UNIVERSITY OF CENTRAL FLORIDA

Remote Area Monitoring

Divide and Conquer

(Version 2.0)

EEL 4914: Senior Design 1

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Group 10

Wyatt Vining	Computer Engineering
Abhijeet Malviya	Computer Engineering
Nicholas Gonzalez	Computer Engineering
Johan Gabriel Castillo	Computer Engineering

Table of Contents

1.0 – Project Narrative and Goals 2

1.1 – Project Narrative 2

1.2 – Core Goals 3

1.3 – Stretch Goals 3

2.0 – Requirement Specifications 4

2.1 – Table 2.1: Hardware Requirement Specifications 4

2.2 – Table 2.2: Software Requirement Specifications 4

2.3 – Diagram 2.3: House of Quality 5

3.0 – Prototype Diagrams 6

3.1 – Diagram 3.1: Node Hardware Block Diagram 6

3.2 – Diagram 3.2: Control Node Hardware Block Diagram 6

3.3 – Diagram 3.3: Mesh Network Topology 7

3.4 – Diagram 3.4: Command and Control System Block Diagram 7

3.5 – Diagram 3.5: Linux Web Server Block Diagram 8

3.6 – Diagram 3.6: Prototype Exterior Diagram 8

4.0 – Finances and Budget 9

Table 4.1: Cost Estimate 9

5.0 – Table 5.0: Project Milestones 10

6.0 – References 11

1.0 – Project Narrative and Goals

1.1 – Project Narrative

In recent years, we have seen the devastating consequences of global warming. One such consequence is the measurable uptick in wildfires. In 2020 alone over 10 million acres of land burned destroying nearly 18,000 structures. Our motivation originates from one event in 2016, the Chimney Tops 2 fire. One group member was present at the origin of this wildfire.

The Chimney Tops 2 fire started on the Chimney Tops trail in the Smokey Mountains just after Thanksgiving in 2016. While hiking the trail, our group member noticed the fire as it started around 100 yards from the peak of the trail. This fire would go on to consume the trail they were walking on and their friends cabin they were staying in mere hours after their flight departed. Some were less fortunate and did not make it out from their cabins before the fire moved through.

In the days following the start of the fire, they contacted the fire service to offer any assistance they may provide from a first-person perspective. The investigator they spoke with had an interesting request. He asked for all the photos taken from the day the fire started. His reasoning was that they needed to determine the fuel load of the area. Fuel load is the amount of combustible materials present. For example, dried brush and dead trees. According to the investigator, this information is hard to ascertain once the fire has passed through an area consuming all the fuel. Being of an engineering mindset, this interaction evoked a line of thinking about how we may help this issue in the future.

We began by examining the options currently available. The options include two main methods of detection both with drastically different approaches. The first method to detect fires is by air. Either from airplanes or satellites. The second method is placing a mesh network of sensors across an area of forest. Both methods have positive and negative features. The fundamental issues with the currently available products that we are aiming to solve is cost and availability. The cost of satellite creation or rental is preventative to many potential users. Additionally, the remaining products are not available for purchase.

We realize that reliably detecting fires is an engineering challenge that may quickly exceed the capacity of two semesters. We will not be creating a fire warning system. With consideration of the fire investigator’s insights, we intend to create an open-source monitoring system.

We will focus on monitoring the environmental factors leading up to wildfires. Some of these factors include fuel load, moisture, temperature, volatile compounds in air and wind speed/direction. Our system will consist of a resilient mesh network of nodes. Each node will report its data back to an aggregator node where the data is stored and displayed. All nodes are modular allowing only the necessary sensors be equipped for the specific application of the system. The system will be fault tolerant, maintaining functionality with a minimal number of nodes remaining.

Our hope is that the information gathered by our system will aid those responsible for forest management in the prevention of forest fires by prompting preventative actions. As well as informing movement of assets when actively fighting a fire. Finally, and most importantly, placing the mesh near populated areas may aid emergency management in issuing earlier warnings to residents in the event an evacuation is required.

1.2 – Core Goals

In this section, we will list the goals we believe will lead to project success.

- Create a network of sensing nodes (Diagram 3.3) capable of off-grid communications and operation
- Collect the data gathered by each node (Diagram 3.3) and aggregate the data in a database. This data may be exported or viewed for a historical representation of the area.
- Each sensing node shall adopt a modular design. This is to reduce the overall cost of the system by either: allowing each node to only have the sensors necessary for the application or reducing the number of fully featured nodes in a given monitoring area.
- A minimum set of sensors will be implemented including temperature, humidity, smoke, and an anemometer (Diagram 3.1)
- All nodes will run on a combination between solar power and a reserve battery for operation at night or in inclement conditions (Table 2.1)
- The aggregator shall provide a method to visualize the live data. This may include a map of each node with a color-coded status (Diagram 3.4 and 3.5)
- The system maintainer may designate persons to receive notifications when a node is no longer communicating with the aggregator (Table 2.2)

1.3 – Stretch Goals

In this section, we will list the nice to have features that we will implement time and resources permitting. See Table 5.1 for our projected milestones.

- Predictive data analysis – Use gathered data in conjunction with outside data to offer suggestions to area maintainers. For example, when the system notices an area is dry and there is no rain predicted in the next few days, the system will recommend the fire danger level is increased
- Fault tolerance in nodes – If a node has a degraded component the system shall automatically shut that component down and continue to function with remaining components where possible
- Preventative Maintenance – The system shall detect a degradation in sensors or batteries of the nodes and suggest preventative actions prior to failure
- Daily or weekly reports with a management friendly layout – Focus on graphics and clear visual representation of the data marked most important by the maintaining agency
- Expand the capacity of the network – Allow for covering much larger areas by increasing the number of nodes the system supports

2.0 – Requirement Specifications

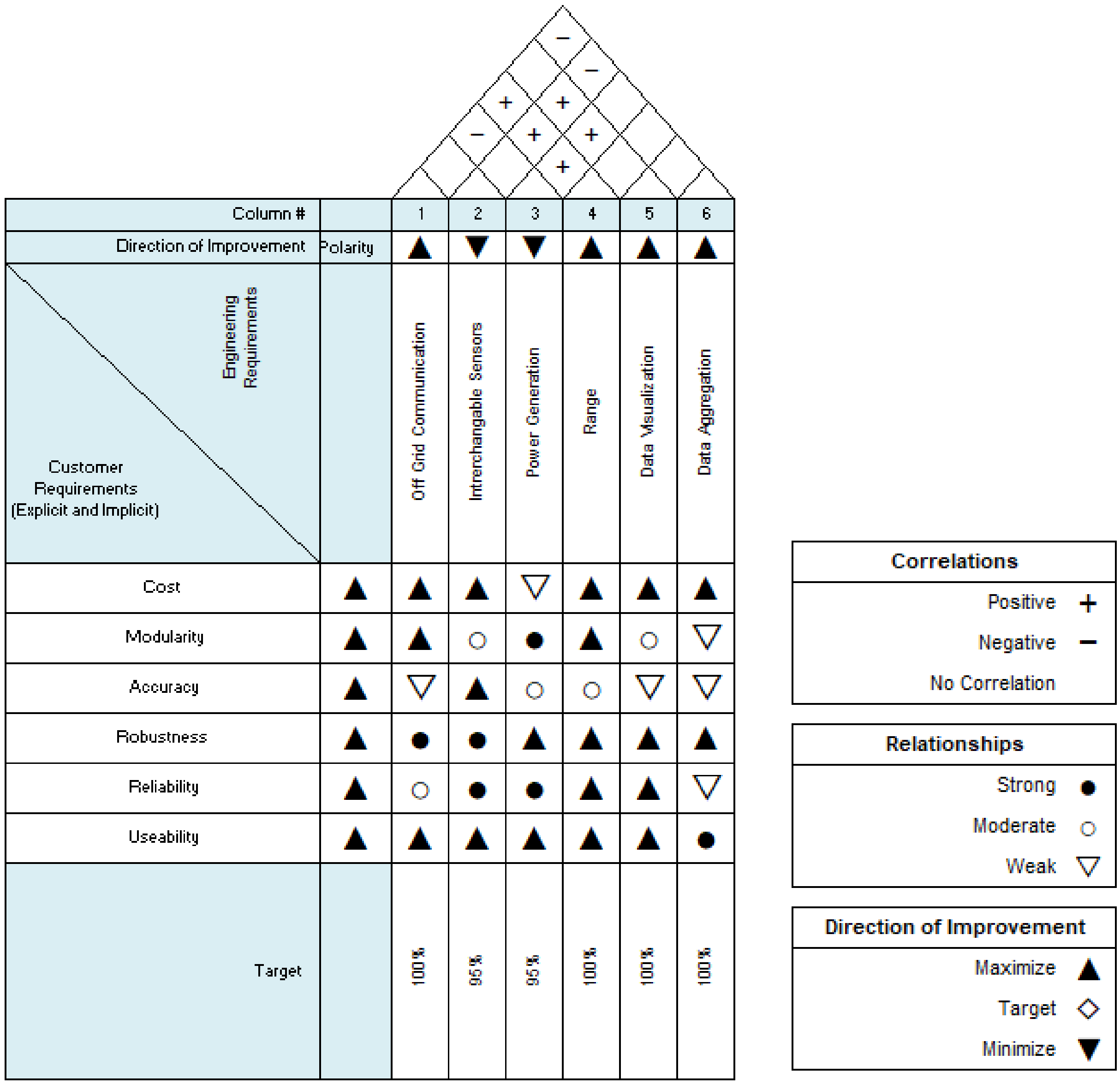
2.1 – Table 2.1: Hardware Requirement Specifications

Requirement ID	Specification	Value
001	Range	400 Meters Minimum
002	Visual Camera	2MP Sensor SPI Interface
003	Infrared Camera	2MP Sensor SPI Interface
004	Power Reserve	3 Days on a Fully Charged Battery
005	Charging	3 Watt Minimum PV Panel – Wall charging option
006	Physical Dimensions	6in x 6in
007	Wind Speed and Direction	+- 5% Accuracy
008	Humidity Sensor	Accuracy +- 3%
009	Temperature Sensor	Accuracy +- 0.5C
010	Barometer	Accuracy: +-5kpa
011	TVOC Sensor	Detects 1000ppm change in TVOCs
012	Carbon Monoxide Sensor	Detects 1000ppm change in CO
013	GPS Module	15m Radial Accuracy
014	Soil Moisture Sensor	Detects 1 Drop of Conductive Liquid
015	Rain Level Sensor	0.2794mm per step

2.2 – Table 2.2: Software Requirement Specifications

Requirement ID	Specification	Description
016	Application	Web application to display real time and historical data – Send alerts to designated users
017	Map View	Show each node on a map with the status of the node
018	Map Overlay	Display a gradient on the map representing the environmental conditions such as temperature
019	Off-Grid Network	Network for communicating to and from the nodes without relying on established networks such as cellular
020	Database	Store a minimum of 5 years of sensor data
021	Number of Nodes	200

2.3 – Diagram 2.3: House of Quality



Our house of quality diagram (Diagram 2.3) shows our inclination to maximize the value to our customer while minimizing the cost. One of the ways we intend to accomplish this is by using off the shelf parts and making our designs available open-source.

3.0 – Prototype Diagrams

3.1 – Diagram 3.1: Node Hardware Block Diagram

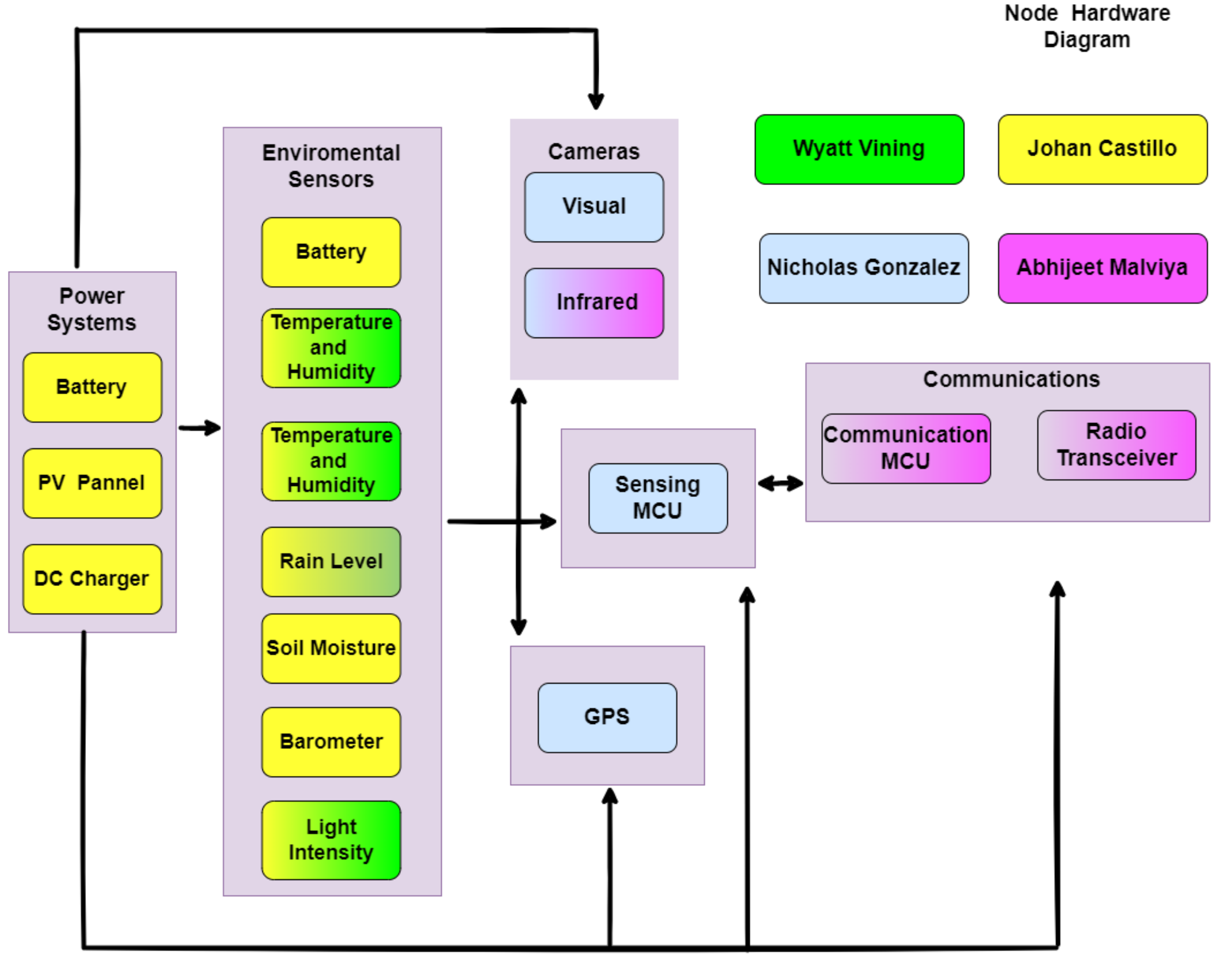


Diagram 3.1 outlines the core systems of a node in the network. These nodes are responsible for capturing and relaying sensor data.

3.2 – Diagram 3.2: Control Node Hardware Block Diagram

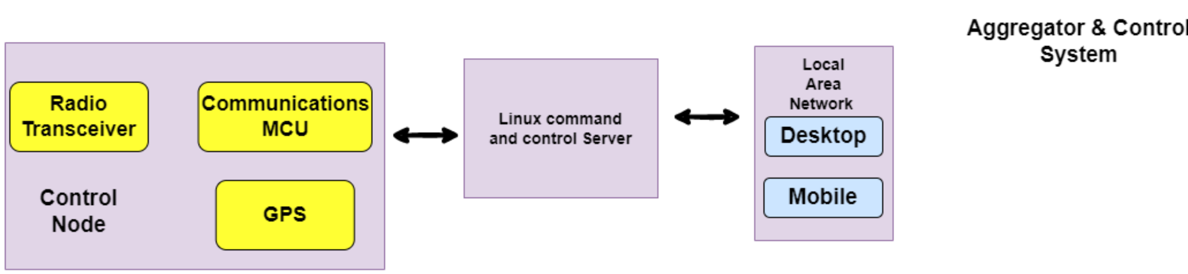


Diagram 3.2 also describes a node in the network. This is a special node responsible for receiving the data from the wider network and send commands out to all nodes on the network.

3.3 – Diagram 3.3: Mesh Network Topology

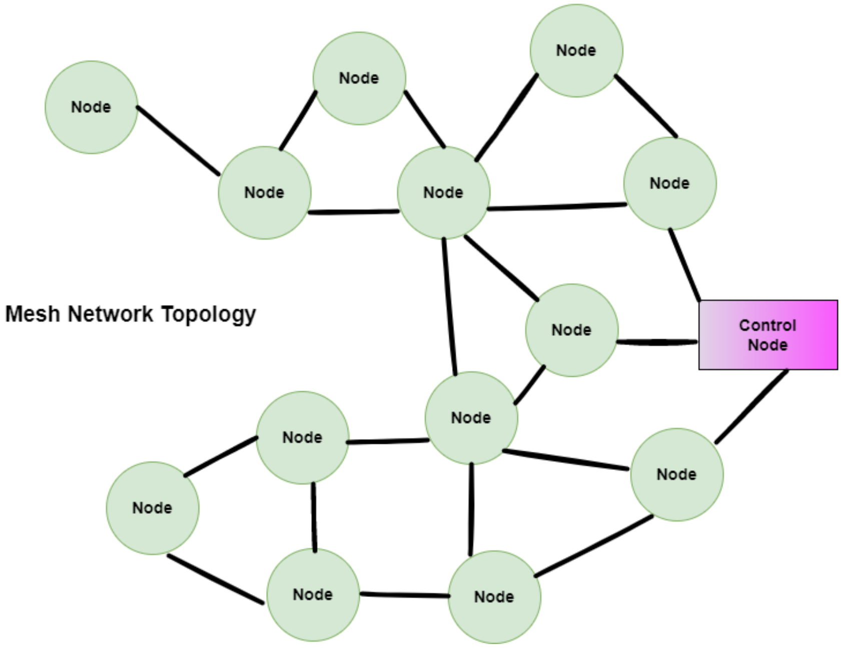


Diagram 3.3 describes the network topology. All nodes in the mesh communicate to one another with each having a unique address. The control node listens for data to pass to the aggregator.

3.4 – Diagram 3.4: Command and Control System Block Diagram

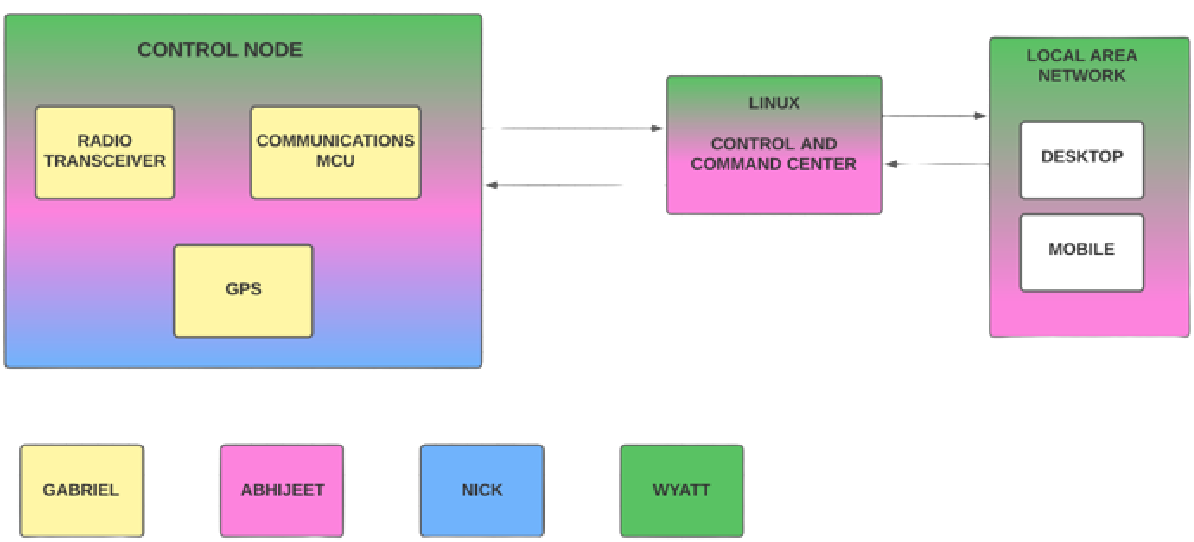


Diagram 3.4 shows the connection between the control node and the server. The server collects the data and passes commands for the network to the control node when needed. The server is also responsible for hosting the user interface.

3.5 – Diagram 3.5: Linux Web Server Block Diagram

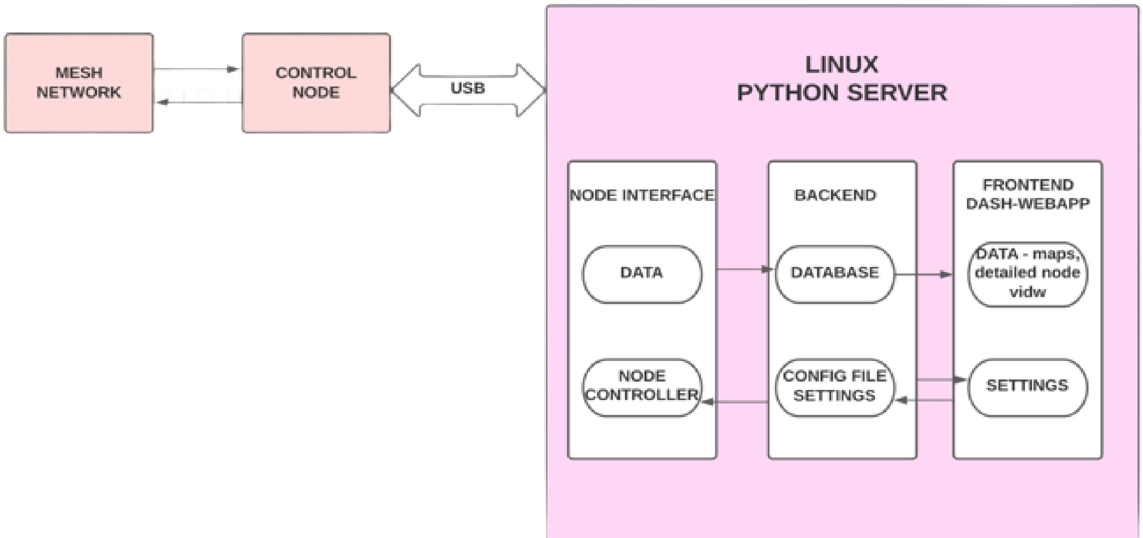


Diagram 3.5 shows the layout of the user side software stack. This includes the data intake and storage from the sensor network. As well as, the hosted frontend web application the user will interact with.

3.6 – Diagram 3.6: Prototype Exterior Diagram

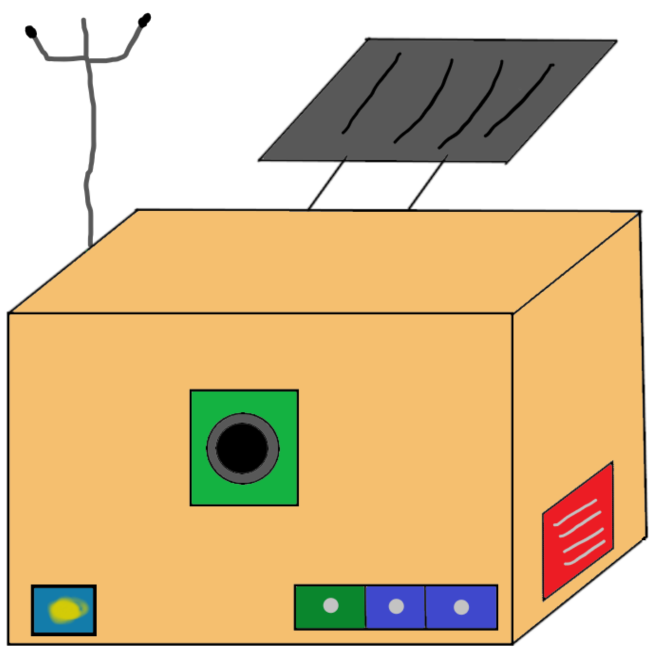


Diagram 3.6 shows a concept of the sensor node itself. The solar panel, and antenna are visible at the top of the node. Then in the green square, the camera. Finally along the skirt of the device, we see the connections for any external sensors or vents.

4.0 – Finances and Budget

The budget and the items that we plan to use for our project and the estimated price are shown here on Table 4.1 - Cost Estimate. We plan to have a budget of around $400-500. According to the table, the estimated total price would be $260.67, which satisfies the budget of $400-500. However, the estimated price might change because we might plan to buy more materials and the prices might be different. We probably expect the total estimated price of all the items to be higher, most likely around $400 due to the vendors and because the shipping price of some products depending the area might be more expensive.

Table 4.1: Cost Estimate

Item	Node Quanitity	Cost per Node	Cost for # Nodes
Camera	3	$25	$75
Photovoltaic Cell	3	$17	$51
Ultrasonic anemometer	1	$93	$93
Temperature and humidity sensor	2	$20	$40
Pressure temperature altitude sensor	1	$8	$8
TVOC	1	$12	$12
CO sensor	1	$8	$8
GPS module	1	$7	$7
Soil moisture sensor	1	$7	$7
Rain Level Sensor	5	$6	$30
RP2040	1	$5	$5
ESP32	1	$4	$4
PCB	5	$2	$10
3V-5V Regulator	1	$2	$2
Total		$216	$352

5.0 – Project Milestones

Table 5.1: Project Milestones

Senior Design Timeline	
Senior Design 1	
Date	**Details**
1/10/22	Project Brainstorming, and forming ideas with Computer Engineering group
1/11/22	Group formed
1/12/22	Decided project idea
2/3/22	Divide & conquer v1.0. Complete the D&C
2/4/22	Divide & conquer v1.0. Complete the D&C. Submit the completed D&C
2/9/22	Discuss the D&C with Dr. Richie
2/17/22	Updated Divide & Conquer Draft ready
2/18/22	Divide & Conquer v2.0 Due
2/21/22	Order parts for basic prototype
3/1/22	Assemble and test basic prototype
3/11/22	New Assignment on Standards
3/22/22	60-page draft final draft
3/25/22	**60 Page Paper due**
4/7/22	100 Page Paper final draft
4/8/22	**100 Page Report submission**
4/23/22	Final Documents draft
4/26/22	**Final Documents due**
4/29/22	Start assessing parts and order
Senior Design 2	
5/16/22	Classes begin
5/17/22	Plan May goals - Build and test components
6/20/22	June - Execute project and test software components
7/25/22	July – Finalized Prototype & Documentation
7/28/22	**Final presentations**
8/5/22	**Final day of class and submit document**

6.0 – References

"Wildfire Statistics - Federation of American Scientists." Federation of American Scientists, Federation of American Scientists, 4 Oct. 2021, https://sgp.fas.org/crs/misc/IF10244.pdf

"Chimney Tops 2 Fire." National Parks Service, U.S. Department of the Interior, https://www.nps.gov/grsm/learn/chimney-tops-2-fire.htm

"Gaining an Understanding of the National Fire Danger Rating System" National Wildfire Coordinating Group, https://www.nwcg.gov/sites/default/files/products/pms932.pdf