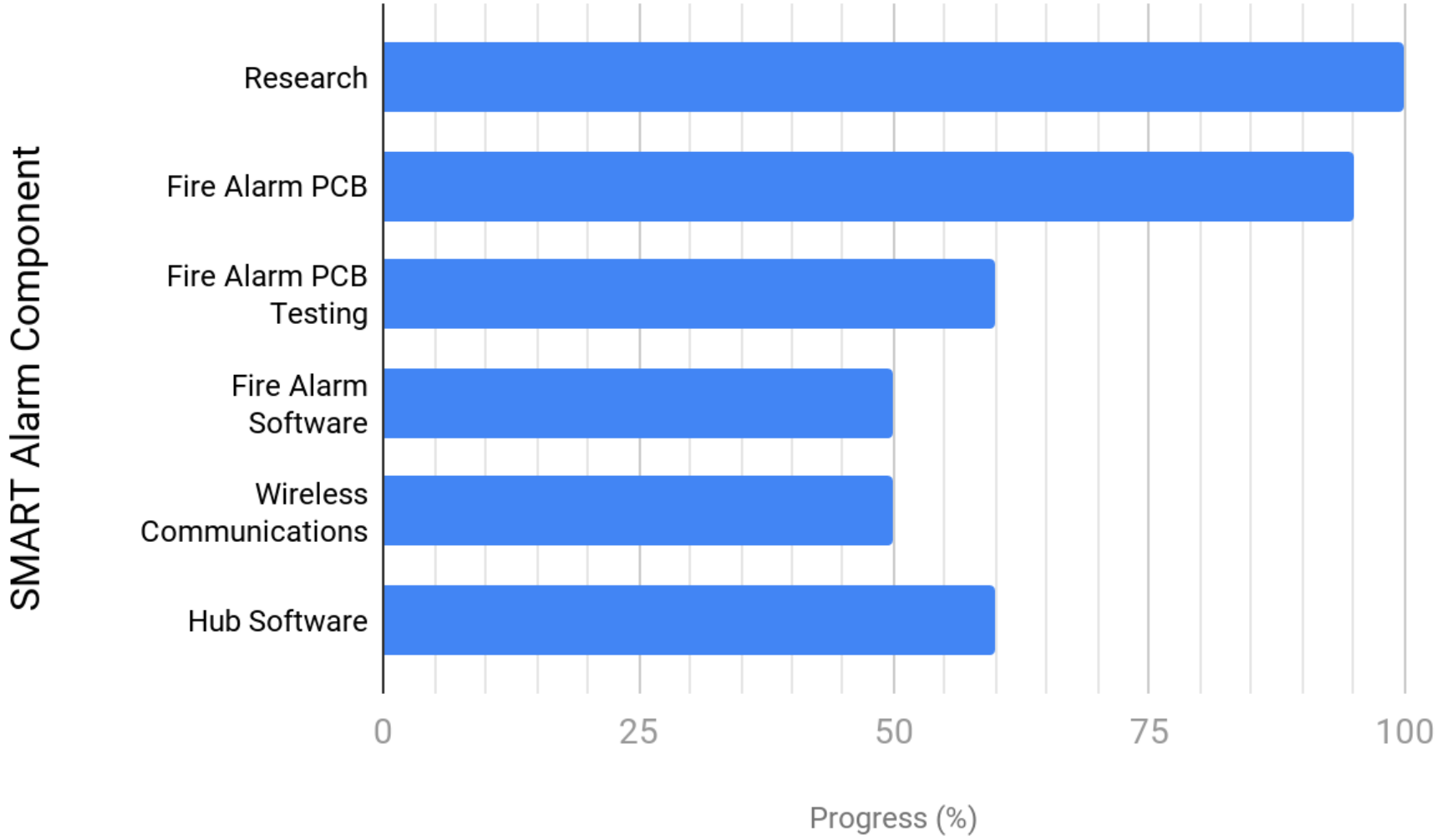
Financing & Costs

No.	Part	Cost	Quantity	Part No.	Source	Part Total
1	Raspberry Pi 3 Model B	$35.00	1			$35.00
2	Elegoo Electronics Kit	$17.86	1	EL-CK-003	Amazon	$17.86
3	9V Battery Snaps	$0.52	2	534-235	Mouser	$1.04
4	Audio Indicators	$0.66	10	810-PS1740P02E	Mouser	$6.63
5	16 MHz Crystals	$0.29	10	815-ABL-16-B2	Mouser	$2.89
6	Mouser Economy Shipping	$4.99	1			$4.99
7	MQ-2 Smoke Detector	$3.95	1	1480	Polulu	$3.95
8	MQ sensor PCB carrier	$0.95	1	1479	Polulu	$0.95
9	Polulu First-Class Mail	$3.95	1			$3.95
10	9V Snap Connectors 5 pack	$1.17	2		Radio Shac	$2.34
11	IR LED Detector Pack	$1.56	1		Radio Shac	$1.56
12	SMT Switches	$0.58	1		Radio Shac	$0.58
13	3.5 mm AC Power Adapter	$5.99	1	262757060	Rakuten	$5.99
14	ATMega328p-pu (3-pack)	$13.49	1		Amazon	$13.49
15	DC Power Socket 10 pc	$5.12	1		Amazon	$5.12
16	Breakout Board for XBEE Module	$2.98	1	1568-1099-ND	Digikey	$2.98
17	RF TXRX Module 802.15.14 U. FL ANT (XBEE)	$18.19	1	602-1559-ND	Digikey	$18.19
18	RF TXRX Module 802.15.14 WIRE ANT (XBEE)	$18.19	1	602-1560-ND	Digikey	$18.19
19	IC REG LDO 3.3V 1A TO220-3	$1.99	5	296-36109-5-ND	Digikey	$9.95
20	Digikey Taxes and Shipping	$ 6.72	1		Digikey	$6.72
21	PCB from PCBWay (11 pieces)	$27.00	11		PCBWay	$27.00
22	ATMega328p-pu (3-pack)	$14.49	1		Amazon	$14.49
23	Flammable Gas & Smoke Sensor MQ-2 (5 pc)	$23.70	1		Polulu	$23.70
24	XBEE S2C Digimesh (5 pc) and Dip Socket (10	$106.54	1		Digikey	$106.54
					Total:	$334.10

Financing

- 100% Financed by Team
- Costs have been shared evenly
- At the end of the course we will ensure everyone paid the same amount

Current Progress



Plans for Completion

- Test Wireless Communication between all devices
- Smoke Sensor Testing
- Final integration of Fire Alarm functionality
- Communication testing to network scale
- Integrate alarm management into Hub Software

Questions?