M.N.S.L.A.C

Mesh Networks for Simultaneous Localization and Communication

Team 1961C
Kevin Abraham
Yassine Bennani
Sai Molugoori
Keenan Nicholson
Norris Nicholson

Project Overview

- Design a cost-effective waterproof technological system to replace GPS modules for real time tracking of sailboats during regattas for audiences at shore.
- Mesh network of radios that utilize distance measurement and triangulation algorithm techniques to convey locations to base stations.
- Cost of entire system was approximately $500.

Overall Design Objectives

- Securely attach nodes consisting of electronics to the top of the mast
- Continuously receive packets from all active nodes
- Use incoming node data to display real time location of boats on web app and base station interface

Key Design Specifications

Radio Systems

Project Element	Category	Specifications
Radio Systems	Localization	Accuracy of 7 feet or better
		Measurements every 3 seconds
	Communications	Range not less than 300 feet
		Adequate data transfer rate
		Must be able to relay messages to other nodes as needed
	Network	Operates with 1 to 12 nodes
		Operates with as little as 1 base station + extender

Key Design Specifications

Base Station

Project Element	Category	Specifications
Base Station	Enclosure	No larger than 10”x6”x6”, no heavier than 5 lbs
		Must be mountable to a tripod
	Antenna	Securely mounted to the enclosure (inside or out)
	Power	Must be powerable from AC power or an internal battery
		Internal battery must last 6 hours and charge in 8 hours
	Interface	Must host a Wi-Fi network for displaying node locations
		Must include settings relevant to system operation

Key Design Specifications

Base Station Extender

Project Element	Category	Specifications
Base Station Extender	Enclosure	No larger than 8”x5”x5”, no heavier than 3 lbs
		Must be mountable to a tripod
	Antenna	Securely mounted to the enclosure (inside or out)
	Power	Must be powerable from AC power or an internal battery
		Internal battery must last 6 hours and charge in 8 hours
	Interface	Have internal buttons/indicators as needed for operation
		Be controllable from the base station

Key Design Specifications
Node

Project Element	Category	Specifications
Node	Enclosure	No larger than 8”x5”x5”, no heavier than 3 lbs
		Water resistant to a depth of 25 feet for up to 5 minutes
	Antenna	Securely mounted to the enclosure (inside or out)
	Power	Run for up to 4 hours and charge in less than 6 hours
		Withstand temperatures between 40 °F and 130 °F
	Interface	Have internal buttons/indicators as needed for operation
		Be controllable from the base station

Design Approach and Details

Power Supply

18650 Battery
(node)

- Thermal and volumetric efficiency
- Higher charge cycle count (~1800)
- Cheaper

Portable Battery Pack
(base)

Antennas

Omni-directional
(node)

- Loop or Dipole

Directional Antenna
(base)

- End-fire or Yagi-Uda

Testing phase

- DWM1000 module integrated antenna

Radio Transceiver

DW1000

- Onboard ToF hardware
- Supports communication between modules

Testing phase

- DWM1000 modules (integrated antenna) with pins broken out to a breadboard

Final Development

- Custom PCB integrating DW1000, RF electronics, external antenna connection

Microcontrollers

AVR vs. ARM vs. Xtensa RISC

- Library compatibility
- Processing speed
- Power consumption

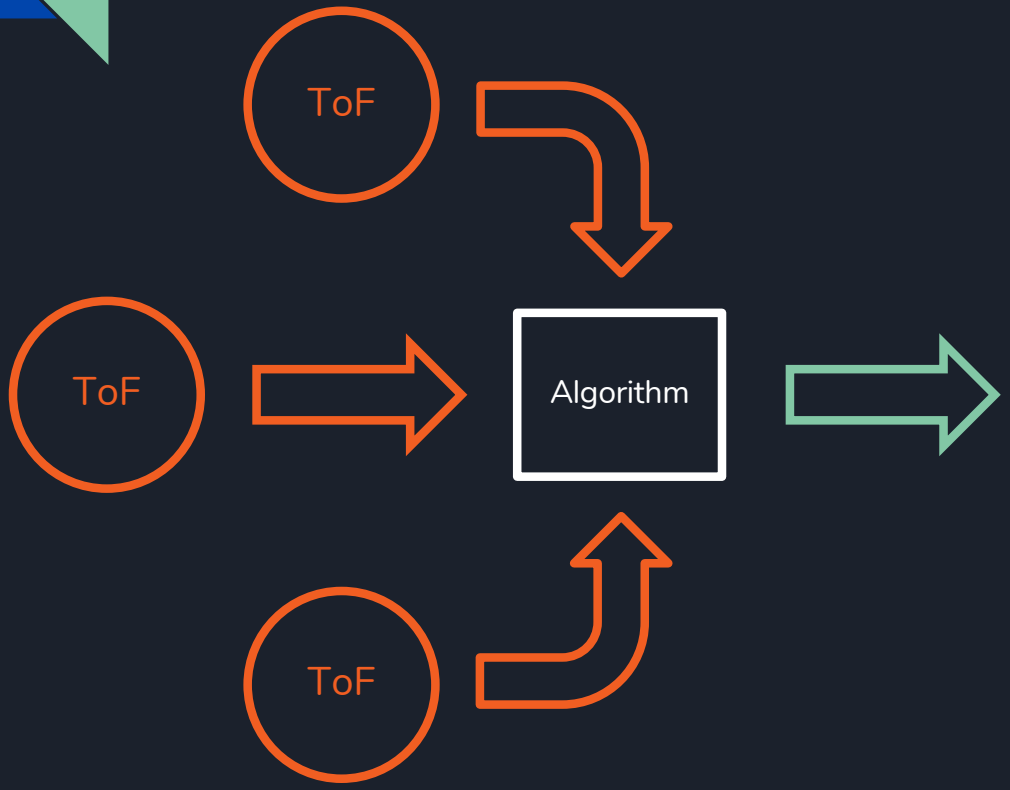
Final Design Considerations

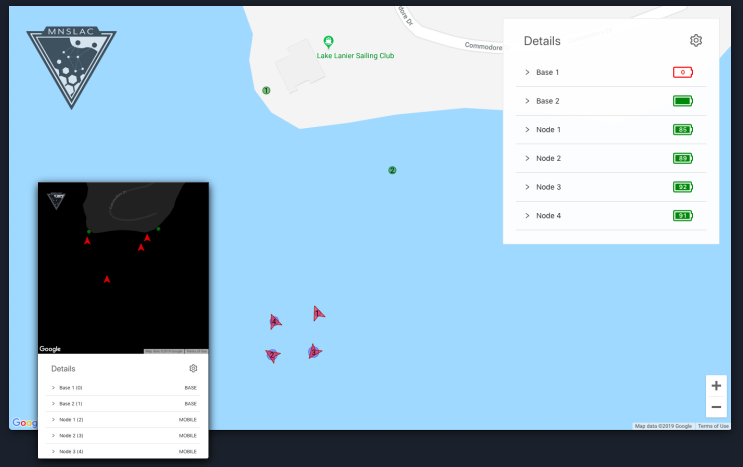
- AVR and ARM-based microcontrollers can be integrated into the PCB
- Modules from Espressif would be soldered to the PCB as is

Product Design

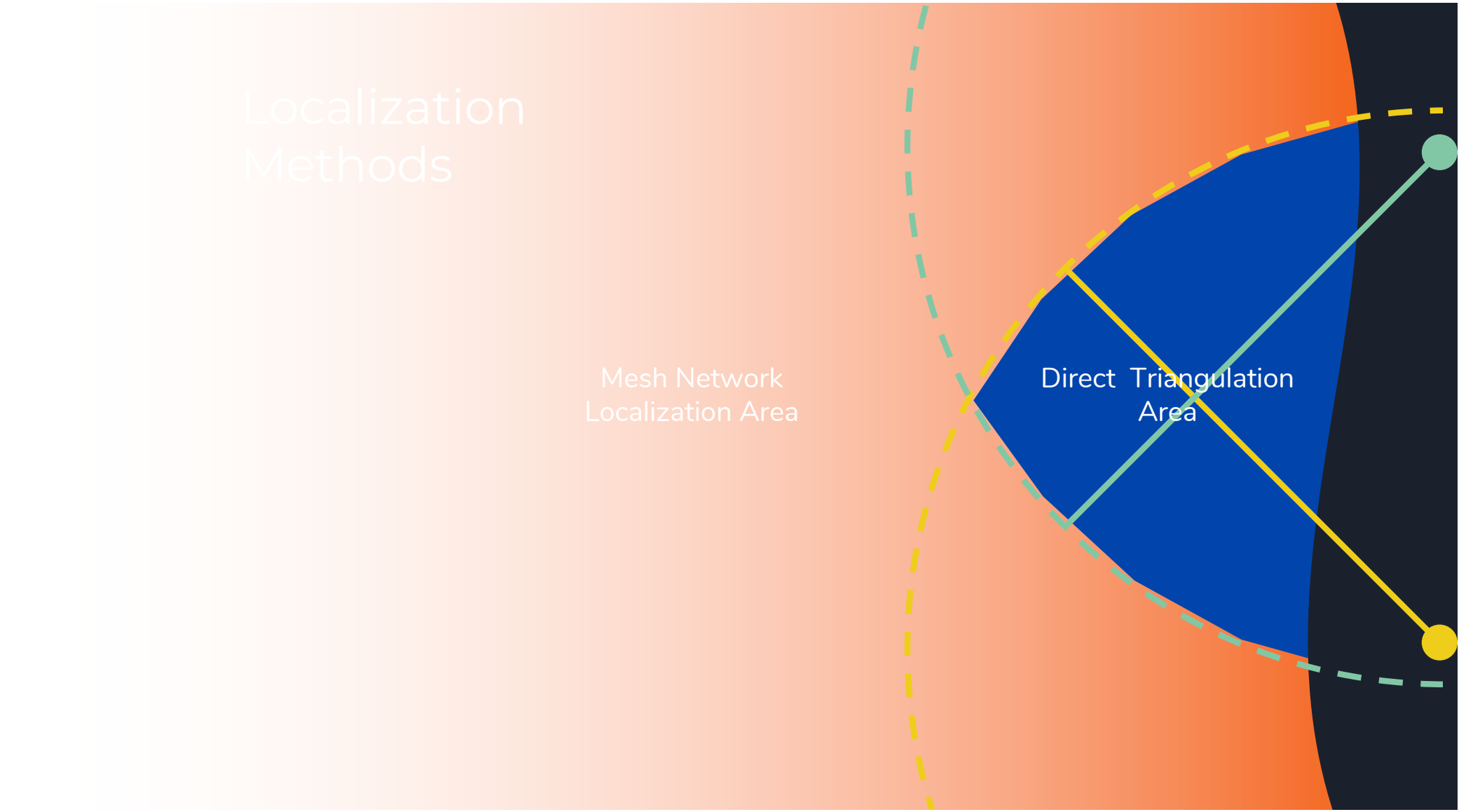
- Custom designed PCB board with microcontroller and DWM1000 radio module along with required components such as external crystal, resistors, capacitors, and diodes.
- Waterproof cases to hold PCB boards, battery powering electronics, and radio to receive and send signals.
- Base station to receive/process data and display to audience watching the regatta.
- Algorithm to use known locations of nodes to find location of nodes not in the range of two base stations.

Algorithm

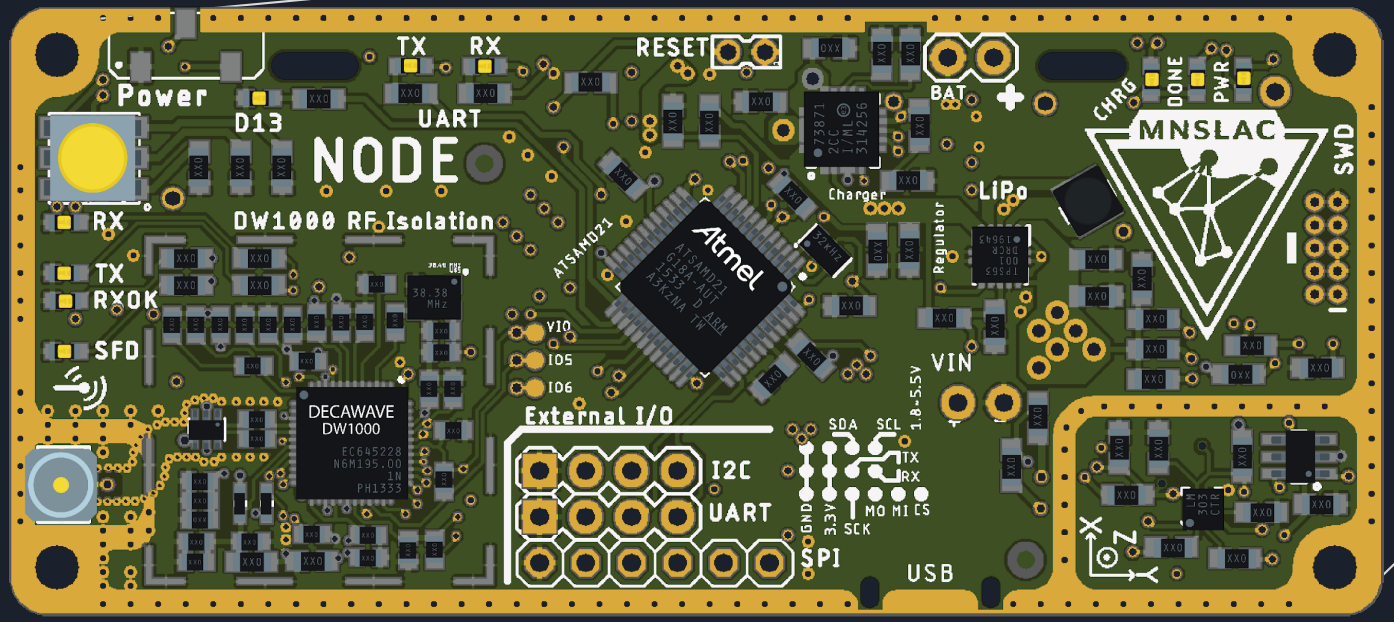

ToF
ToF
Algorithm
ToF

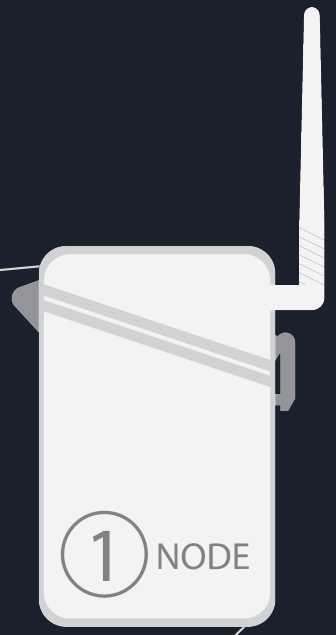

MNSLAC
Lake Lanier Sailing Club
Commodore
Details
Base 1
Base 2
Node 1
Node 2
Node 3
Node 4
Google
Details

Localization Methods

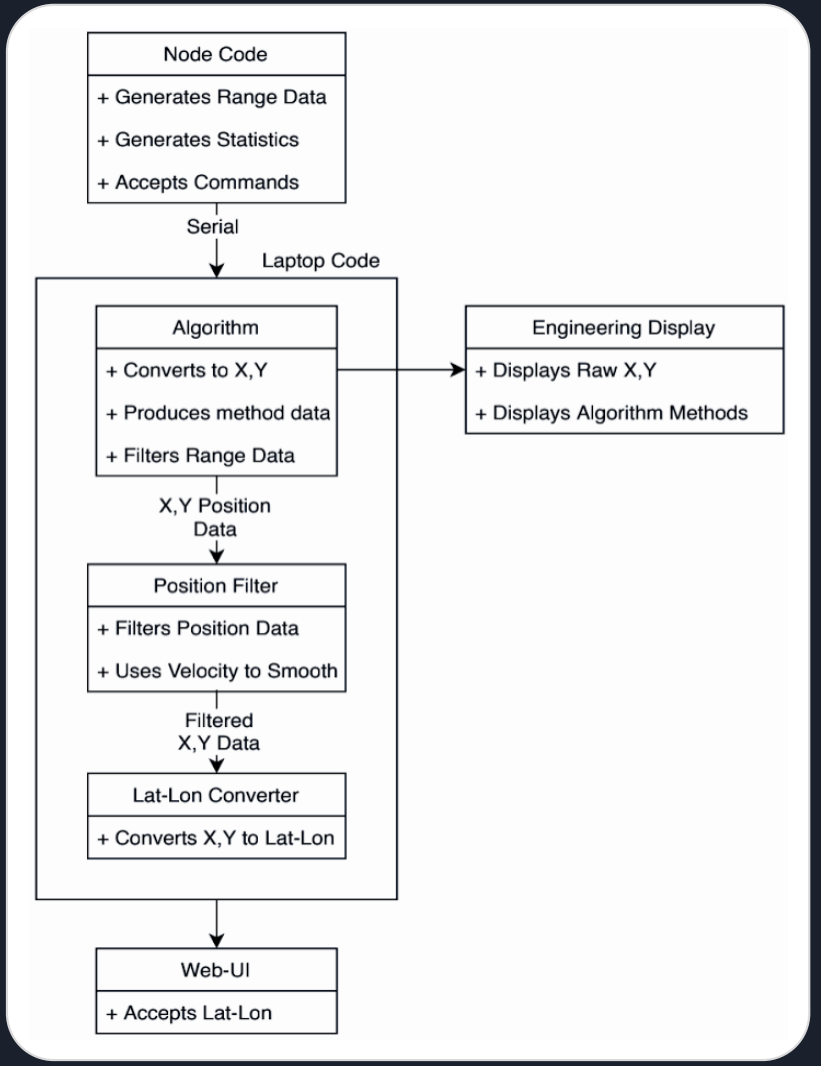


PCB Design


TX
RX
RESET
Power
D13
UART
NODE
BAT
CHRG
DONE
PWR
MNSLAC
SWD
RX
DW1000 RF Isolation
Charger
LiPo
Regulator
TX
RXOK
SFD
ATSAMD21
Atmel
VIO
IO5
IO6
VIN
1.8-5.5V
DECAWAVE
DW1000
External I/O
SDA
SCL
TX
RX
I2C
UART
SPI
GND
3.3V
SCK
MO
MI
CS
USB


1
NODE

System Code Overview



Project Demonstration

Georgia Tech Sailing Club at Lake Lanier

- Nodes were placed on C420 sailboats
- One base station was placed on shore while the extender pair was on the dock (red dots)
- Sailboats were out on the Lake cruising

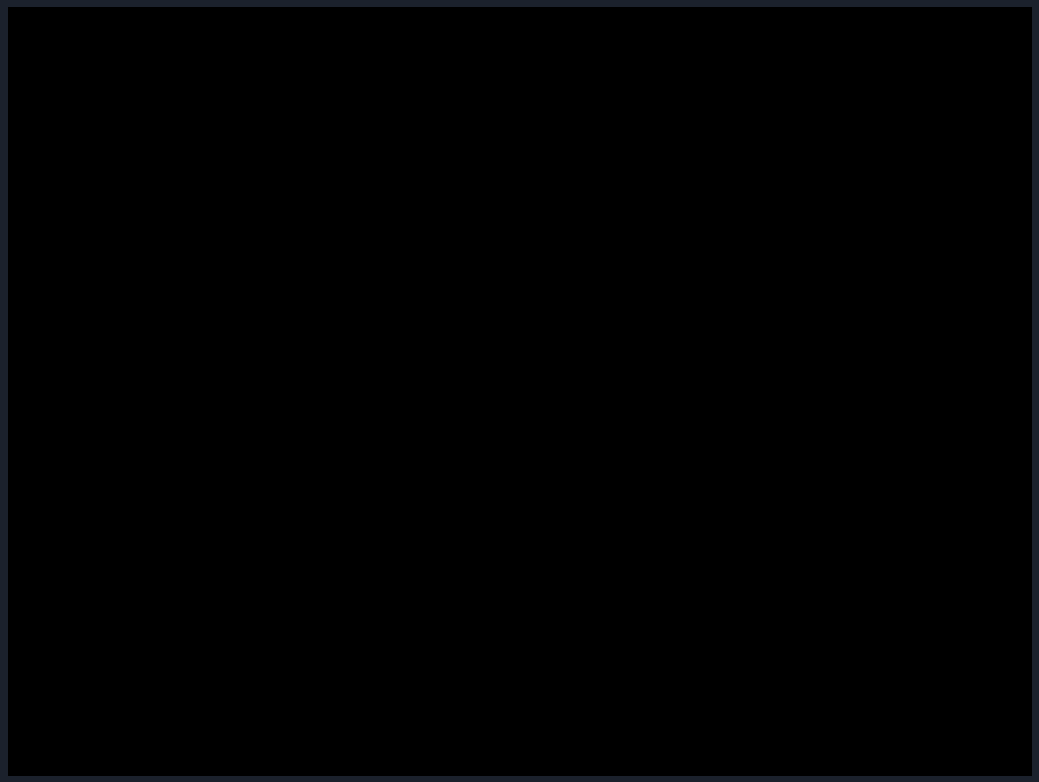
Testing Parameters

- Both base stations must be communicating with each other
- Node must be seen by both base stations before venturing off
- Minimum number of packets should be received for connection to be considered successful

Results

Minimum Range	~ 5 meters
Maximum Range	~ 300 meters
Refresh Rate	1.5 Hz
Avg. number of packets per cycle	30
Waterproof	Successful

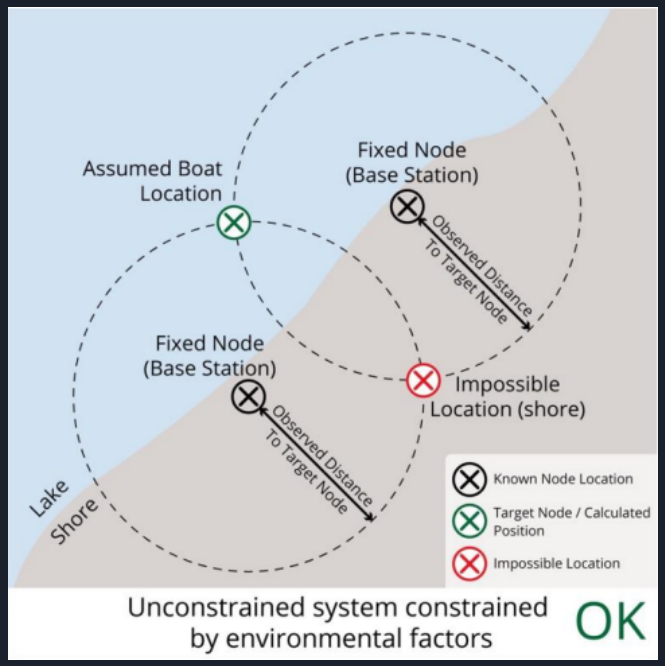
Results - Meshing Algorithm

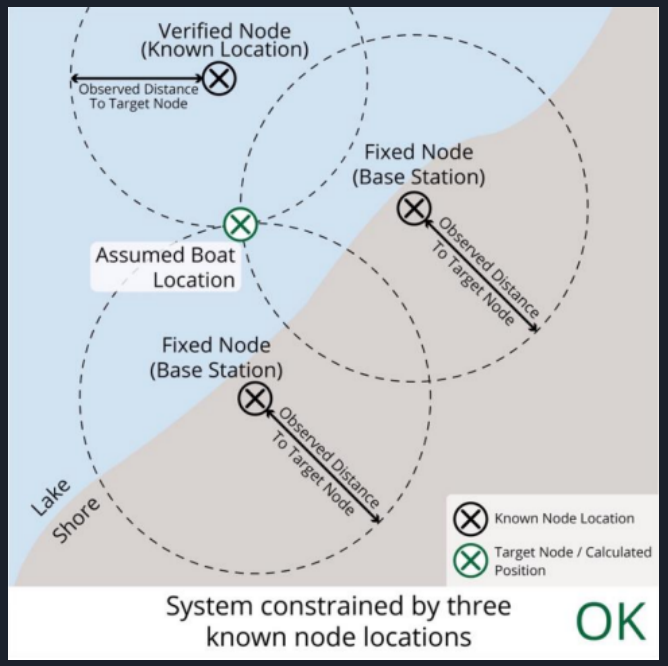


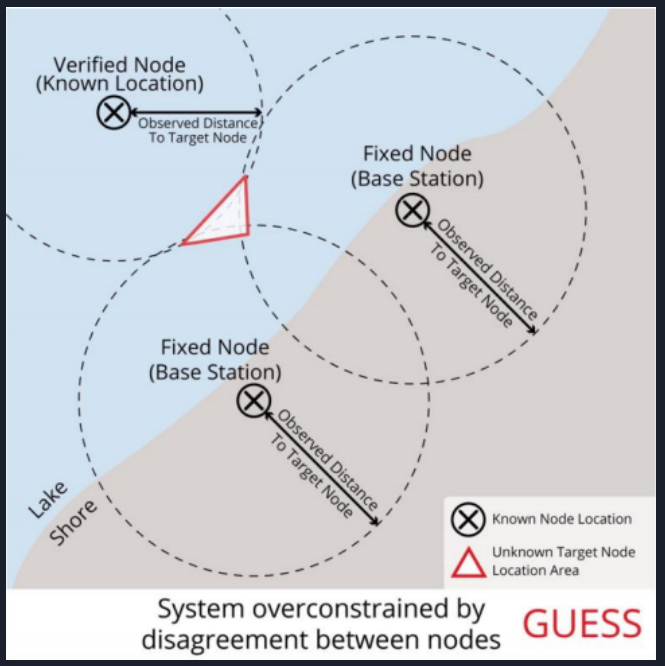
Project Challenges

- Antenna that operated at desired frequency
- Soldering all components on PCB board
- Node message timing and synchronization
- Packets queuing due to running multiple threads on main
- Reliable and accurate meshing algorithm

Challenge - Overconstrained Localization







Schedule, Tasks, and Milestones

Activity	Assigned to	January				Febuary				March				April				
		7	14	21	28	4	11	18	25	4	11	18	25	1	8	15	22	29
Oral Proposal Presentation	Team																	
Revised Proposal	Team																	
Revised PSF to Advisor	Team																	
Define PCB requirements	Norris, Keenan																	
Design initial hardware (PCBs, enclosures, mounts)	Kevin, Yassine																	
Test enclosed units for shock/water resistance	Sai, Keenan																	
Program MCUs for distance measurement, communication	Norris, Kevin																	
Conduct initial real-world tests (Lake Lanier)	Team																	
Revise hardware design (if necessary)	Sai, Kevin																	
Improve software based on feedback from tests	Yassine, Keenan, Norris																	
Conduct final real-world tests (Lake Lanier)	Team																	
Improve software (small changes, if necessary)	Team																	
Design Notebooks	Team																	
Final Presentation	Team																	
Capstone Design Expo	Team																	
Final Project Demonstration	Team																	
Final Project Report	Team																	
Final Project Summary	Team																	
Website	Team																	

Current Status

- Base stations can successfully receive packets from nodes and display on the web and mobile app.
- Time of flight calculations give accurate distance measurements with an error of few centimeters.
- Antennas are calibrated to decrease the amount of error
- Algorithm uses nodes to create mesh network and detect other nodes that base station cannot detect directly.

Next Steps

- Build more nodes and conduct tests on a larger scale.
- Buy better antennas to optimize the range of our network.
- Increase the overall efficiency of meshing algorithm.
- Sturdier mounting platform for both base stations.
- Obtain band licensing and increase transmit power

Questions?