Project: Gotcha!

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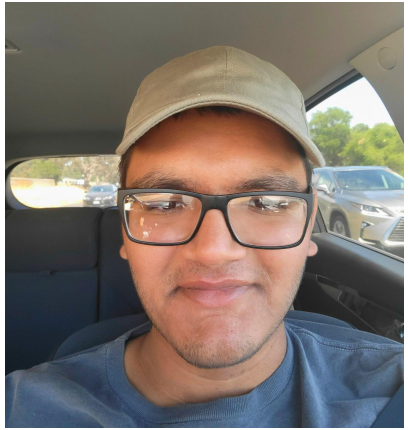
Advisor: Yadi Eslami

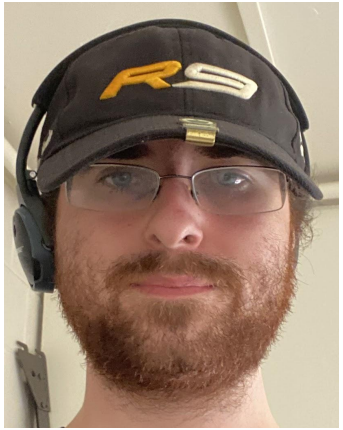
Team 14

Jackson Wallace (EE)



Tirth Patel (EE)

Hakan Saplakoglu (EE)



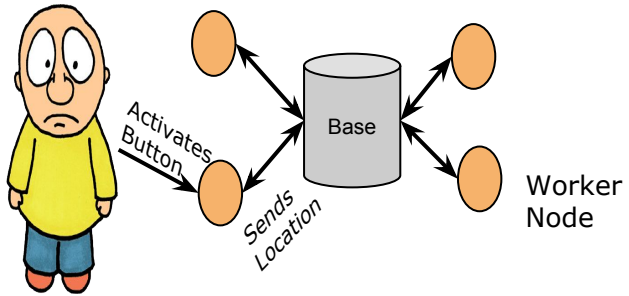
Joseph Mitchell (CompE)

Updated Problem Statement

Natural disasters are an annual occurrence that cause people to lose their homes and loved ones. Even when a person survives a disaster they can go missing or get injured, which may lead to them not getting the help they need right away if communication networks are down. An example of this occurred with Hurricane Michael in 2018, where many people were in need of rescue, but the communication networks being down resulted in massive delays.

Our Solution

- Low-power worker nodes and base nodes connected through a mesh network.
- Each worker node will have a GPS module which would be manually activated by a person seeking rescue, and using LoRa a packet containing GPS coordinates of the worker node is sent through and goes to the base station.
- A frontend on the base station (web server for local use) for first responders to locate nodes after location is reported
  - Mapping API with overlays of mesh network nodes
- The worker node is able to be deployed before or after a disaster occurs.



System Specifications

General Specifications for Each Node

1. Can communicate with any worker node or base node in range
   a. Act as a relay host for other network traffic
   b. Be able to differentiate individual nodes in the network
   c. At least 1 km range in urban environment
2. Can identify the best neighbor node to propagate signal to (acting as relay host in mesh)
3. Can locate itself using the GPS module
   a. Within 10m
   b. Within 60 seconds

System Specifications

Worker Node

1. Less than 4” on the larger side
2. Able to survive a fall at terminal velocity
3. Water resistant and can float on water
4. Battery capacity: At least 3 days of runtime in relay mode, 6 hours in active mode
5. LED for signalling to user
6. Button used to activate the device

Base Station

7. Less than 6” on the larger side
8. Serve a web server to act as a front-end for first responders
9. Rechargeable Battery with enough capacity for 2 hours disconnected runtime
10. Can display worker node information (location) with no connection to the internet

Network Configuration

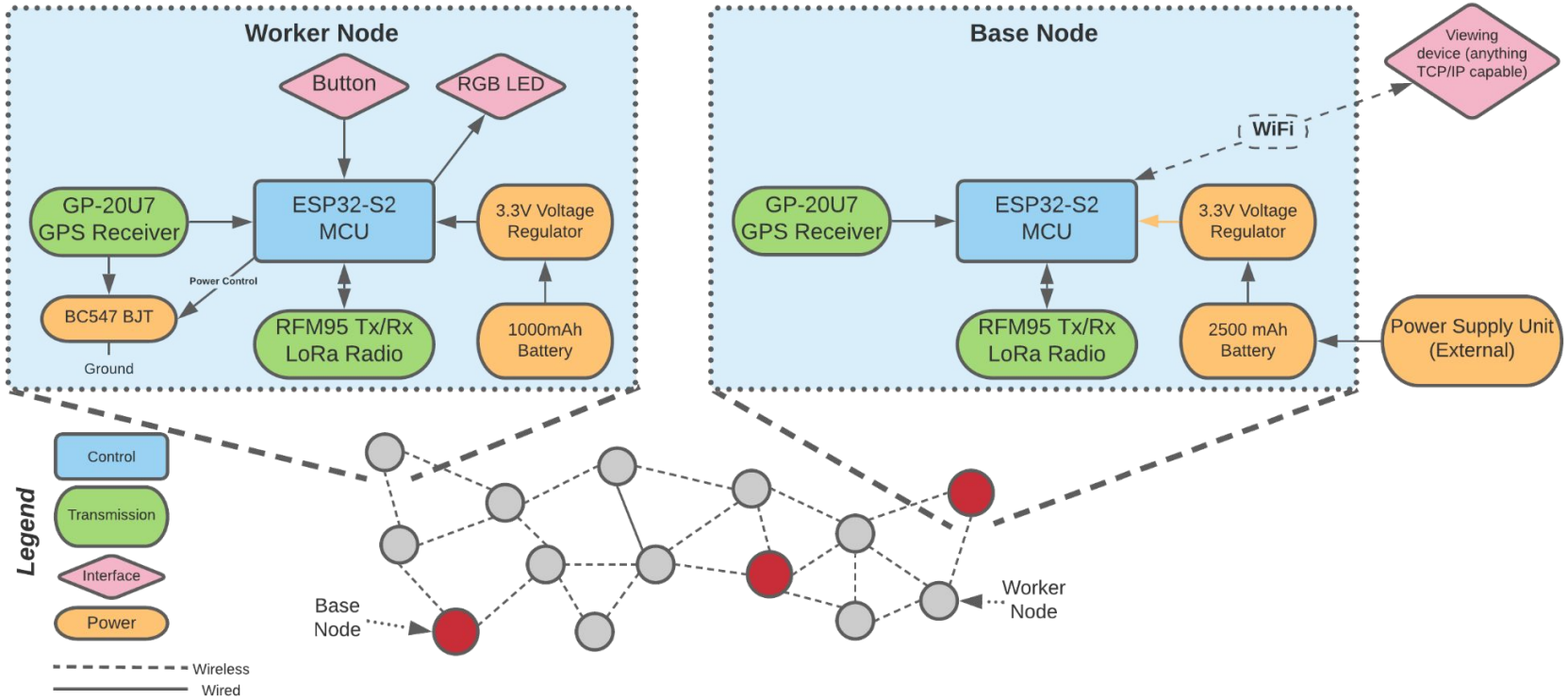
- Set Parameters
  - 915 MHz Frequency Band
- Variable Parameters (subject to change)
  - +17dB Transmission Power (ranges from +2dB to +20dB,)
  - 62.5 kHz Bandwidth (lower BW increases range, decreases data rate)
  - Spreading Factor of 9 (ranges from 6-12, each increase doubles transmission duration, but increases sensitivity and range)
  - Coding Rate of [4:5] (ranges from 4:5 to 4:8, increasing coding rate increases error protection, but increases power usage and transmission time)
  - Data Rate of about 879 bits/s, determined using equation above:

$$R_b = SF * \frac{\left[\frac{4}{4+CR}\right]}{\left[\frac{2^{SF}}{BW}\right]} * 1000$$

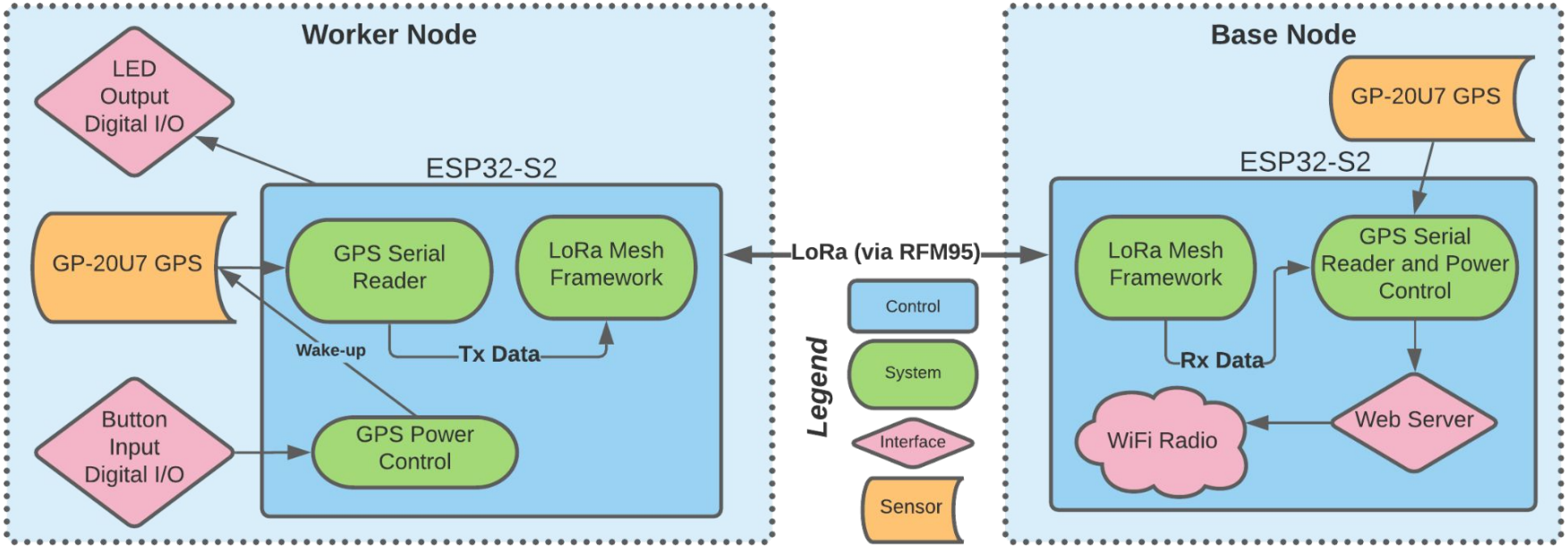
Power Consumption Estimates

- Worker Nodes have 2 modes
  - Active
    - GPS is on and receiving location (~99 mW)
    - LoRa radio is in Rx and Tx mode (Tx = 287 mW, Rx = 40 mW)
    - LED is blinking at 4 Hz (13.2 mW)
    - ESP32 at 80 mHz (39.6 mW)
    - Power
      - At 879 bits/s, 1024 bit packet, 1.16s in Tx mode
      - Send packet every 30 seconds
      - 1000 mAh, 16.4 hours runtime
  - Relay
    - GPS is off (0 mW)
    - LoRa is in Rx mode and switches to Tx if needed for relay (40 mW)
    - LED is blinking at 1 Hz (3.3 mW)
    - 1000 mAh battery, 76 hours runtime (3.18 days)

Hardware Block Diagram



Software Block Diagram



Hardware and Software Used

Current Hardware

- GP-20U7 GPS Modules
- RFM95W LoRa Transceiver
- Arduino Uno
- BJTs
- Pushbuttons
- LED

Future Hardware

- ESP32-S2-Saola-1
- 3D Printing Parts
- PCB
  - Worker Node
  - Base Node
- Speaker (possibly not needed)
- Rechargeable Battery

Current Software

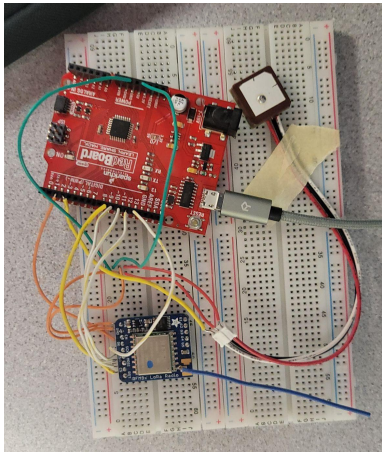
- Arduino IDE
- Arduino Libraries
  - LoRa
  - TinyGPS++

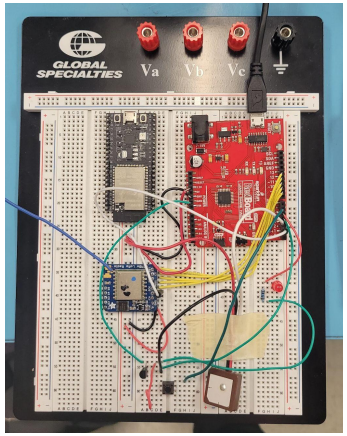
Future Software

- VSCode
  - Mesh Network
  - Website
- C/C++ Libraries
- Altium PCB Design
- MPLAB X IDE

MDR Deliverables Proposed/Accomplished

- 1 base station node ✔
- At least 2x worker nodes ✔
- Constructed using off-the-shelf modules, prototyping boards ✔
- Communication of at least 2 worker nodes with 1 base station ✔
- Rudimentary front-end which will print coordinates of activated nodes ✔
- Associated shortest path algorithm (Revisited)





Custom Hardware Design

- Extract the microprocessor from the ESP32 development board and solder it on a custom PCB.
- 2 PCBs
  - Worker Board
  - Base Board
- PCBs should have
  - ESP32 Microprocessor
  - GPS module, with shielding due to low power
  - LoRa RFM95 915MHz Tx/Rx
  - Antenna Shaped to Housing
  - Transistor (Worker, for power control)
  - Other small components

CDR Deliverables

- **Hardware**
  - 1 base station node
  - 3 worker nodes
  - Custom PCB hardware described previously with ESP32-S2 as the MCU
  - All devices use onboard battery
- **Software**
  - GPS Receiver Code
  - LoRa Mesh project
  - Offline web server with coordinates received from worker nodes on a map
- **Demonstration**
  - Worker node is activated
  - Front-end receives coordinates over at least 1 relay and show worker location

Testing Plan

1. Ensure that a signal from a worker node at least 1 km away is received at a base station (demo)
2. Measure how long it takes for gps to get an accurate reading at various times of day and weather conditions, readings should take less than 60 seconds (test)
3. Compare various gps coordinate readings to that of a phone or other computer to determine accuracy, which should be within at least a 10 meter radius of the device's true location (test)
4. Measure how long it takes for a signal to reach a base node after activation of a worker node (test)
5. Use the completed worker node until battery death to determine lifetime of nodes and compare results to projected battery life of 3 days (test)
6. Ensure that a mesh network is established by sending and receiving data from the 3 worker nodes and the base station (demo)

(Mesh network: establish a local network with multiple worker nodes and a base station that talk to each other and is able to relay information from a worker node with their associated GPS coordinates to the base station and display it to the website)

Project Expenditures

Components	Total Units Needed	Price/Unit	Units Bought	Cost Spent
ESP32 Microprocessor	4	$14.50	3	$43.50
GP20U7 GPS Receiver	4	$17.95	3	$53.85
LoRa RFM95W	4	$19.95	3	$59.85
500 mAh Battery	6	$7.95	3	$23.85
2500 mAh Battery	1	$14.95	0	$0
3D Printed Housing	5	$0 (available in M5)	0	$0
PCBs (At least 2 Revisions)	5	$200 (total)	0	$0
Shipping	-	-	-	$34.03
Total System	-	**$491.78**		**$215.08**

Member Responsibilities

Hakan Saplakoglu

- MCU Programming, Mesh Network, Network Comms

Joseph Mitchell

- MCU Programming, Web Development, Network Comms

Tirth Patel

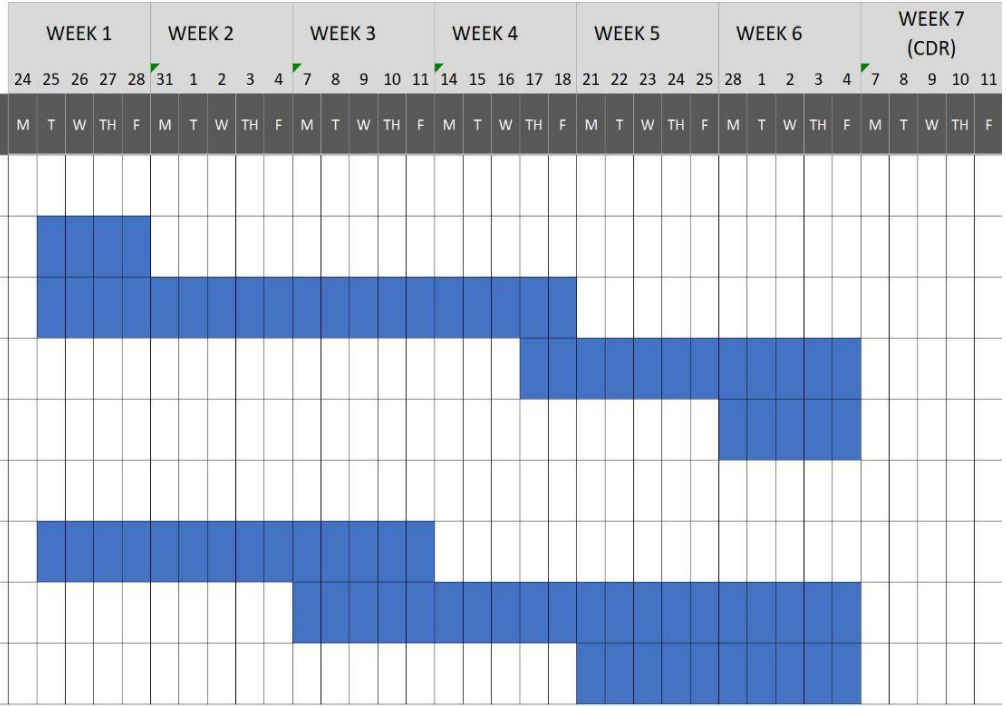
- PCB Design and Routing, Power/Battery Management, MCU Programming, Budget Manager

Jackson Wallace

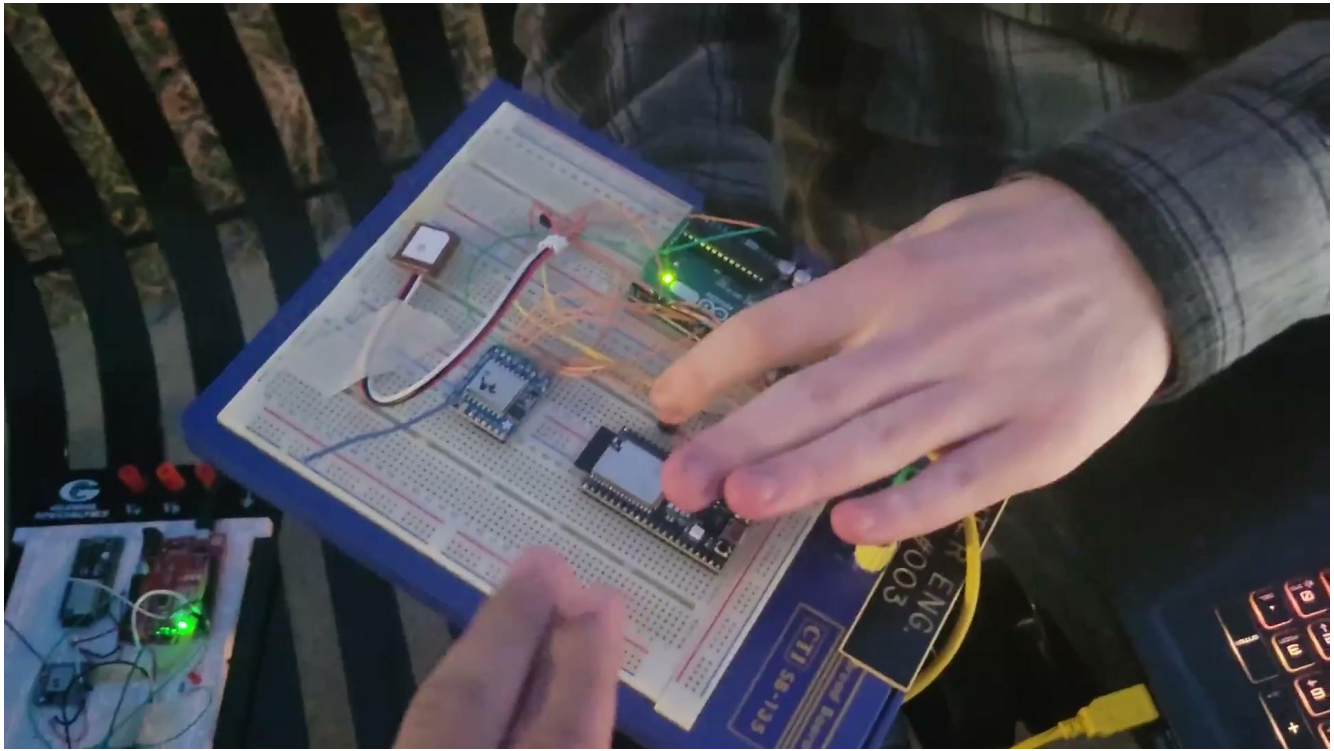
- Team Coordinator, PCB Design, Power/Battery Management, 3D Housing Design

Gantt Chart

TASK	ASSIGNED TO	START	END
Worker and Base Nodes			
ESP32 Integration	HS, TP	1/25/22	2/9/22
PCB Design and Ordering	TP, JW	1/25/22	2/11/22
Battery/Power Optimization	TP, JW	2/10/22	2/25/22
3D Printing Prototype Case	ALL	2/28/22	3/4/22
Software			
Mesh Network Implementation	JM, HS	1/25/22	2/11/22
Offline Map API + Webserver Integration	JM, HS, TP	2/7/22	3/4/22
WiFi/USB Webserver Access	JM, HS	2/21/22	3/4/22



Demo



Questions? Comments? Concerns?