Team 8: NeverLost

Mid-Year Design Review

December 3rd, 2021 - 4pm

Advisor: Professor Arbabi

Evaluators: Professor Burleson, Professor Pishro-Nik

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Meet the Team!

Shelby Anderson
Computer Engineering
Team Manager

Eric Anderson
Computer Engineering
Budget Lead
Software Lead

Louis Gencarelli
Computer Engineering
Embedded Systems Lead

Eric Sutherland
Electrical Engineering
PCB Lead

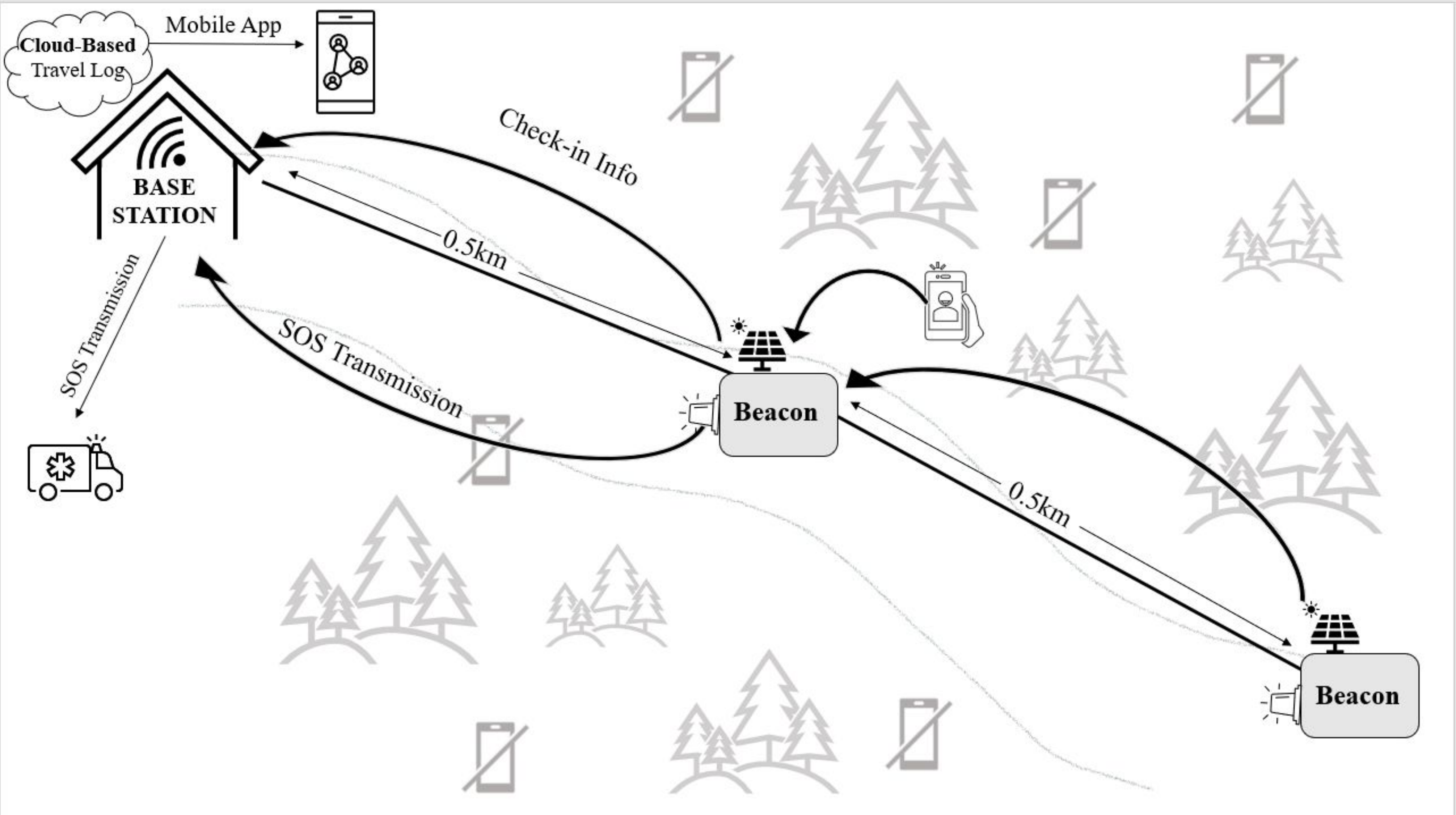
Problem Statement

When hiking through long trails such as the Appalachian trail, it is not uncommon for a hiker to become injured making it difficult to complete their journey. It is often difficult to gage a loved ones progress on these trails to confirm their location and that they are ok. In addition, many of these hikes are in remote areas with no cell service and no way of contacting emergency services or a loved one. If a hiker is injured, it might be days before anyone is aware.

Our NeverLost survival beacons will provide ***checkpoints along hiking trails*** *that would include a check-in system and ability for search and rescue teams to begin with* ***exact coordinates within minutes of their emergency.*** *Our beacons would be accessible to everyone, especially to injured hikers that may not be able to walk to the trailhead.*

Goals

- *Develop a dependable system that allows hikers to access emergency services.*
- *Devise a secure check-in system to track hikers progression. Viewable by friends and family*


Cloud-Based
Travel Log
Mobile App
BASE
STATION
Check-in Info
0.5km
SOS Transmission
SOS Transmission
Beacon
0.5km
Beacon

System Specifications

Beacon System

- Multi-hop linear network topology, **500m** Distance between beacons
- **300ms** avg propagation between beacons
- **97% transmission success rate** at 500m line of sight
  - **Reliable Data Transfer,** utilizing ACK
- SOS transmitted in *(1- number of beacons)(prop delay) + Server delay*
- 2.1 Second avg SMS Server Delay

Mobile Application

- Bi-directional communication
  - Bluetooth module + Mobile application
- Location updated via cloud computing when check-in received by base station

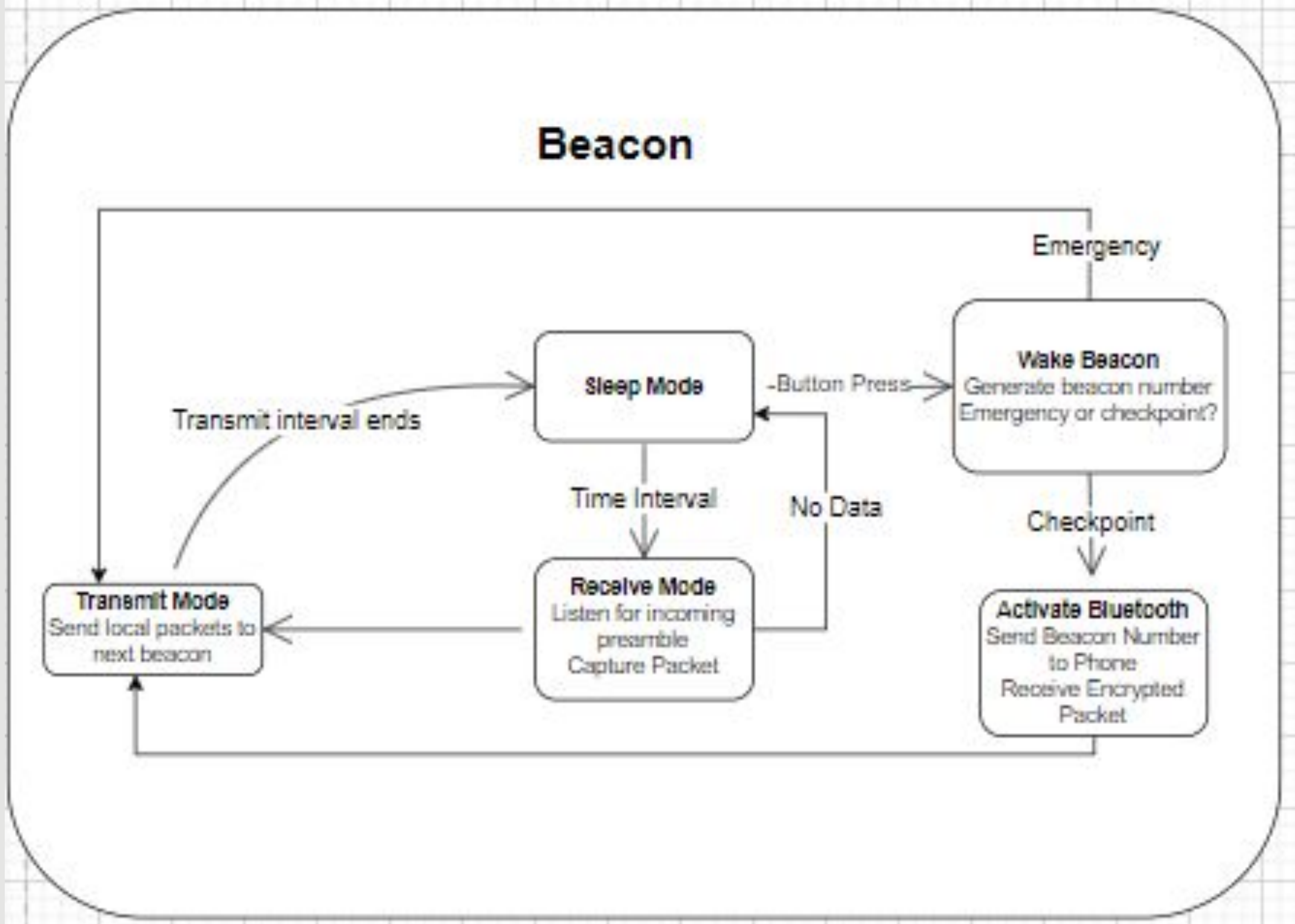
Power Systems

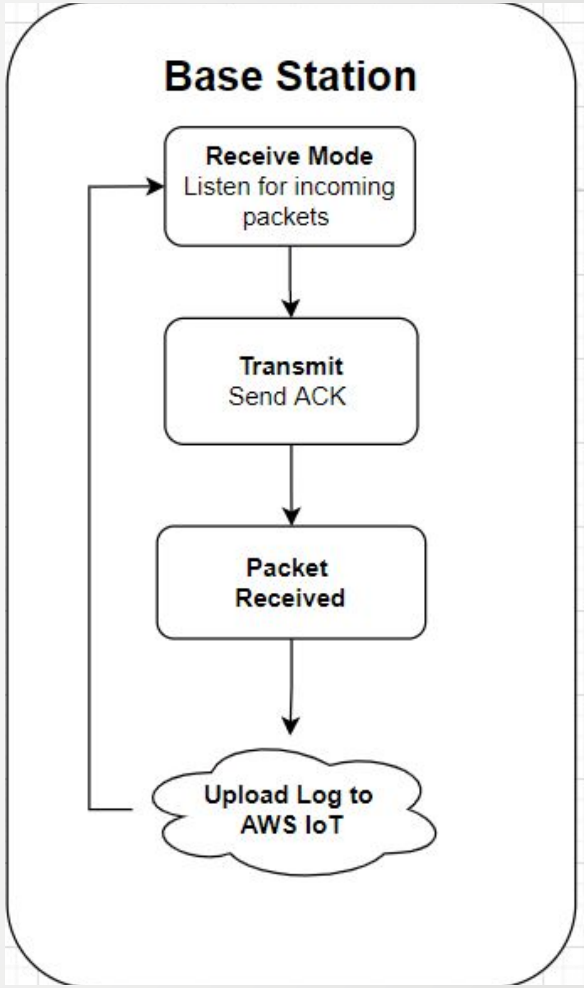
- Low power consumption allows for **1.5 days battery life** without relying on solar
- Implementation of ***2W*** **solar system** with ***190mA*** **output** current

Cost

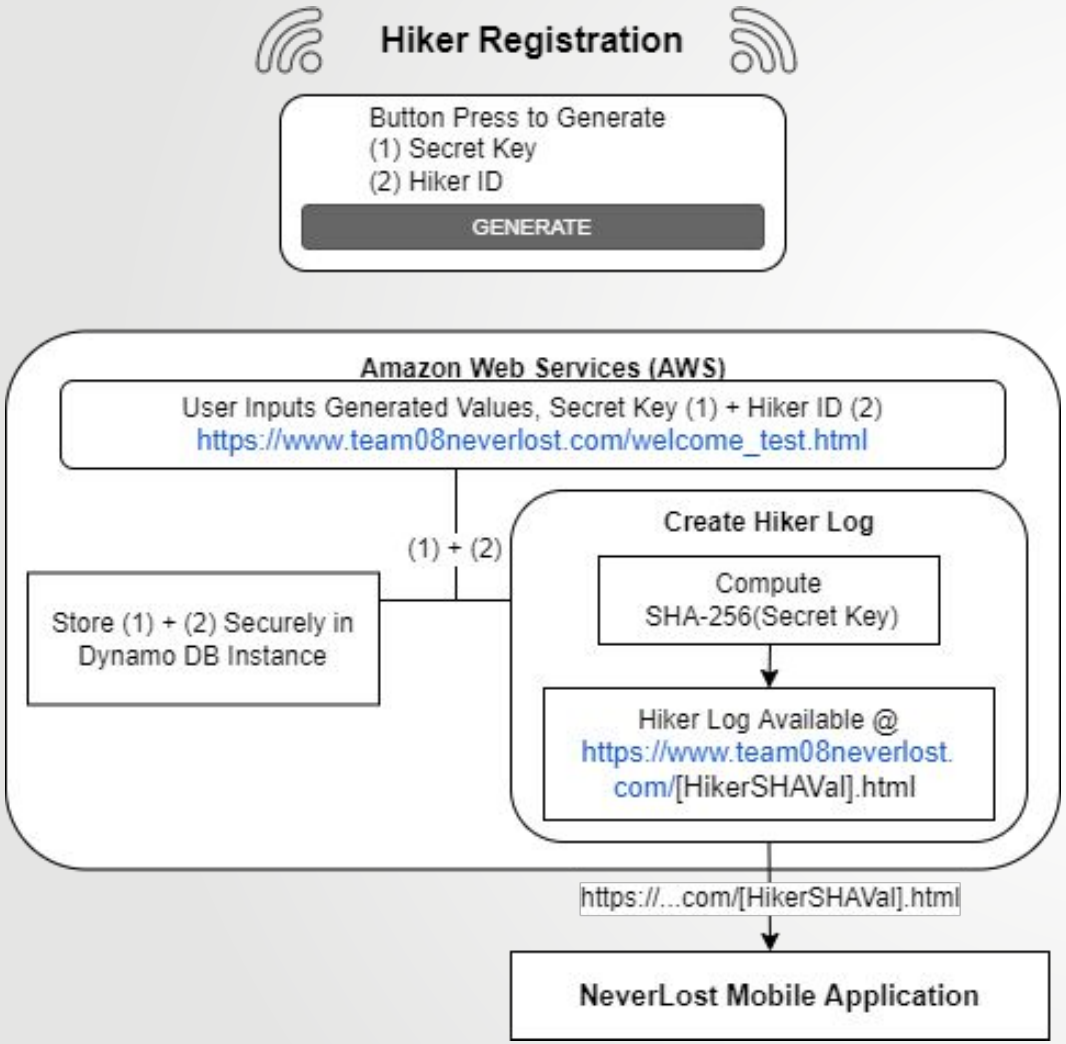
- Beacon: $86.19
- Base Station: $50.16

Embedded Software Diagram





Software Diagram



Cloud Computing

Base Station to AWS

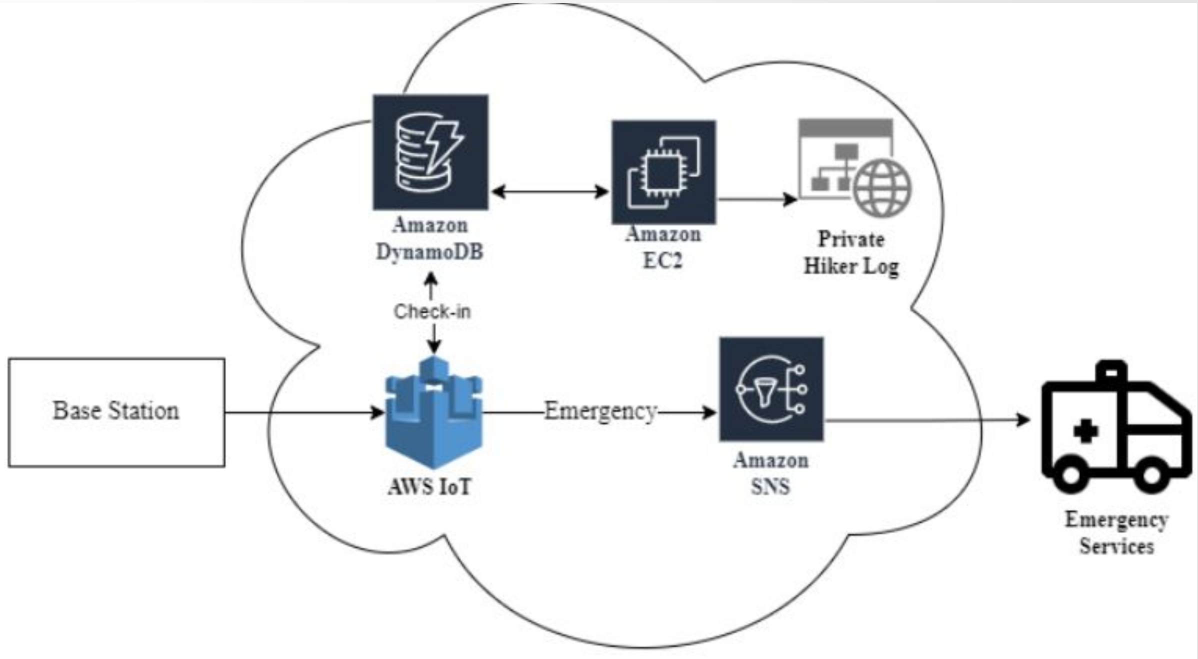
- ESP32 connected to AWS IoT sends MQTT message over WiFi publishing entries to topic
- AWS DynamoDB adds entries to EC2 published to IoT topic

Webpage Hosting

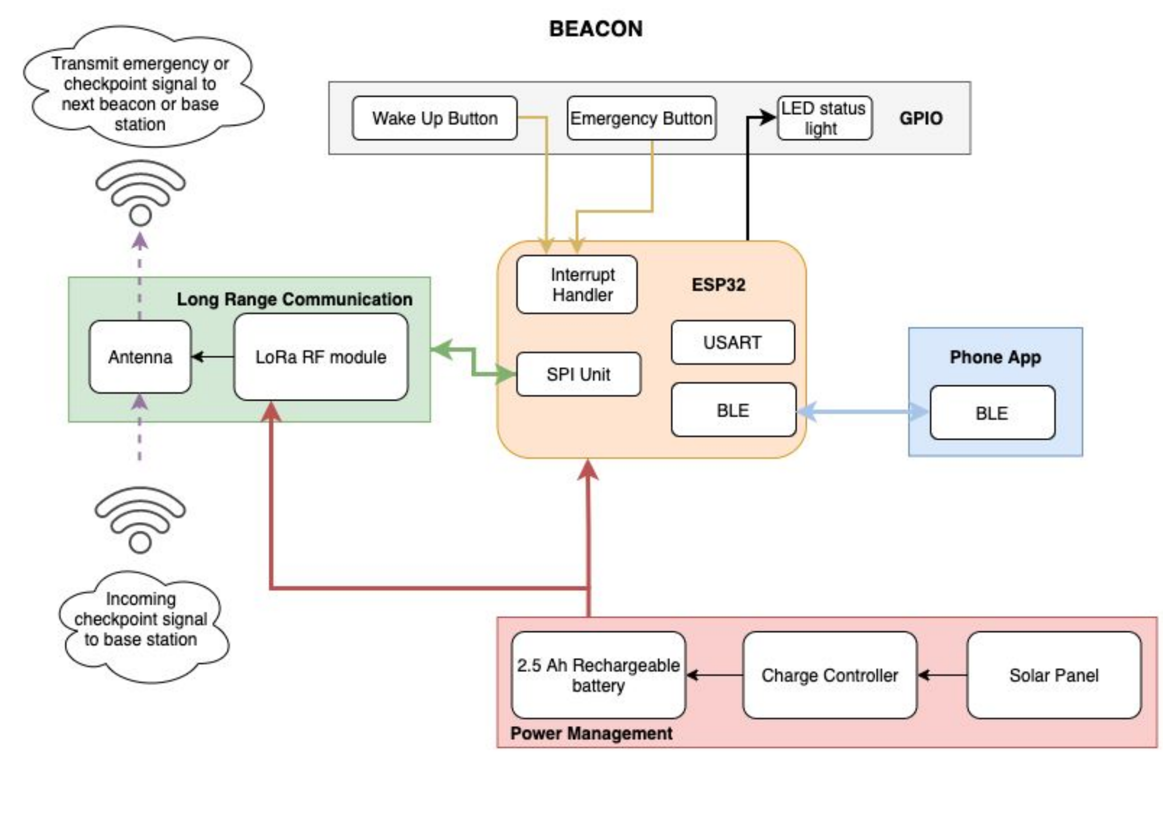
- AWS EC2 instance running Linux virtual machine hosts web pages containing hiker log data

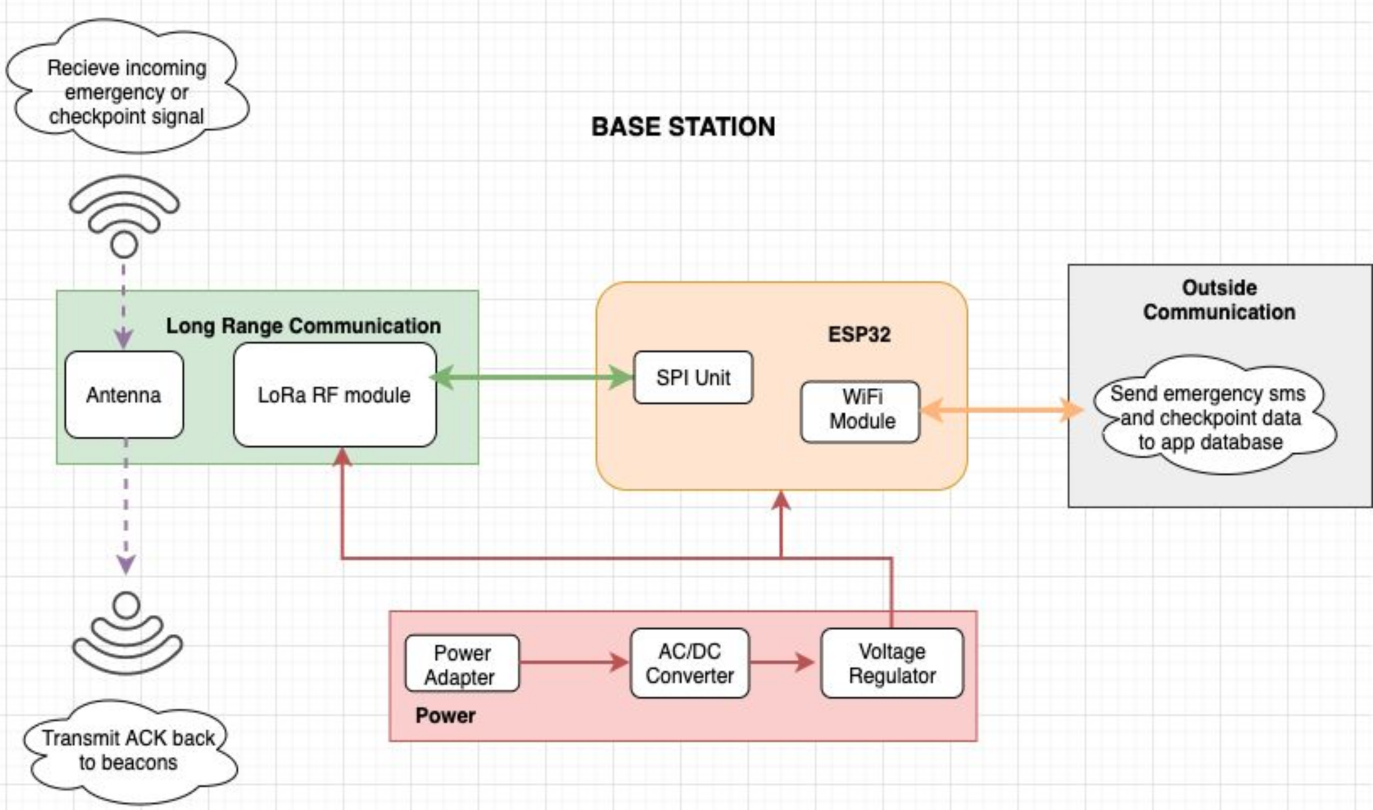
Cloud Security

- Base Station is assigned X.509 certificate and RSA keys
- Device connects to AWS IoT over secure TLS connection



Hardware Diagram





Proposed MDR Deliverables

We will produce 1 prototype beacon, and 1 prototype base station for testing

Short Range Communication and Mobile App

- Working user interface in app to communicate data from smartphone to beacon via bluetooth
- Ability to contact the outside world from base station via SMS in less than 5 minutes

Long Range Communication

- Send a serial 44 byte message with the LoRa transceiver
- Find the max range of the LoRa and measure the packet received/fail rate (~500 meter goal)

Power Systems

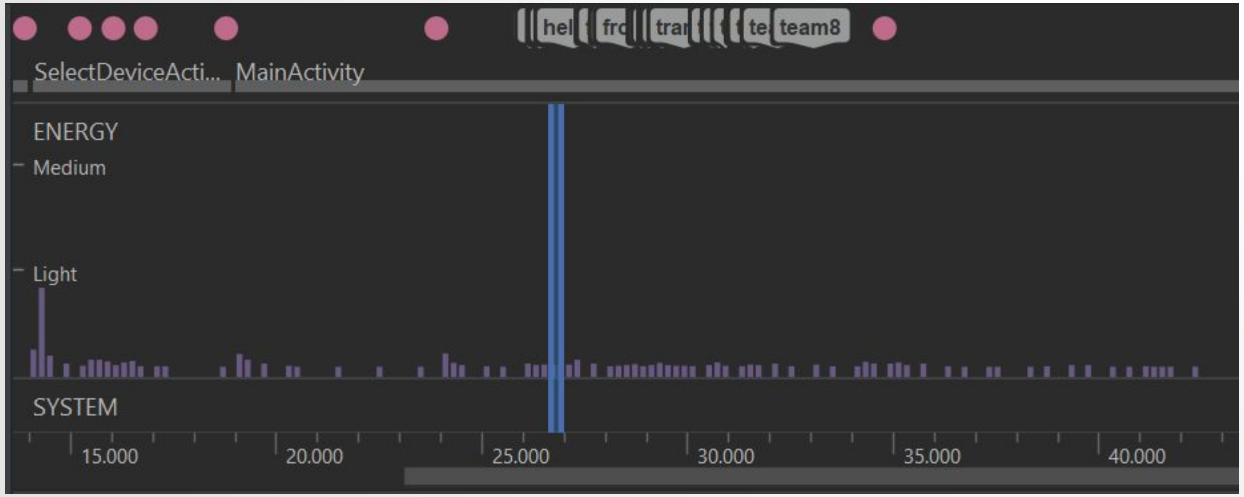
- Prototype including all proposed modules to measure power consumption
- Set up working solar charging system
- Confirm min and max power of modules

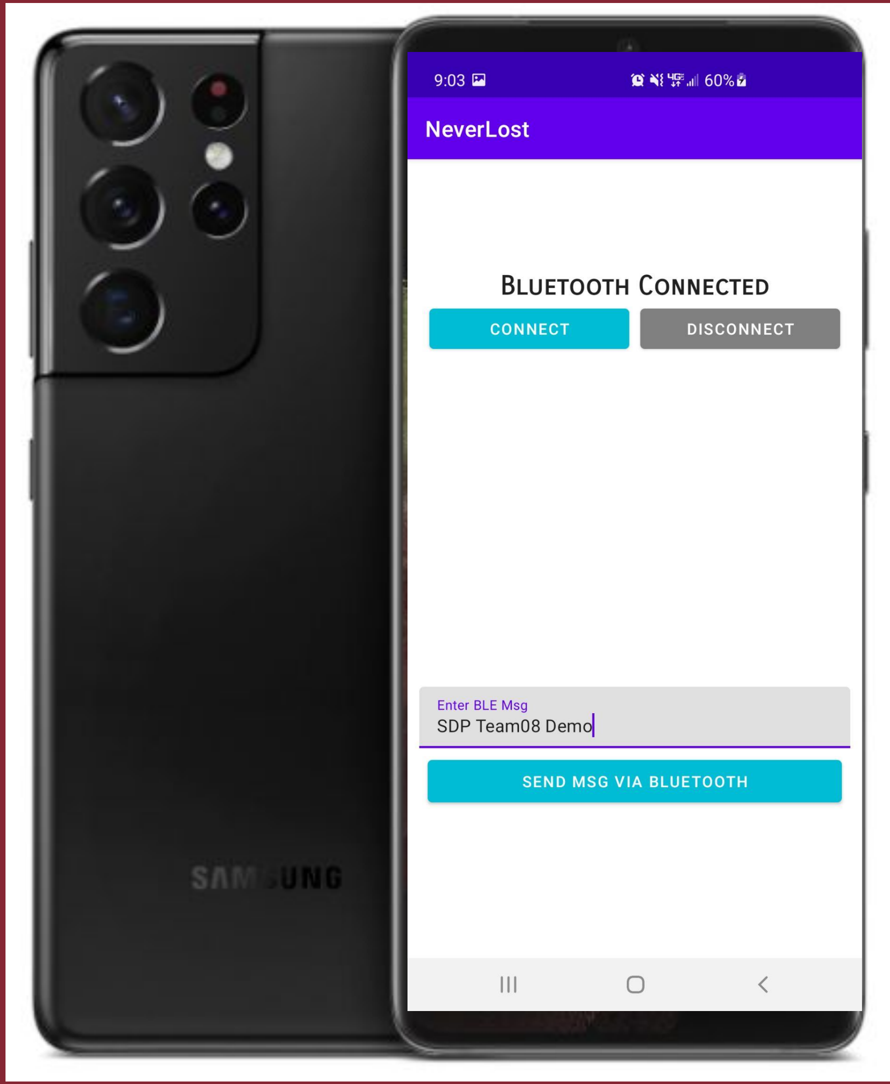
Short Range Communication - Mobile App / BLE

Short Range Communication and Mobile App

✓ Working user interface in app to communicate data from smartphone to beacon via bluetooth

- Create Comm Socket to enable communication
- Bi-directional communication:
  - Android Application ↔ BLE Module (ESP)





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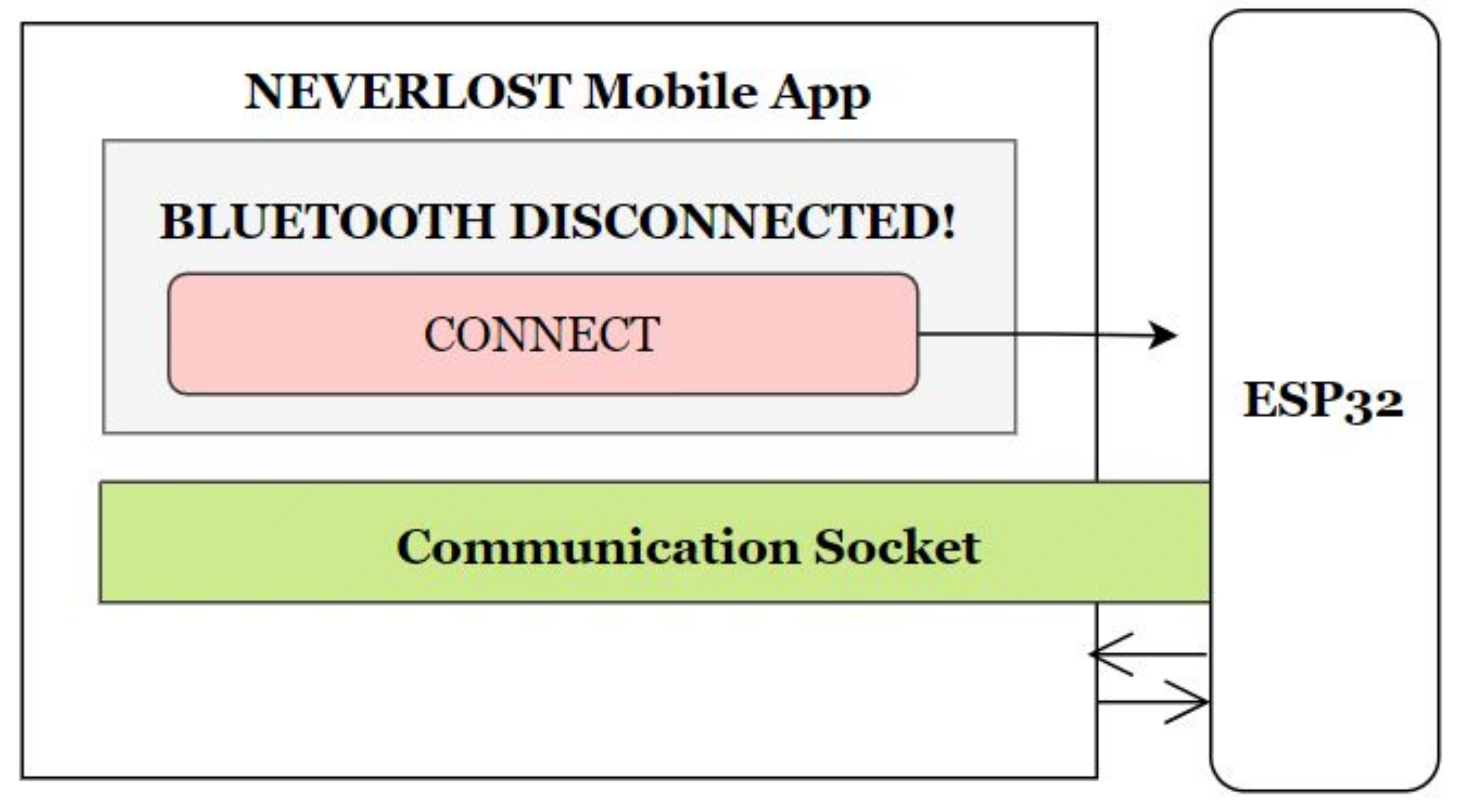
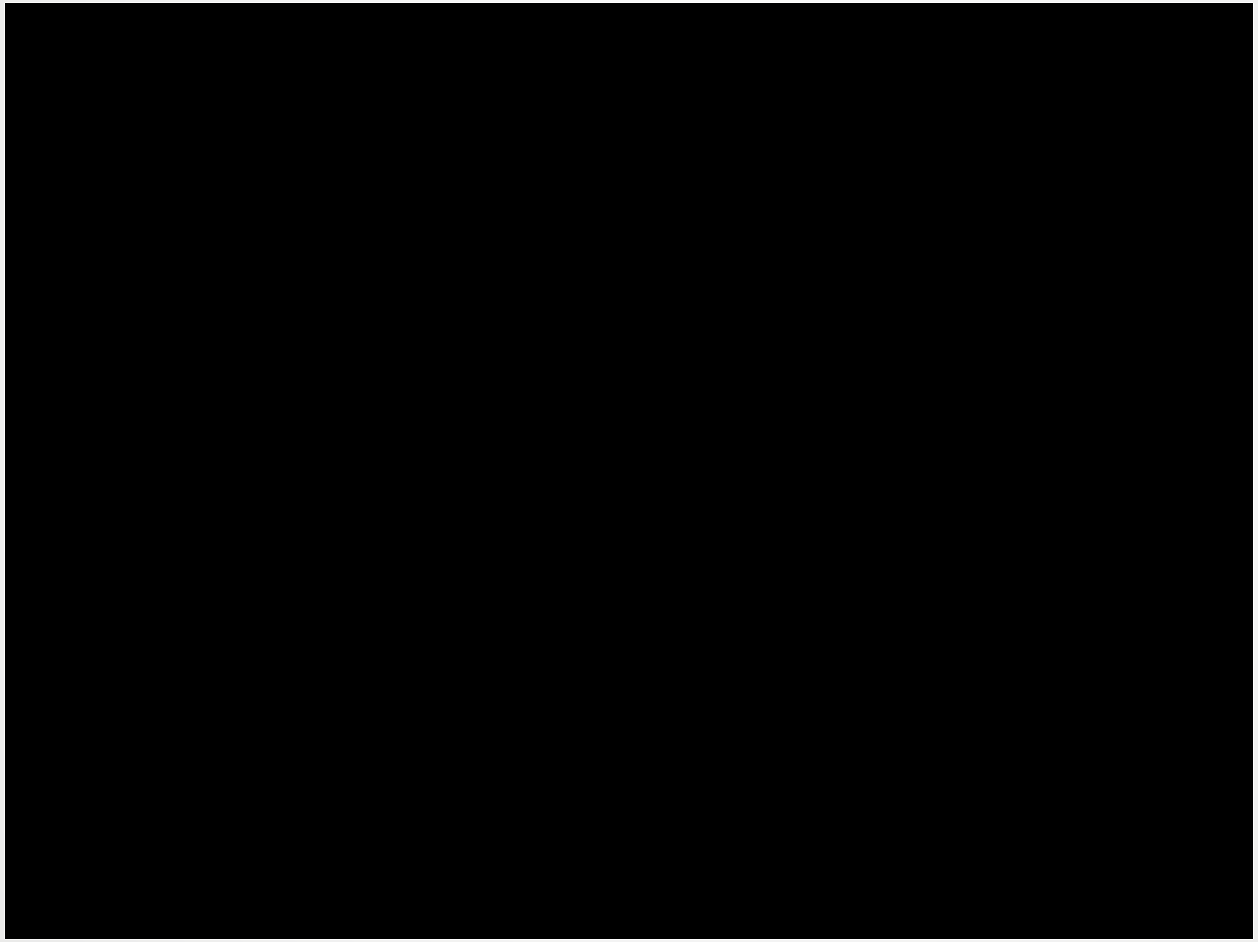
DEMO - Short Range Communication



DEMO - Short Range Communication and App Backup



Long Range - Reliable Data Transmission

- Radio module sends packets and waits for acknowledgement
- Once the packet is received by the base station, an acknowledgement is sent back to the sender
- Reattempts transmission on failed acknowledgement
- 3 ACK, attempts before considered transmission failure

Long Range Communication

Long Range Communication

✓ Demonstrate ability to *send and receive 44 byte serial data* via LoRa

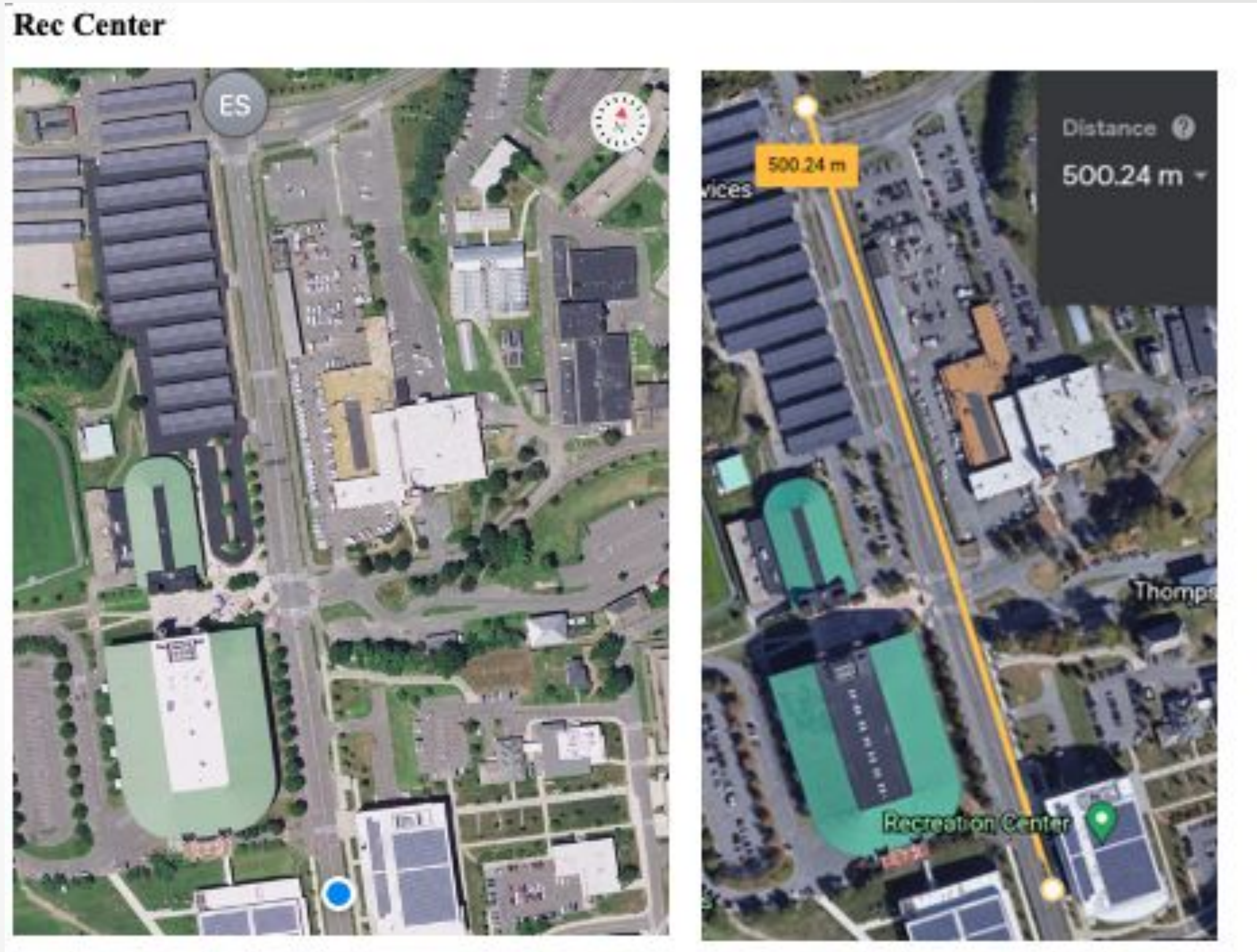
✓ Measure the maximum accurate range of the LoRa transceiver (*minimum goal 0.5km*)

Testing Plan:

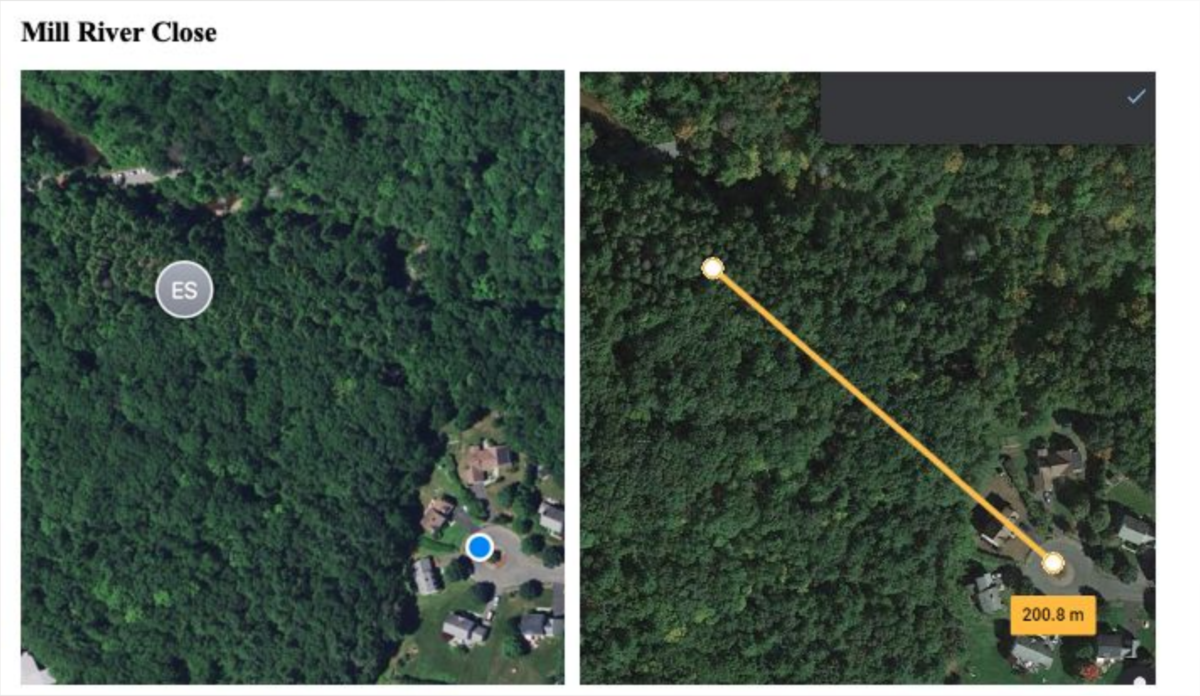
- Range testing of our LoRa with…
    - line of sight
    - obstructions
    - in the woods
- Packet Loss, Reliable Data Transmission

Long Range Demo - Line of Sight

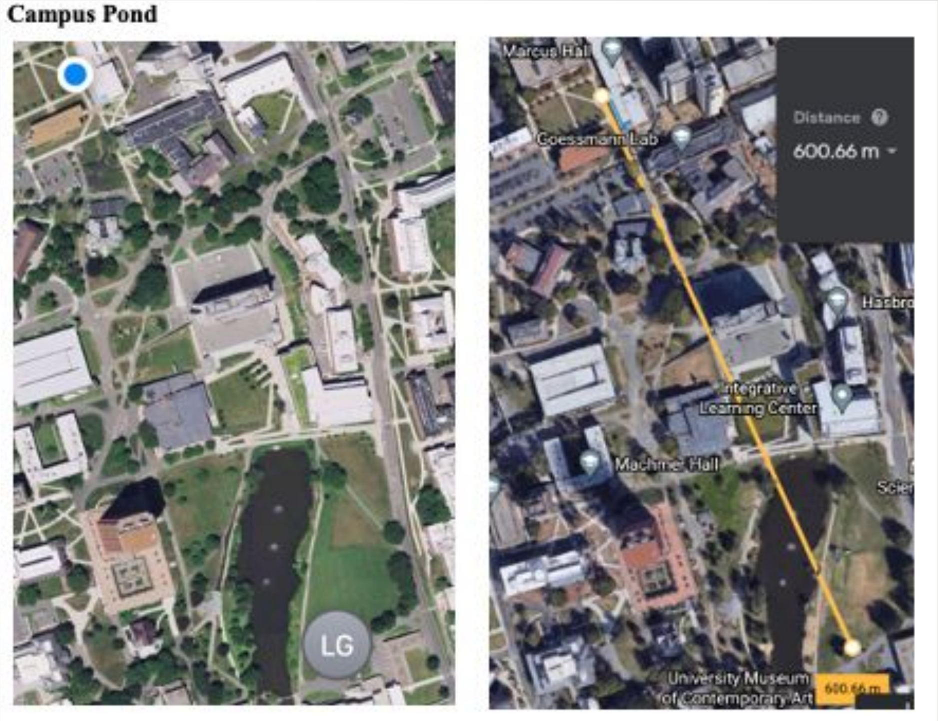
500 Sent, 485 Received, 15 Failed
 97% Success Rate
Avg. duration: 410.392ms



Long Range Demo - Successful Transmissions

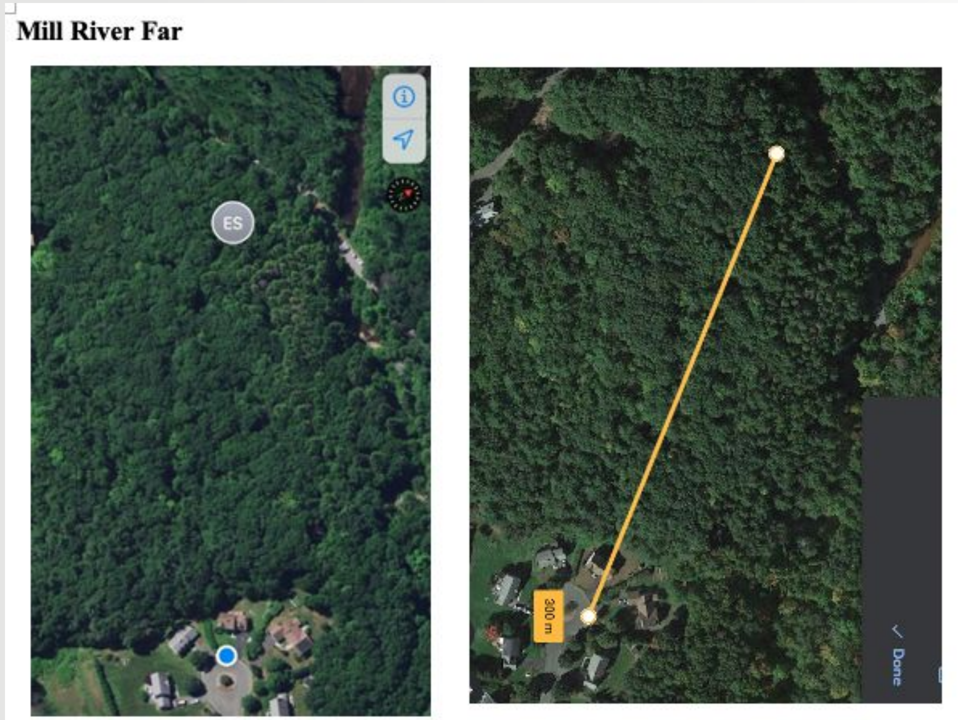


500 Sent, 478 Received, 22 Fails
96% Success Rate
Avg Duration: 427.43ms

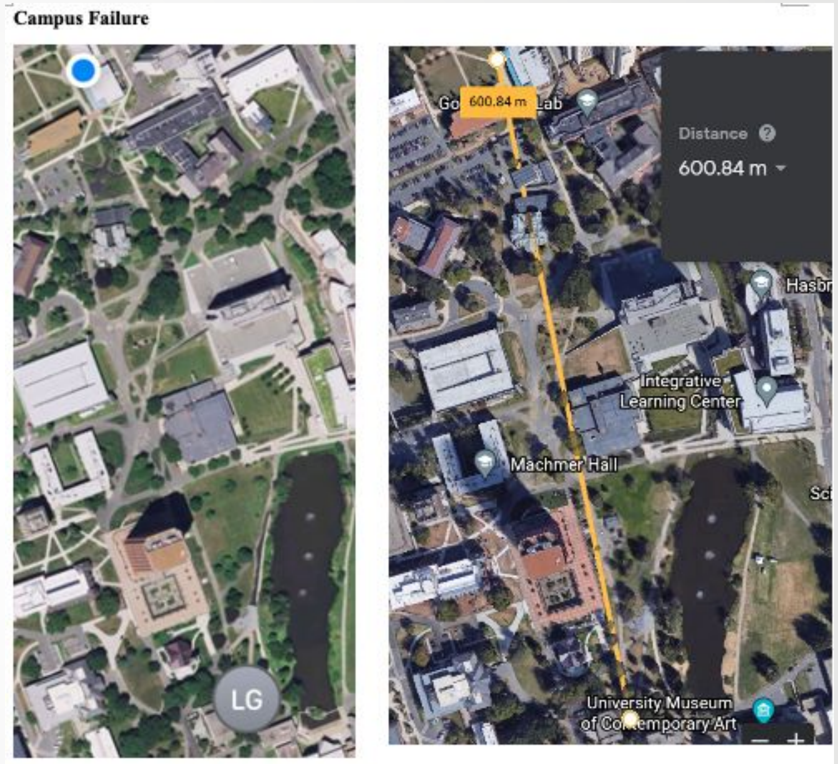


500 Sent, 491 Receive, 9 Failed
98.2% Success Rate
Avg Duration: 421.26ms

Long Range Test - Failure Points



500 Sent, 356 Received, 144 Fails
71% Success Rate
Avg Duration: 427.43ms



265 Sent, 60 Received, 205 Failed
22.6% Success Rate

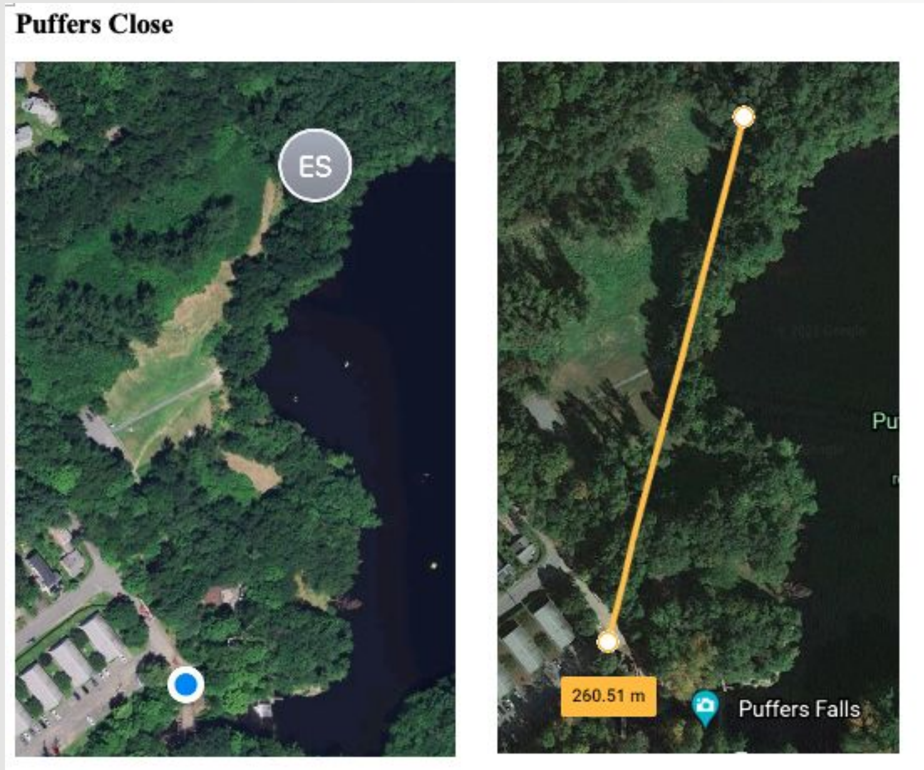
Improving Transmission Success Rate

Location	Pass	Fail (>0 attempts)	% Success	Attempts for 100%
Mill River 200m	461	39	0.922	13.53937556
Mill River 300m	319	181	0.638	33.99192973
Puffers 250m	492	8	0.984	8.352644451
Puffers 400m	456	44	0.912	14.21136997
Rec Center 500m	480	20	0.96	10.73032259
Campus 600m	475	25	0.95	11.52959371
Campus failure	49	216	0.184906	168.9378155

- Found success rate for a single transmission at each location
- Used this success rate to estimate number of resend attempts to reach 100% transmission success rate

Using: $\mu = 1 - (1-\lambda)^N$

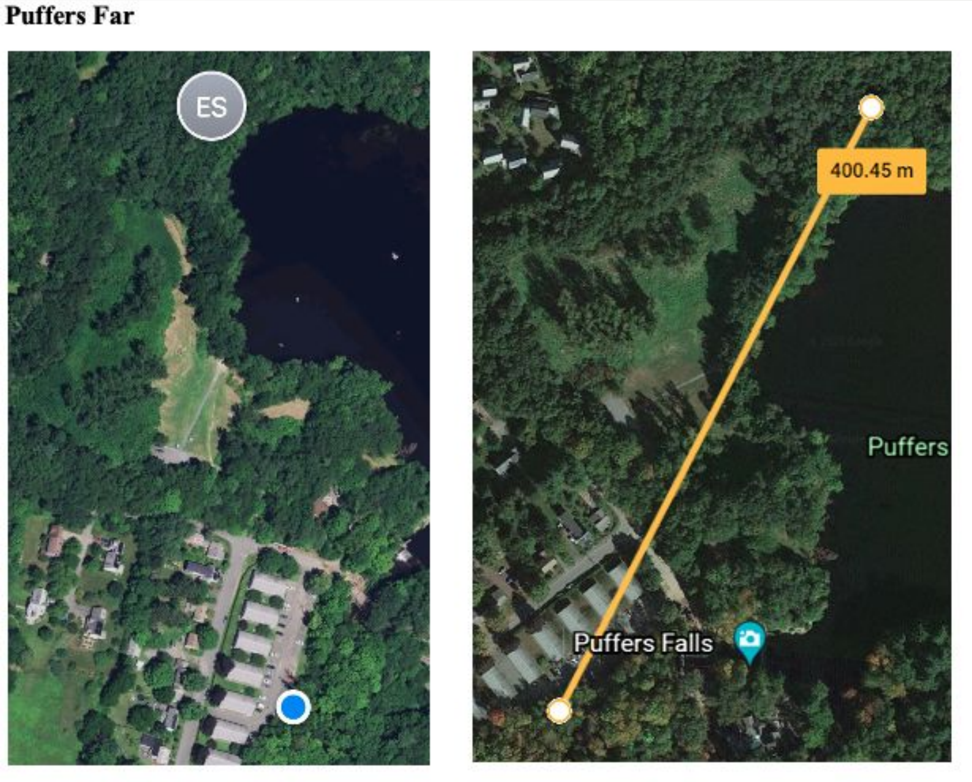
Long Range Demo - Range Tests Woods



500 Sent, 500 Receive, 0 Failed

100% Success Rate

Avg Duration: 399.6ms



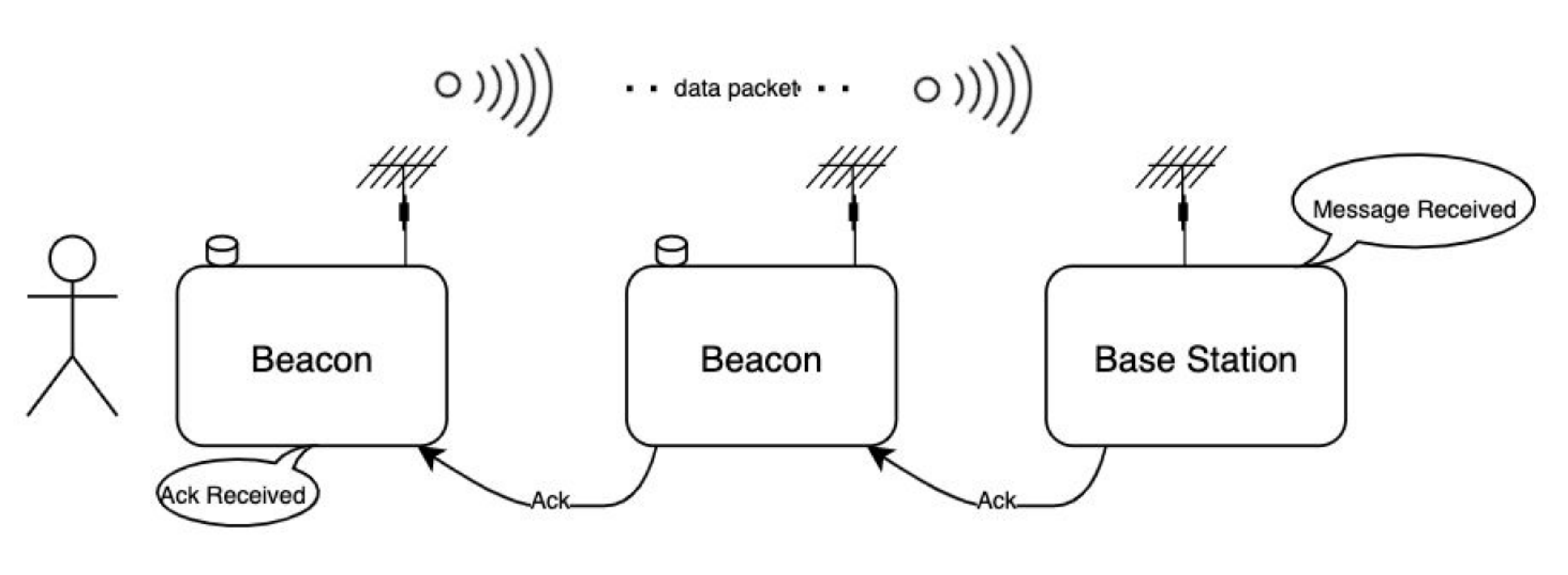
500 Sent, 476 Receive, 24 Failed

95.2% Success Rate

Avg Duration: 428.63ms

Demo Video - Puffers 250 m

Linear Repeater Network Demo



Linear Repeater Network Demo Backup

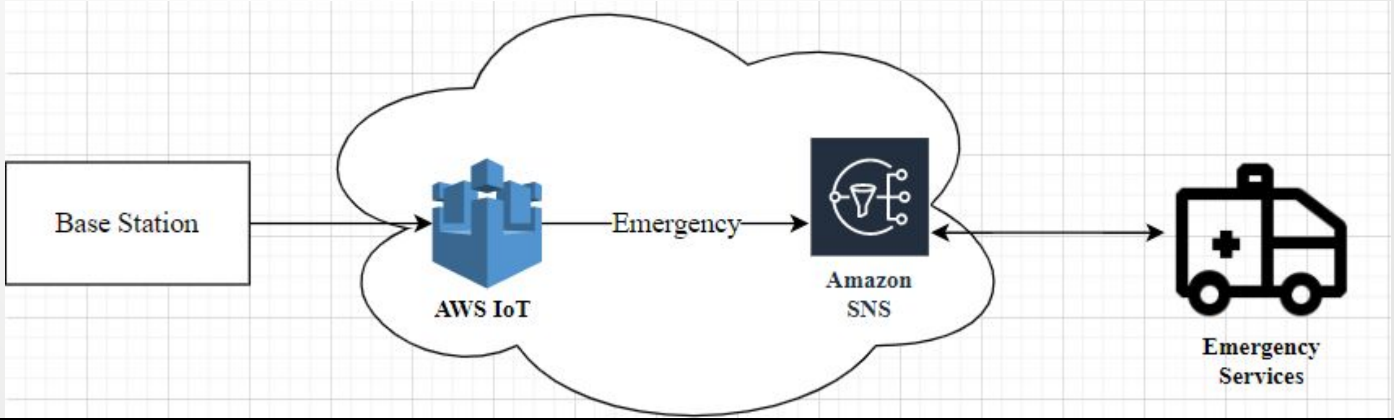
DEMO SMS → Emergency Services

Cloud

✓ Ability to contact the outside world from base station via SMS in less than 5 minutes

SMS

- Published IoT topic triggers AWS SNS action sending contents of beacon message to mobile phone through SMS
- 100% of SMS messages sent under 5 minutes
- 2.1 Second server delay



DEMO SMS Emergency Signal Backup

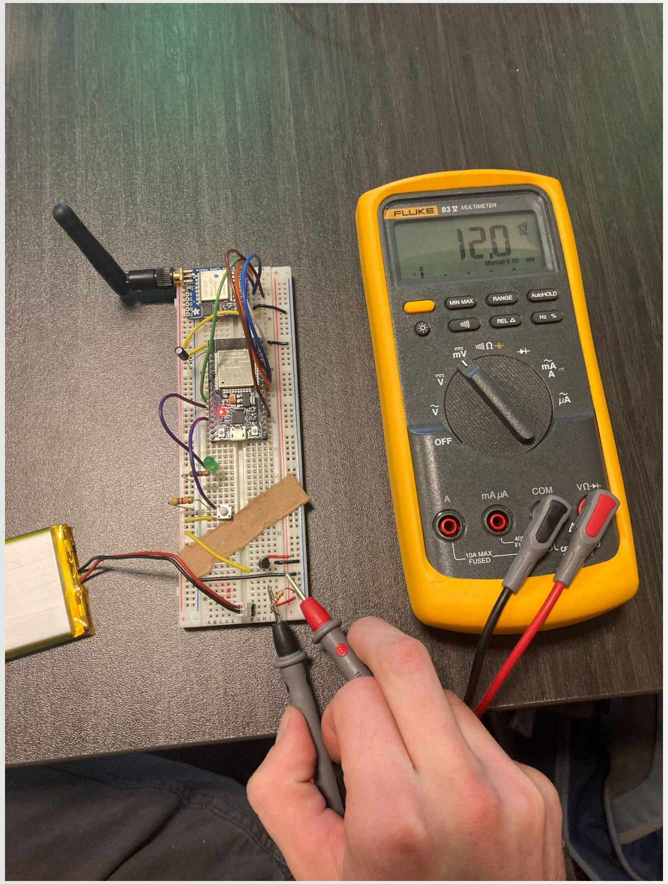
Power Systems

Power Systems

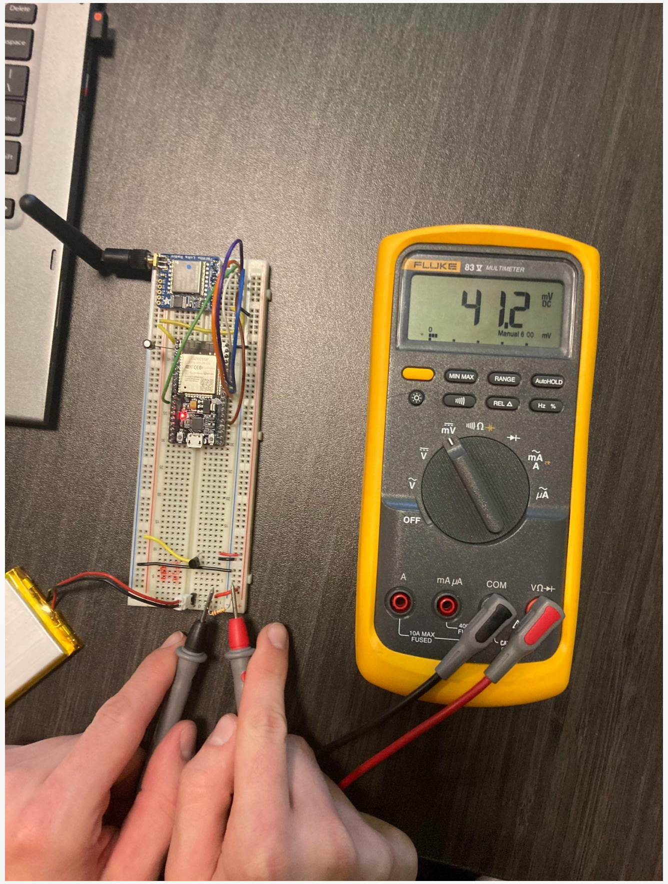
- ✓ Test the solar cell efficiency by measuring output current - *expect 63mA (190 mA actual)*
- ✓ Measure min system current *302uA (12mA actual)* and max system current *142mA*

Moving to bare modules rather than breakout boards and dev boards should allow us to come closer to the power specs stated on respective datasheets

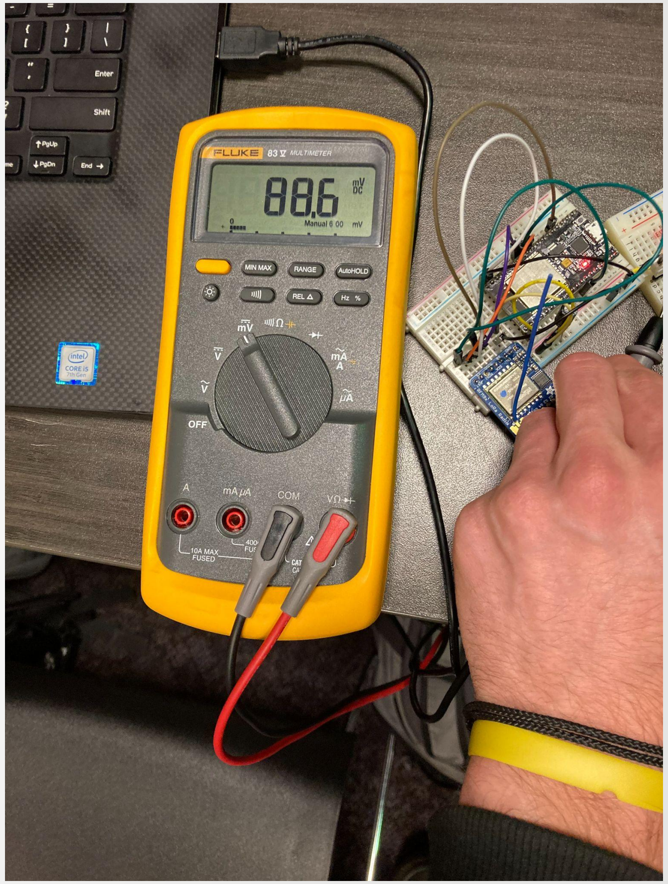
Power Demo - Steady States



ESP and LoRa Sleep Mode

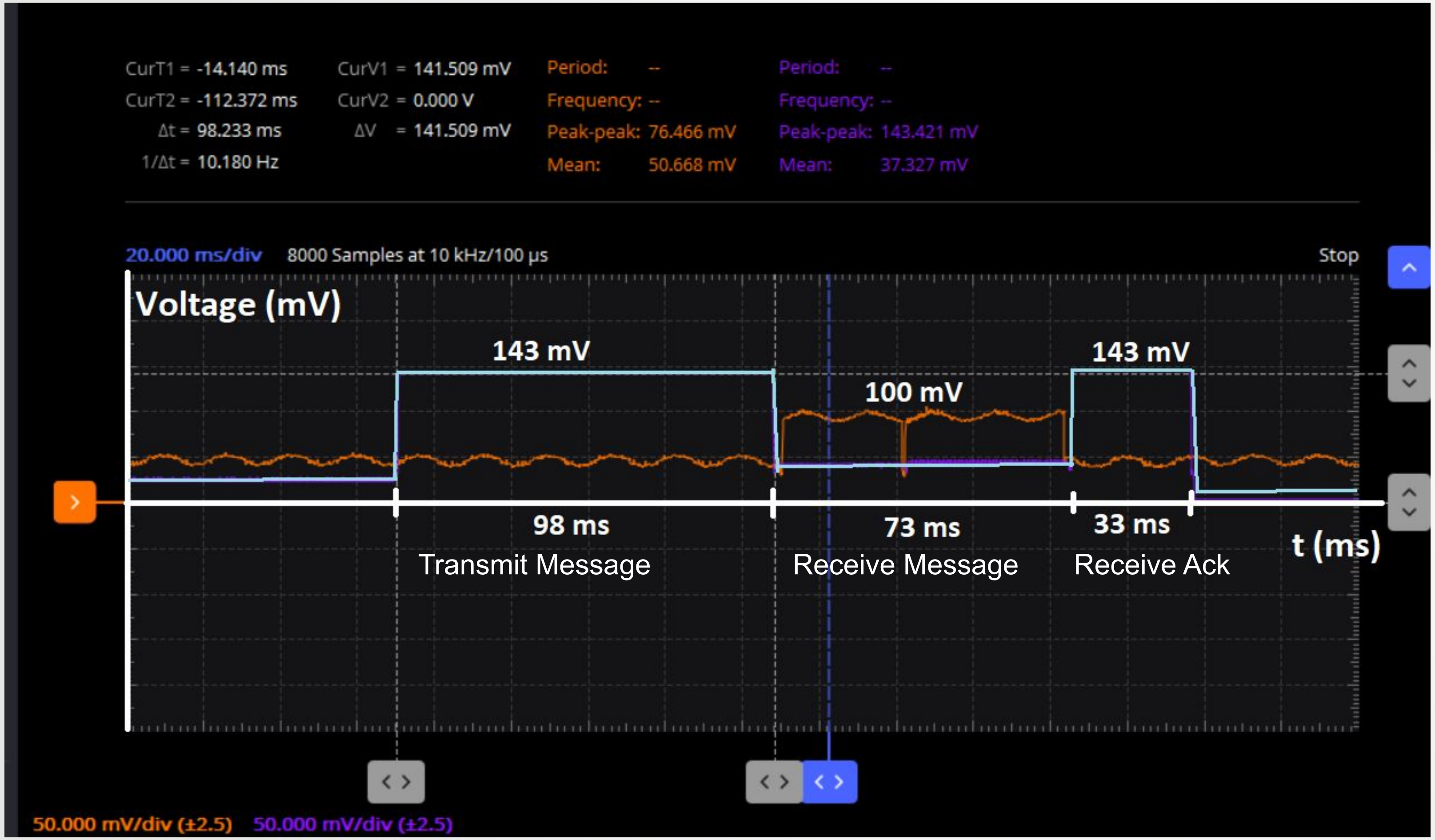


ESP Awake, LoRa in Receive Mode



ESP Connected to Bluetooth

Power Demo - Active Transmit and Receive



Transmit and Receive Power

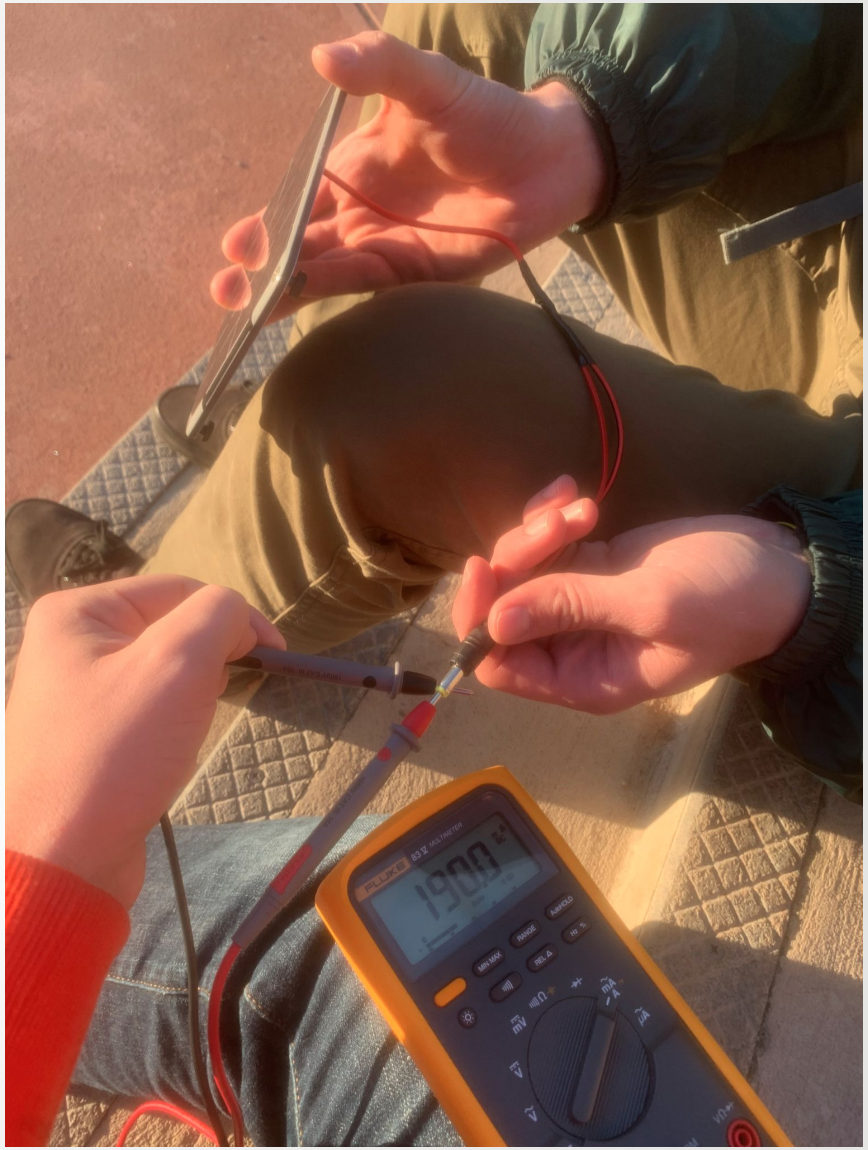
- Active Tx *143 mA*
- Active Rx *100 mA*
- Idle Rx *43 mA*

Power Demo - Solar

Measured solar panel DC output characteristics

- *190 mA* output current at *4.2 V*
    - measured with some clouds and indirect sunlight
- Produces *0.8 W*

- Assuming 8 hrs sunlight (winter months), maximum output 6.4 Wh
- 1.9 Ah at system voltage (3.3V)



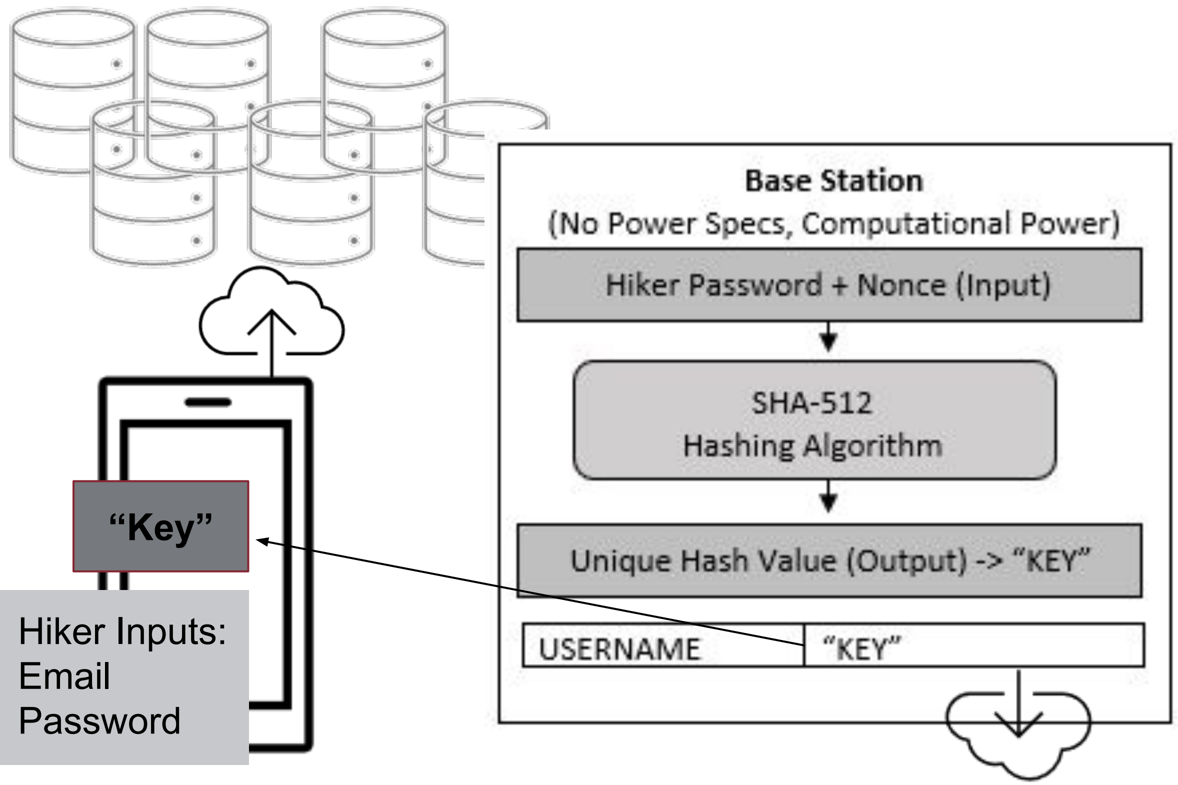
Timing Scheduling

- **Implement a duty cycle to switch between Sleep and Receive modes**
  - When in receive mode look for a message preamble, must receive 2 symbols from preamble to know to begin actively listening for packet data
  - This allows all beacons to be ready to receive a message at all times - reduces time for message to reach base station

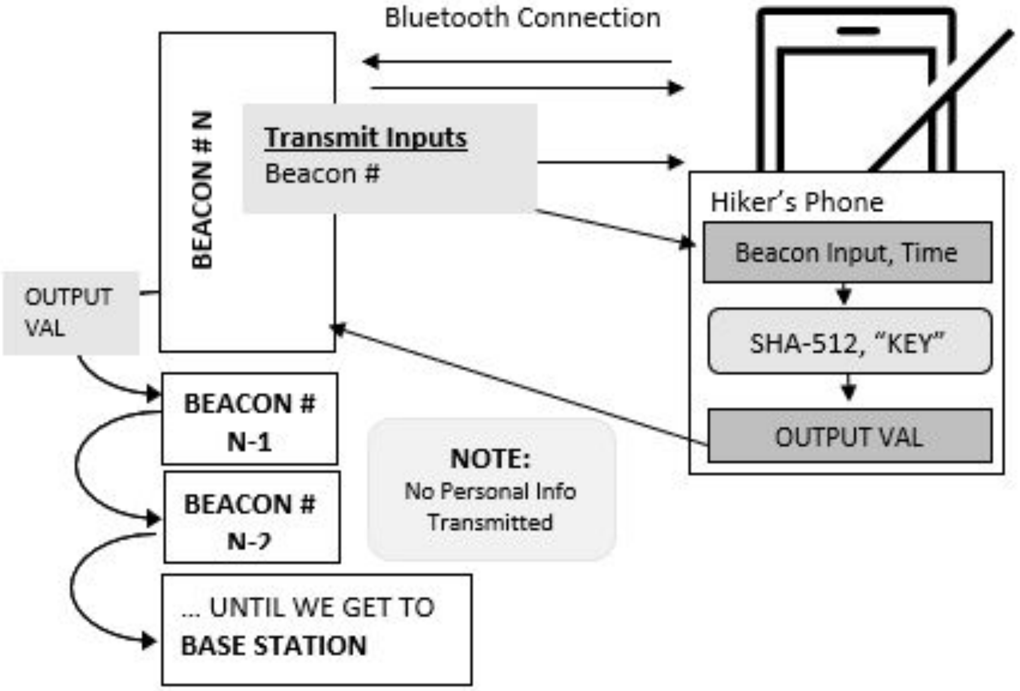
- **Plotted power as function of preamble length to find minimum power**
  - From plot, found 8 symbol preamble is optimal
  - Our beacons will sleep for 6 symbols and wake up for 2 - meaning system will be asleep for 75% of time, awake for 25%

Security of Personal Information

1 - Hiker Registration



2 - Check In @ Each Beacon



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Security of Personal Information

3 - Check In Info to Cloud-Based, Mobile Application

Receive Secure Check-In Information

CLOUD COMPUTATION

→Apply each Personal "KEY" to Inputs until Success

HIKER1	KEY(SECURE INFO) →UNRECOGNIZABLE...	FAIL
HIKER2	KEY(SECURE INFO) →UNRECOGNIZABLE...	FAIL
HIKER3	KEY(SECURE INFO) → "SUCCESS...INFO"	SUCCESS!

Scalability Issues

- **As number of beacons increases, so will power consumption as each message must be sent through the system**
  - The first beacon in line must transmit and receive (number of beacons) * (number of hikers) times per day which means that it will use far greater power than any other beacon in the chain
  - To help this we can have multiple beacons between each check in beacon such that there are fewer check ins

Custom Hardware Plan for PCB

Beacon

ESP32-WROOM

RFM95C

SMA Connector

3.3V Switching Voltage Regulator

LiPo Battery Connector

Barrel Connector for Solar Panel

MCP73831 LiPo BMS IC

GPIO Connections to Buttons

Status LED

Base Station

ESP32-WROOM

RFM95C

SMA Connector

3.3V Switching Voltage Regulator

Connector for 5V DC Supply

Justification of Hardware

ESP32-WROOM

- WiFi+BLE MCU
- Sleep Mode ~12mA
- 240MHz -> 80MHz clk
- 520Kb on-chip SRAM

RFM95C

- Low power LoRa based packet radio module
- License-free ISM band 915MHz
- 135mA transmit, 43mA receive
- ~600m line of sight

Current Expenditures

Item	Quantity	Cost
Lithium Polymer Battery	2	29.9
Solar Panel	2	58
RFM95C LoRa Breakout	2	79.8
Charge Controller	2	19.9
Antenna Connector	3	7.5
ESP32-WROOM	2	17.9
Antenna	2	25.7
Shipping + Tax		35.99
Total		**274.69**

Future Expenditures

Beacon	Quantity	Price	Total	**Base Station**	Quantity	Price	Total
ESP32-WROOM	5	8.95	44.75	ESP32-WROOM	3	8.95	26.85
RFM95C	5	13.44	67.2	RFM95C	3	13.44	40.32
3.3V Switching Voltage Regulator	5	1.2	6	3.3V Switching Voltage Regulator	3	1.2	3.6
LiPo Battery Connector	5	0.26	1.3	Connector for 5V DC Supply	3	0.72	2.16
MCP73831 LiPo BMS IC	5	0.74	3.7	5V AC/DC Wall Charger	3	6.5	19.5
Buttons	5	0.25	1.25	SMA Connector	3	2.5	7.5
Status LED	5	0.55	2.75	**Basestation Total**			**99.93**
SMA Connector	5	2.5	12.5			**PCB x 8**	**32**
Beacon Total			**139.45**			**Total**	**271.38**

Team Responsibilities

Shelby Anderson

- Team Manager
- Application Development

Eric Anderson

- Budget
- Software/Cloud Lead

Louis Gencarelli

- Long/Short-range Communication
- Embedded System Lead

Eric Sutherland

- PCB Lead
- Power Consumption

Gantt Chart

	Task Name	Start Date	End Date	Members	1/24 - 1/28	1/31 - 2/4	2/7 - 2/11	2/14 - 2/18	2/21 - 2/25	2/28 - 3/04	CDR!
					M T W TH F	M T W TH F	M T W TH F	M T W TH F	M T W TH F	M T W TH F	
Hardware											
	Design and Prototype Charge Controller	24-Jan	2-Feb	ES + L							
	Interface battery and solar to Charge Controller	3-Feb	11-Feb	ES + L							
	Design and Order PCB	12-Feb	23-Feb	ES + L							
	Test PCB functionalitly	21-Feb	4-Mar	ES + L							
Software											
	Implement Network Security Approach	24-Jan	2-Feb	S+EA							
	Add Additional App Features	3-Feb	11-Feb	S+EA							
	Web Interface w/ Real User Data	14-Feb	25-Feb	S+EA							
Both											
	Translate from Arduino IDE to Professonal IDE	7-Feb	11-Feb	ALL							
	Design and Create Device Enclousure	14-Feb	18-Feb	ALL							
	Power Optimization	7-Feb	18-Feb	ALL							
	General Testing & Optimization	21-Feb	4-Mar	ALL							

Thank you!
Any Questions?

Appendix - Budget Calculations: Future Expenditures

Beacon	Quantity	Price	Total	Basestation	Quantity	Price	Total
ESP32-WROOM	5	8.95	44.75	ESP32-WROOM	3	8.95	26.85
RFM95C	5	13.44	67.2	RFM95C	3	13.44	40.32
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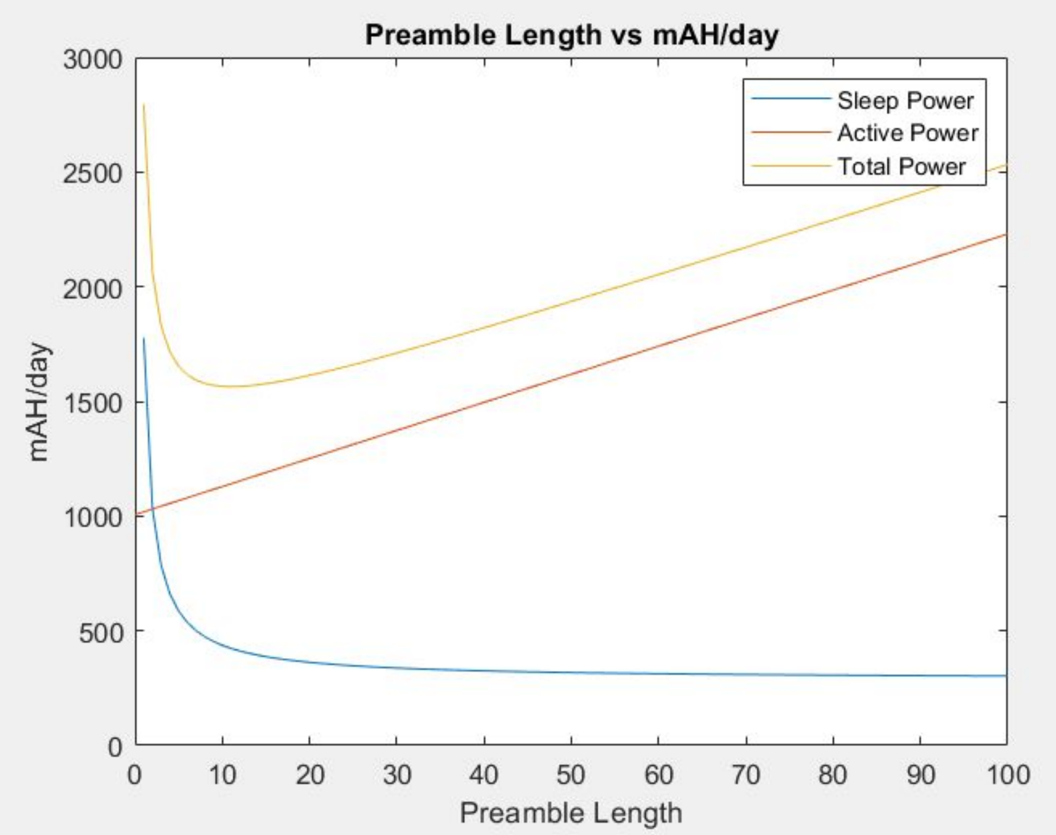
SMA Connector	5	2.5	12.5			**PCB x 8**	**32**
Beacon Total			**139.45**			**Total**	**271.38**

Appendix - Budget Calculations: Cost Per Device

Cost Per Beacon	Quantity	Price	Total	**Cost Per Basestation**	Quantity	Price	Total
ESP32-WROOM	1	8.95	8.95	ESP32-WROOM	1	8.95	8.95
RFM95C	1	13.44	13.44	RFM95C	1	13.44	13.44
3.3V Voltage Regulator	1	1.2	1.2	3.3V Voltage Regulator	1	1.2	1.2
LiPo Battery Connector	1	0.26	0.26	5V DC Supply Connector	1	0.72	0.72
MCP73831 LiPo BMS IC	1	0.74	0.74	Antenna	1	12.85	12.85
Buttons	1	0.25	0.25	5V AC/DC Wall Charger	1	6.5	6.5
Status LED	1	0.55	0.55	SMA Connector	1	2.5	2.5
Battery	1	14.95	14.95	PCB	1	4	4
Solar Panel	1	29	29	**Total**			**50.16**
Antenna	1	12.85	12.85				
PCB	1	4	4				
Total			**86.19**				

Appendix - Power / Scheduling Justification



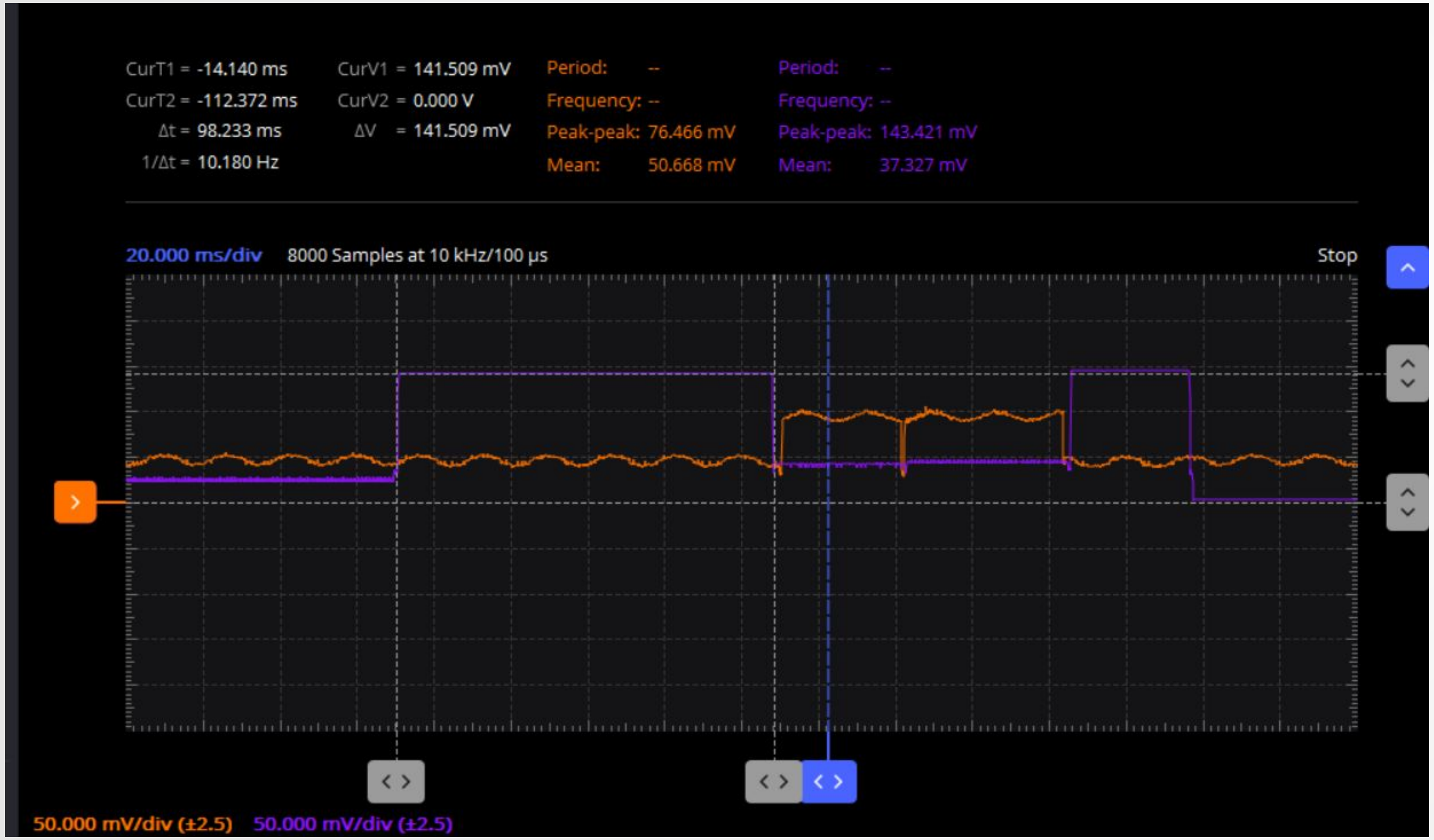
- Created equation for total power related to preamble length
  - equation is based off of worst case scenario (first beacon from base station which will see a message from each hiker and each beacon)
- minimized equation to find optimal preamble length

- use new preamble length, test Tx and Rx current and time measurements to find actual power consumption

```
totalPower = [percent.*24*Isleep]+[(1-percent).*24*Iidle]+[ToA*hiker*beacon]*[activeTx+activeRx]
```

Appendix - Power Measurements

Peak Transmit



Appendix - Power Measurements

Peak Receive

Appendix - Power Measurements

Acknowledgement