Team 8: NeverLost

CDR

March 11, 2022 - 4pm

Advisor: Professor Arbabi
Evaluators: Professor Burleson, Professor Pishro-Nik

University of Massachusetts Amherst
BE REVOLUTIONARY™

Meet the Team!

Shelby Anderson
Computer Engineering
Team Manager

Eric Anderson
Computer Engineering
Software Lead
Budget Lead

Louis Gencarelli
Computer Engineering
Embedded Systems Lead

Eric Sutherland
Electrical Engineering
PCB Lead

Problem Statement

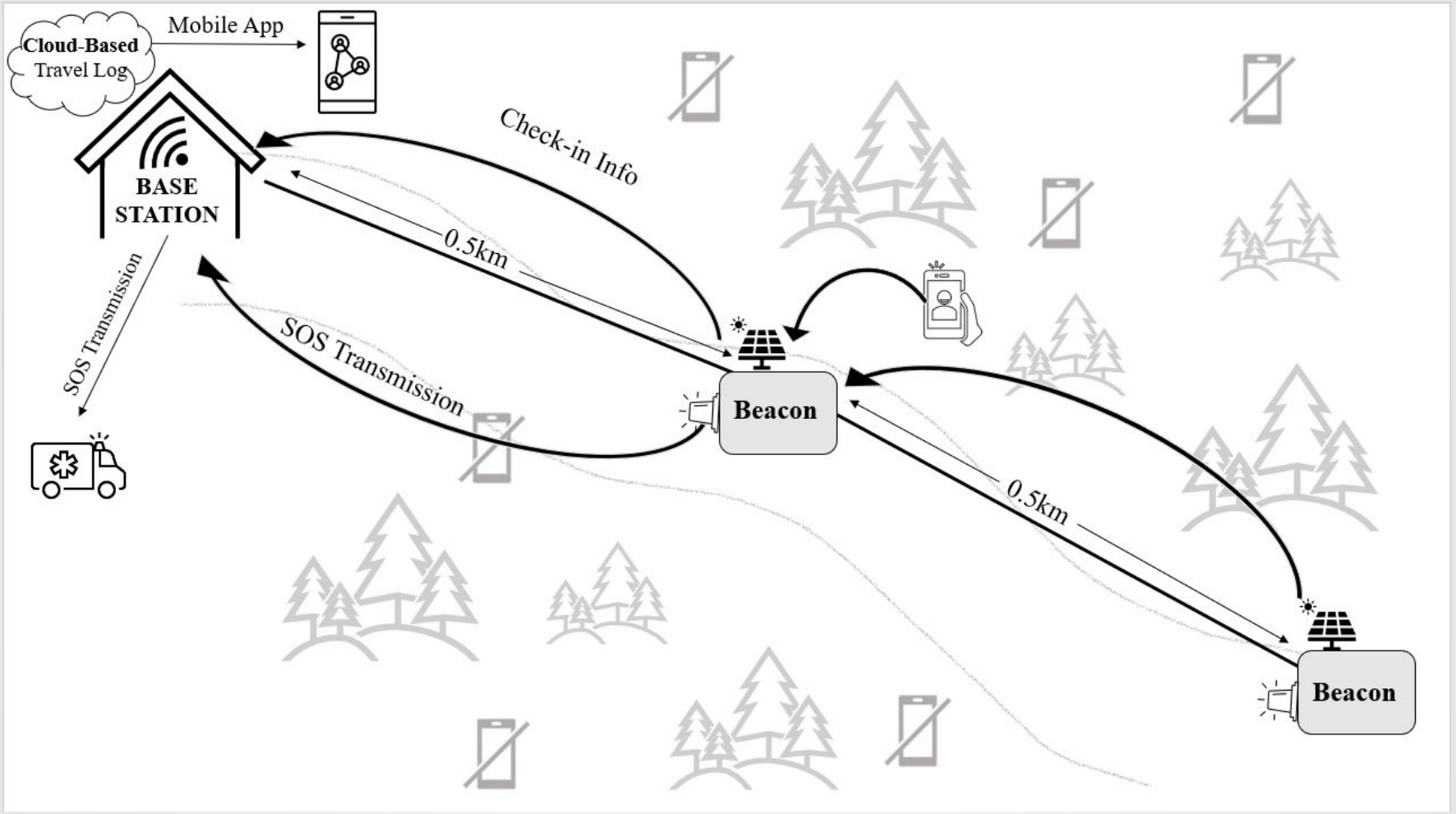
When hiking through long trails such as the Appalachian trail, it is not uncommon for a hiker to become injured making it difficult to complete their journey. It is often difficult to gage a loved ones progress on these trails to confirm their location and that they are ok. In addition, many of these 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.*

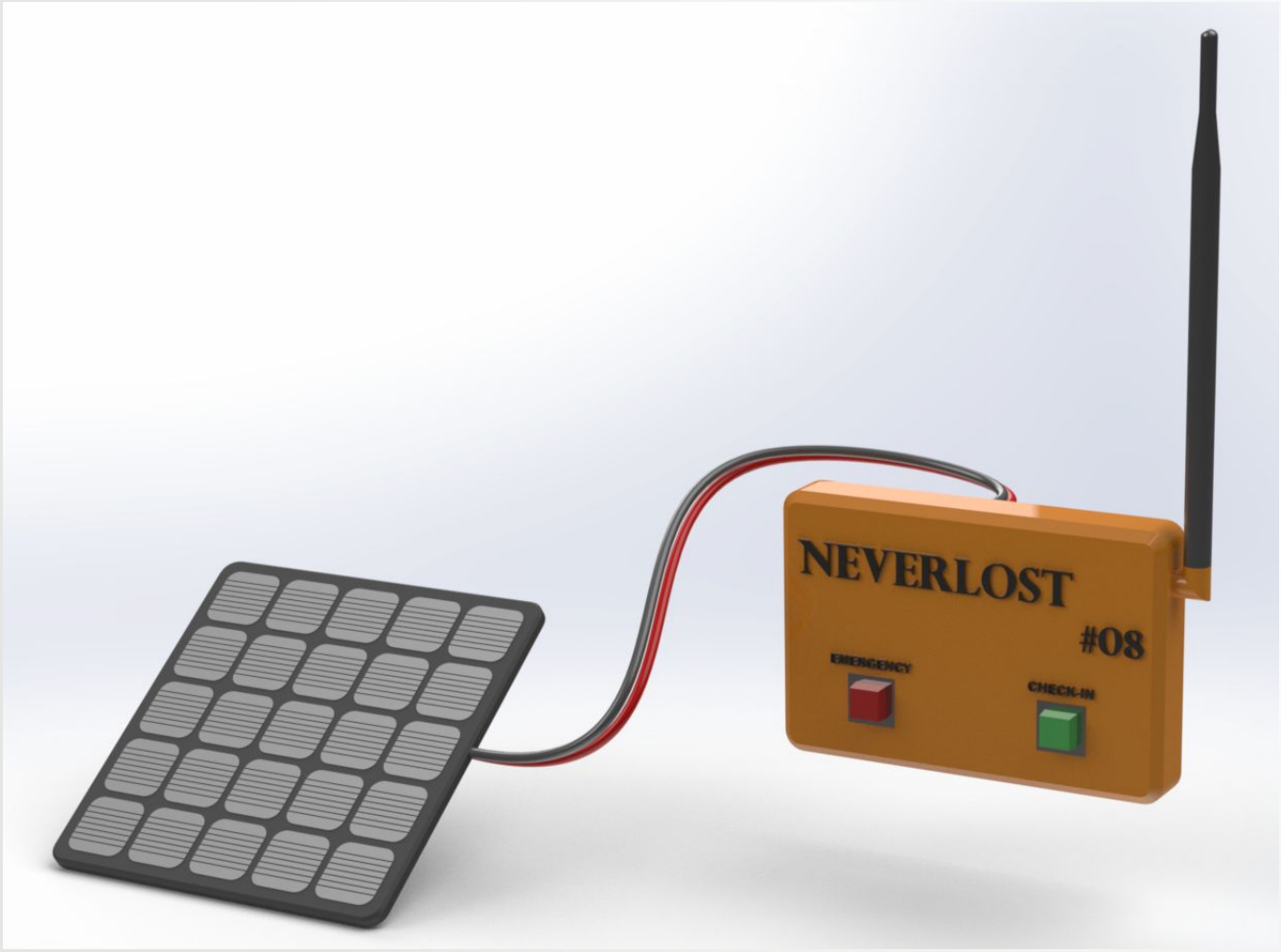
Goals

- *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*

NeverLost Beacon System: Process



NeverLost System: 3D Models



System Specifications

Beacon System

- Multi-hop linear network topology, **500m** distance between beacons
- **300ms** avg propagation between beacons
- **99% transmission success rate** at 500m line of sight
  - **Reliable Data Transfer,** utilizing ACK
- SOS transmitted in *(1- numer of beacons)(prop delay) + Server delay*
- 7.48 Second avg SMS Server Delay

Power Systems

- Low power consumption allows for **100 Beacons and 500 Hikers** per battery charge
- Implementation of **2W solar system**

Mobile Application

- Bluetooth Check-In System via Mobile App
  - Secure Data Transfer (Bluetooth → LoRa → Cloud → End Users)
- Location updated via cloud computing when check-in received by base station
- Generate viewable, secure links to Check-In Information

Cost

- Beacon: $86.19
- Base Station: $50.16

CDR Subsystem Testing Plan

Beacon System

- Ran 4 different packet transmission (250) tests at 500m to calculate packet retransmission statistics
- Measured the amount of time it takes for an emergency signal to be sent and text message received
- Measured propagation between beacons

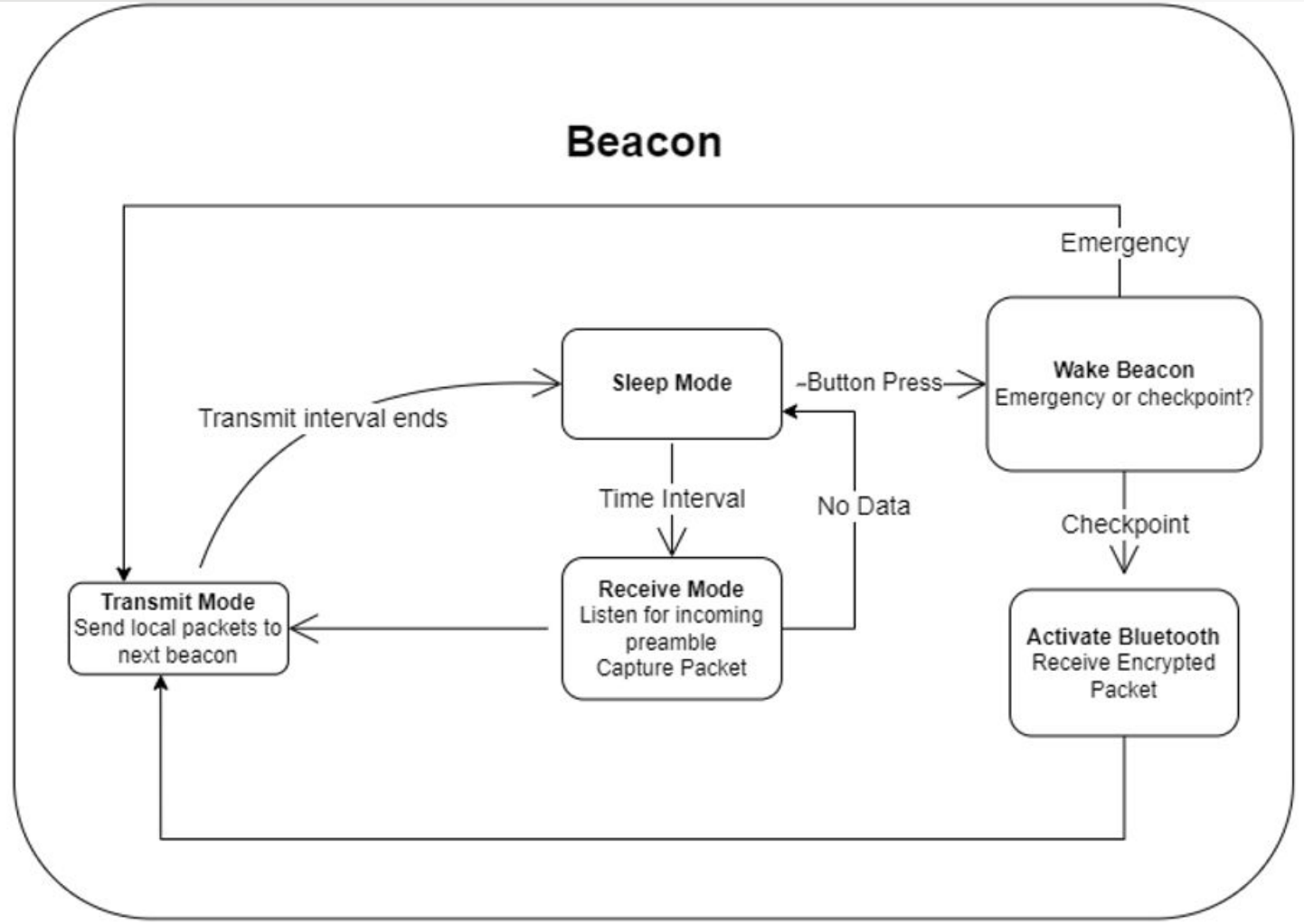
Power Systems

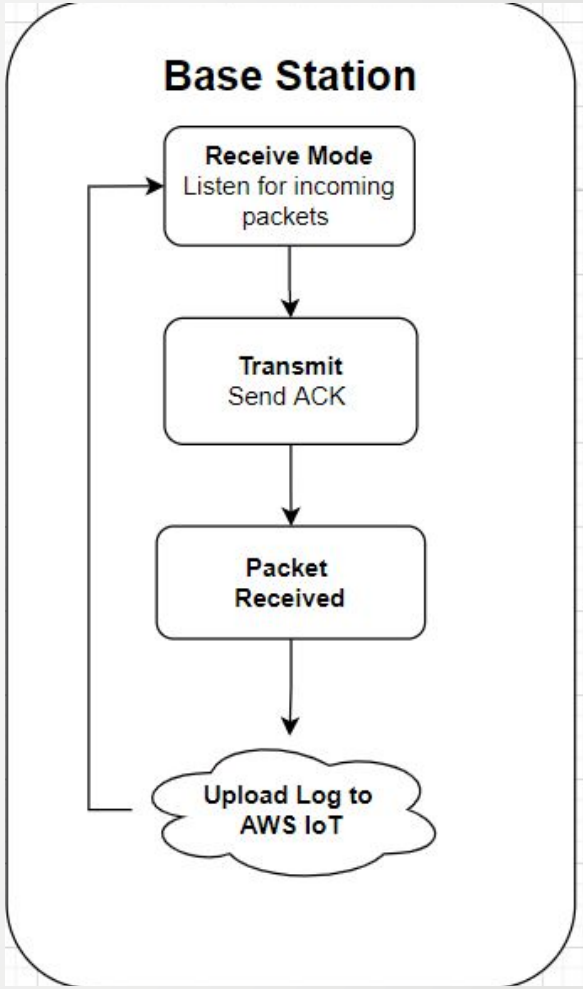
- Measured current output from solar panel each hour of the day. Plotted, this, fit a curve and integrated to find total power produced - measured using solar panel flat on ground and at 45° to compare

Application/BLE

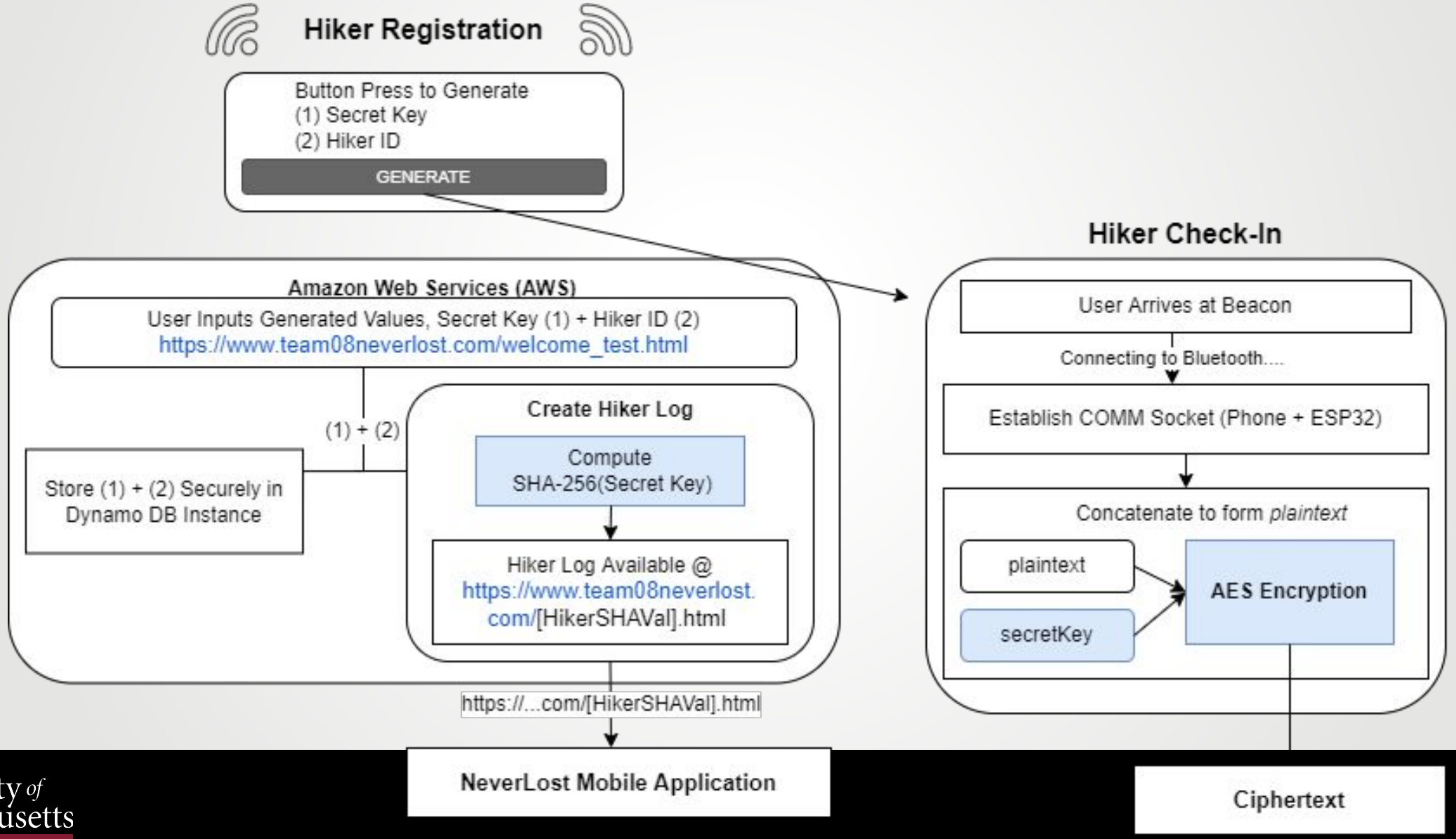
- Verified secure data transfer with keys and encryption working on backend
- Confirmed correct check-in and location data on the secure link

Embedded Software Diagram





Software Diagram



Cloud Computing

Base Station to AWS

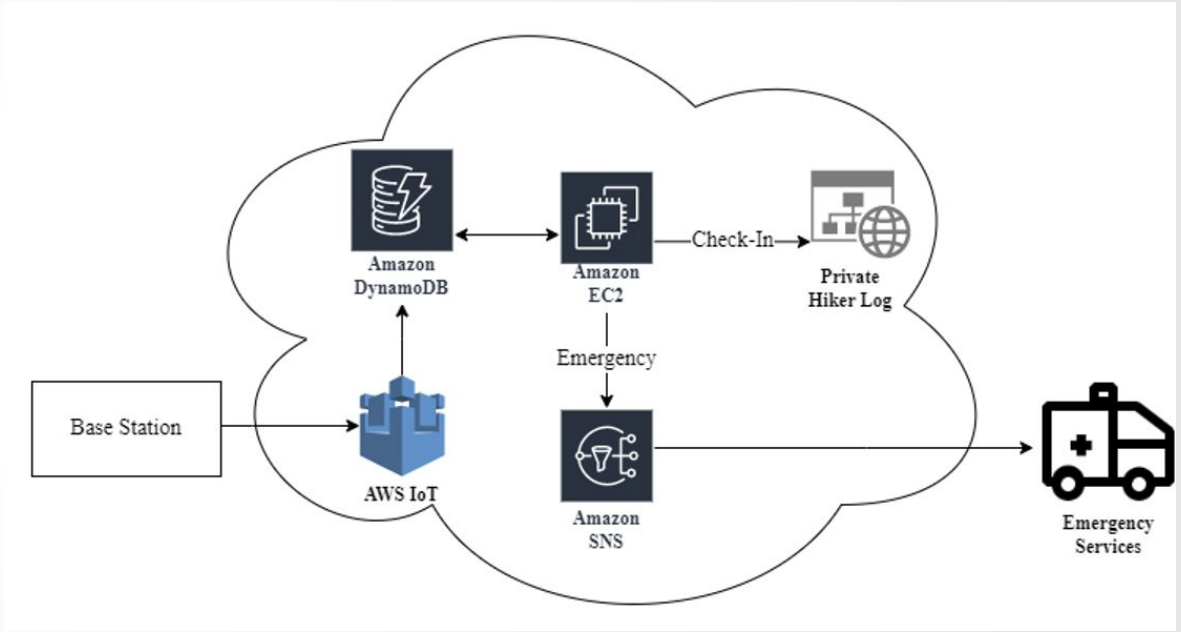
- ESP32 connected to AWS IoT sends MQTT message over WiFi publishing entries to topic
- AWS DynamoDB adds entries to EC2 published to IoT topic

Webpage Hosting

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

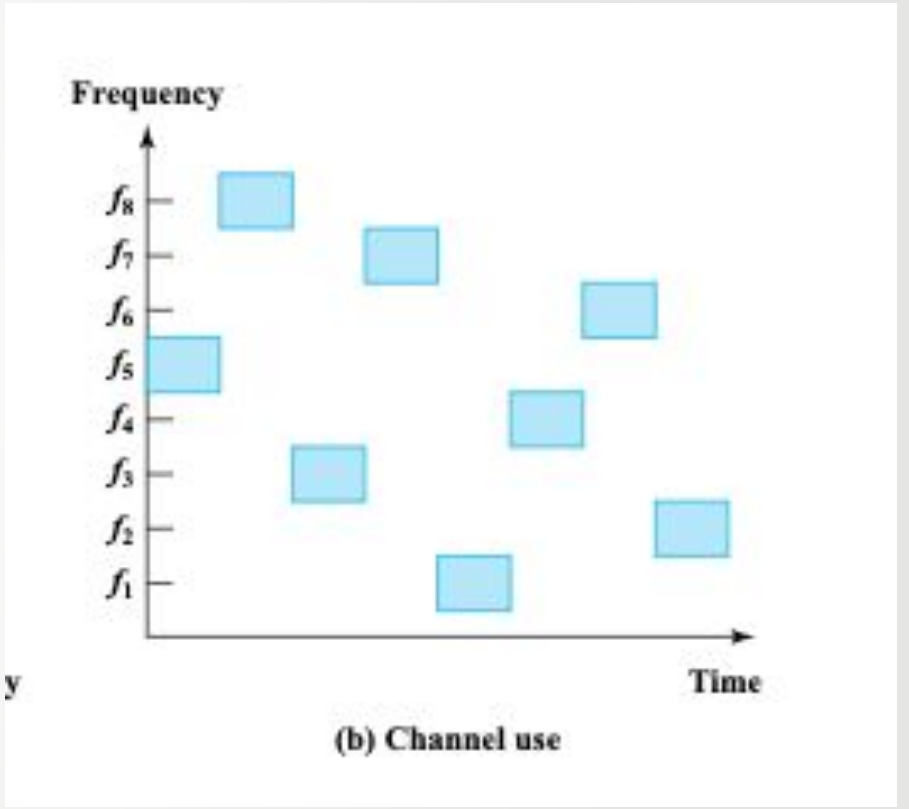
Cloud Security

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

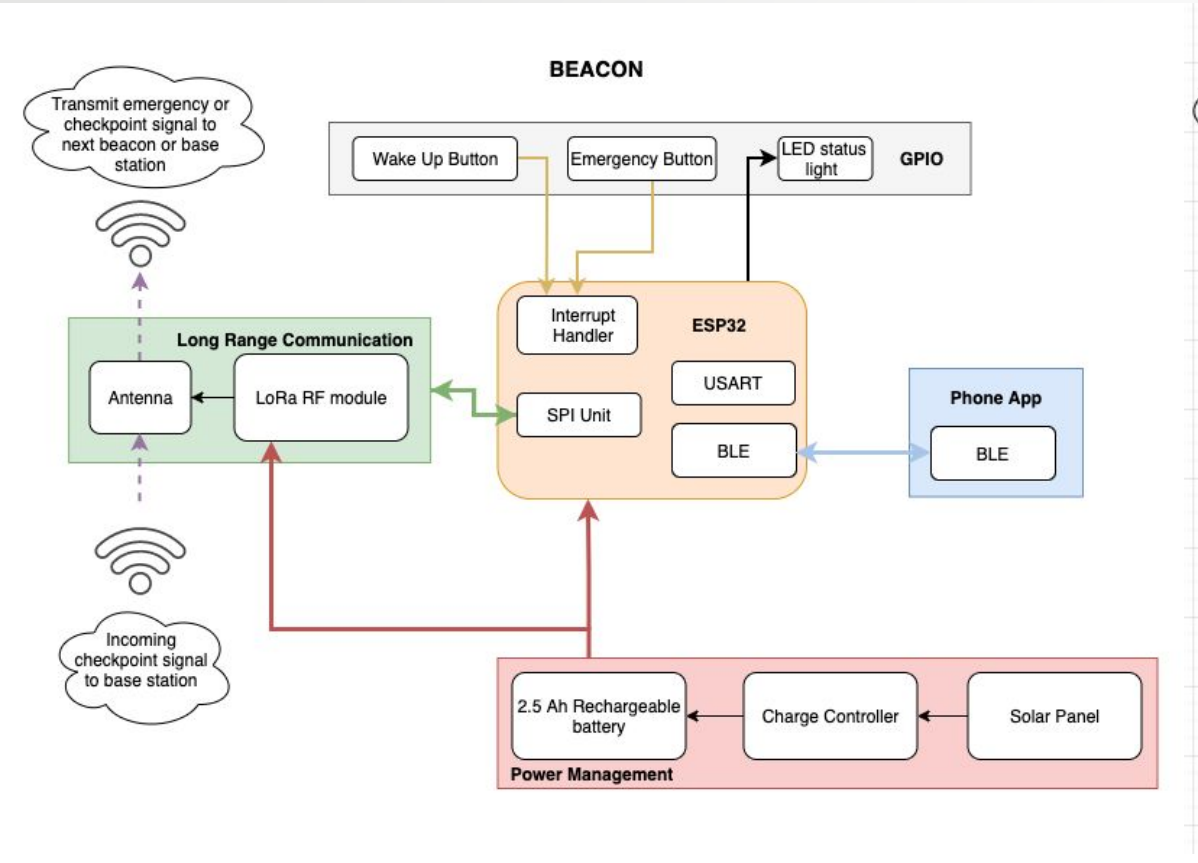


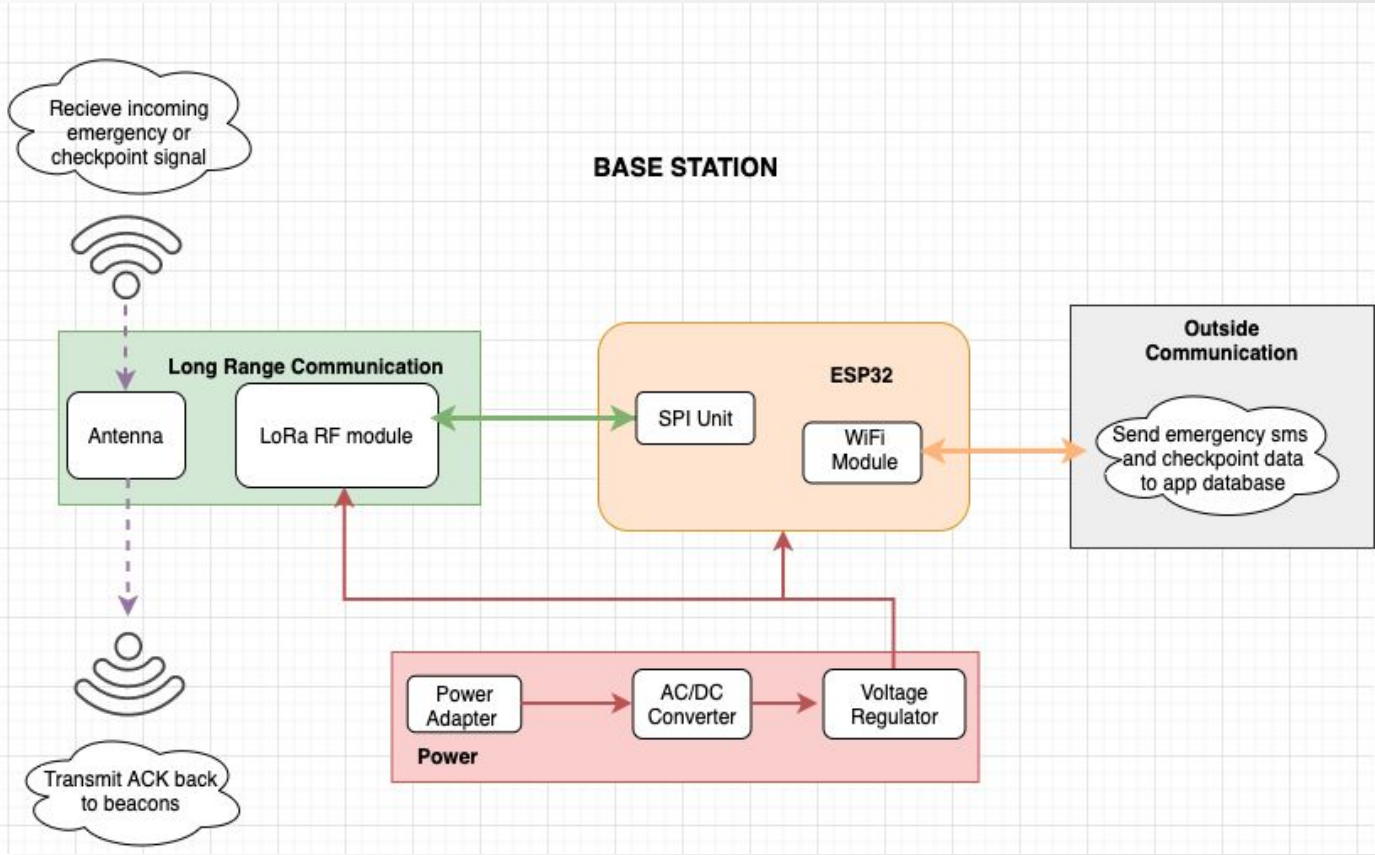
Hardware Security
Hiding the Signal

- Lora uses FHSS (Frequency Hopping Spread Spectrum) and FSK (Frequency Shift Keying)
- Transmitter “hops” packets between different available narrowband frequencies within a specified channel
- Highly resistant to jamming unless the adversary has knowledge of the pseudo-random hopping pattern or hopping Algorithm
- Used in Military Applications

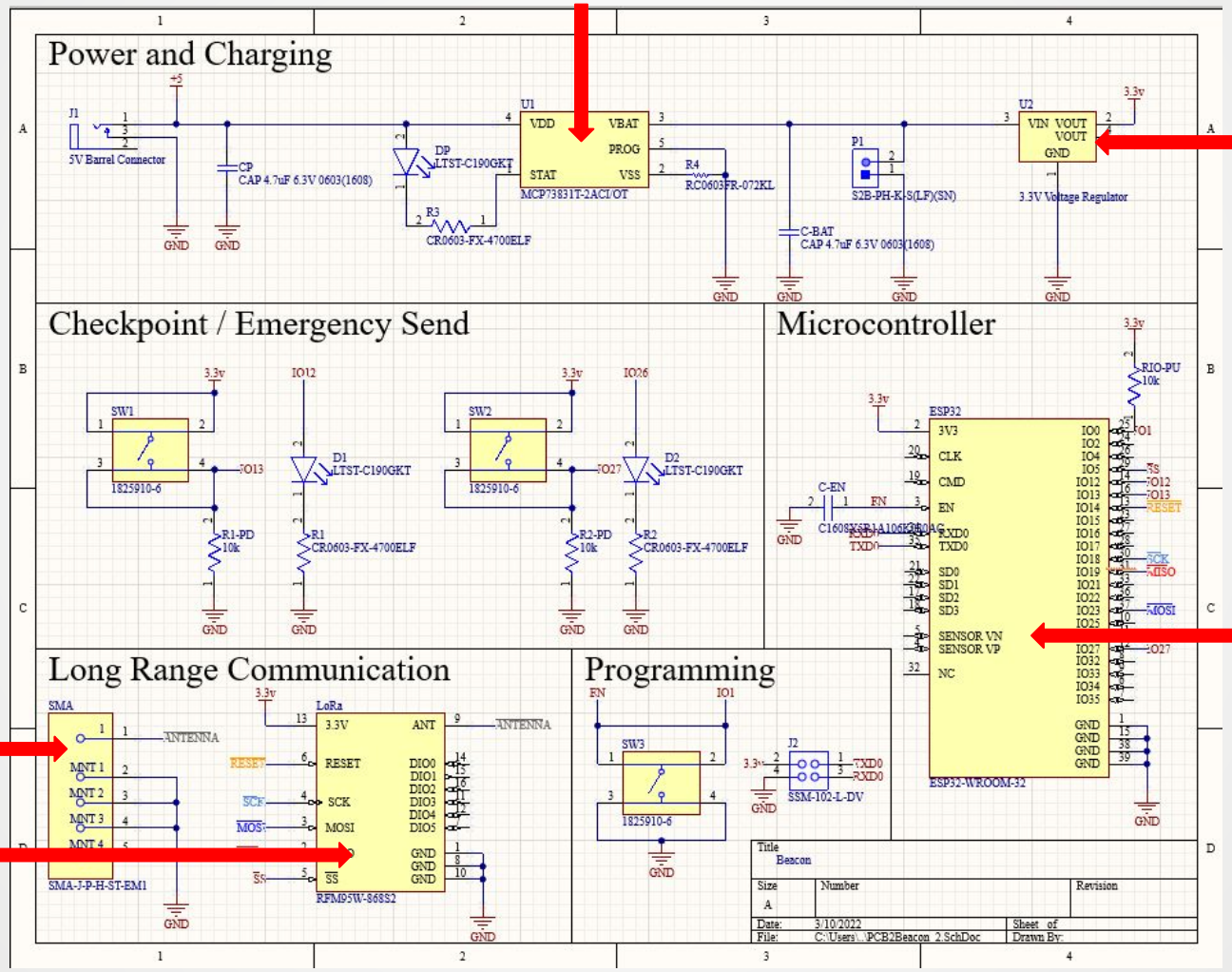


Hardware Diagram

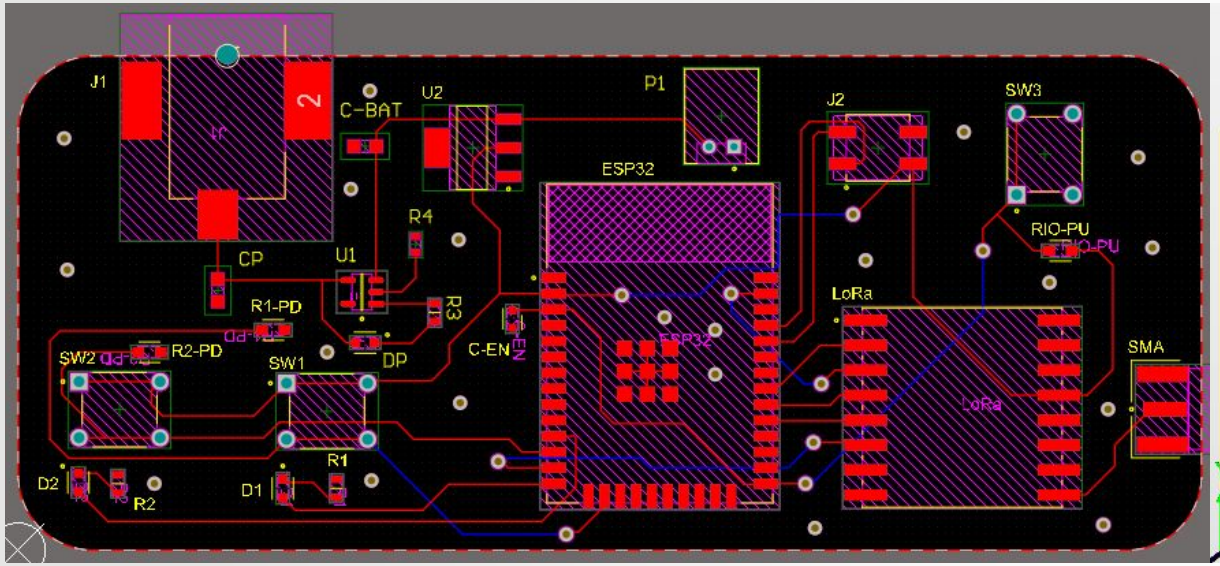


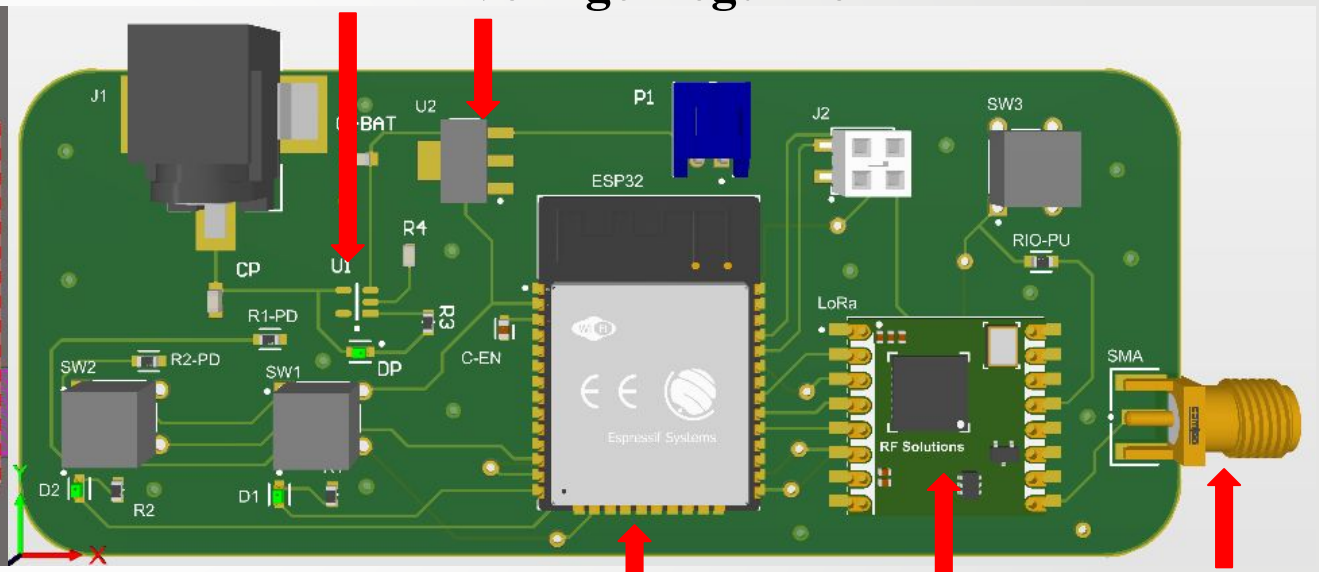


Beacon Schematic

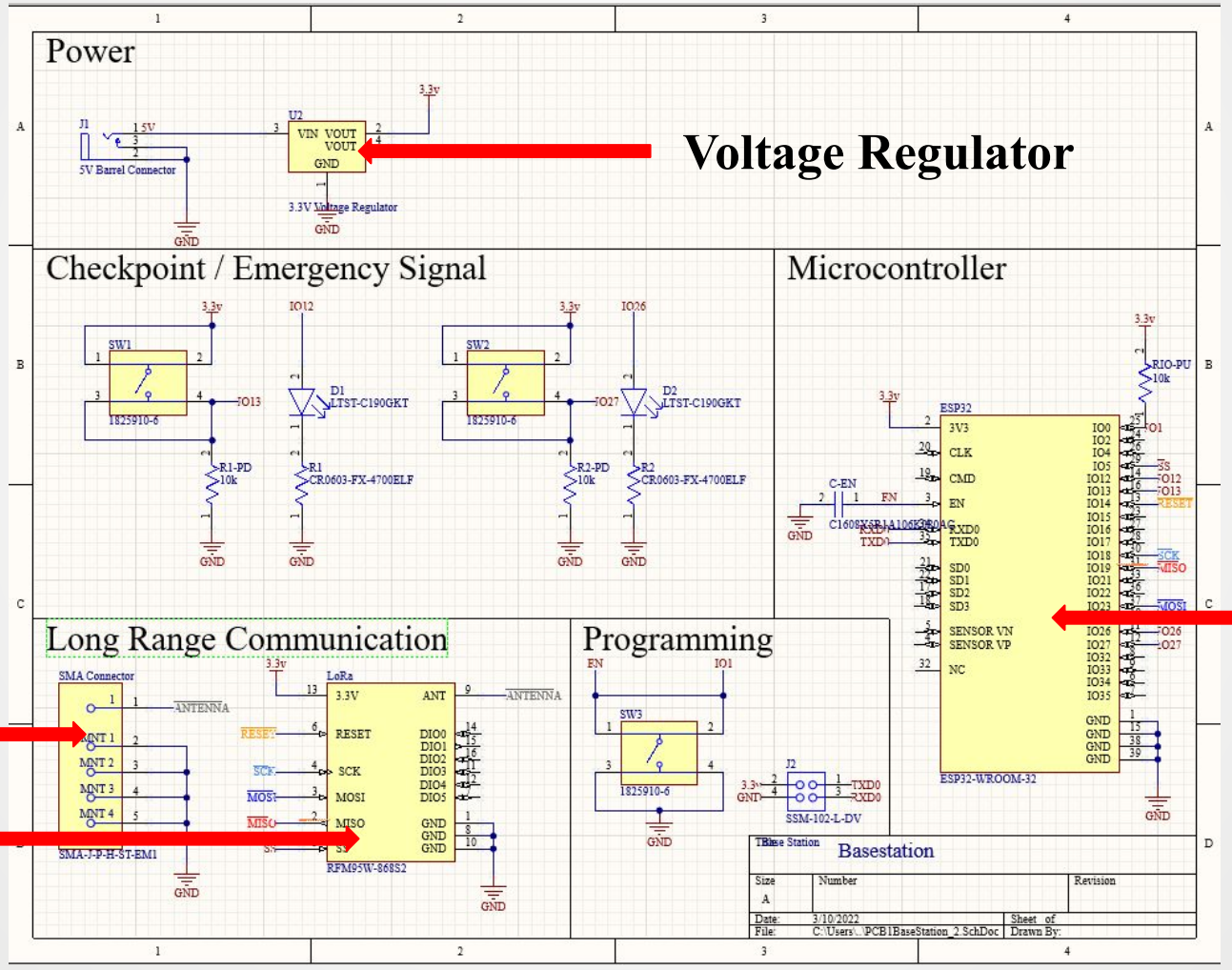


Beacon PCB

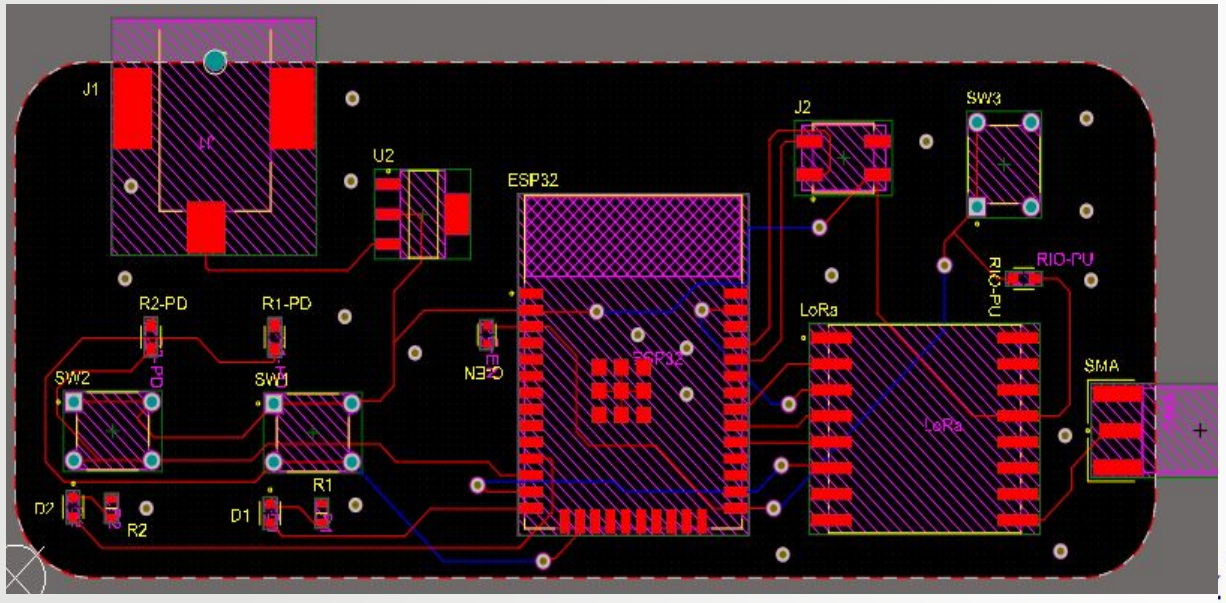

J1
C-BAT
U2
P1
J2
SW3
ESP32
R4
RIO-PU
CP
U1
R1-PD
LoRa
SW2
R2-PD
SW1
DP
C-EN
SMA
D2
R2
D1
R1

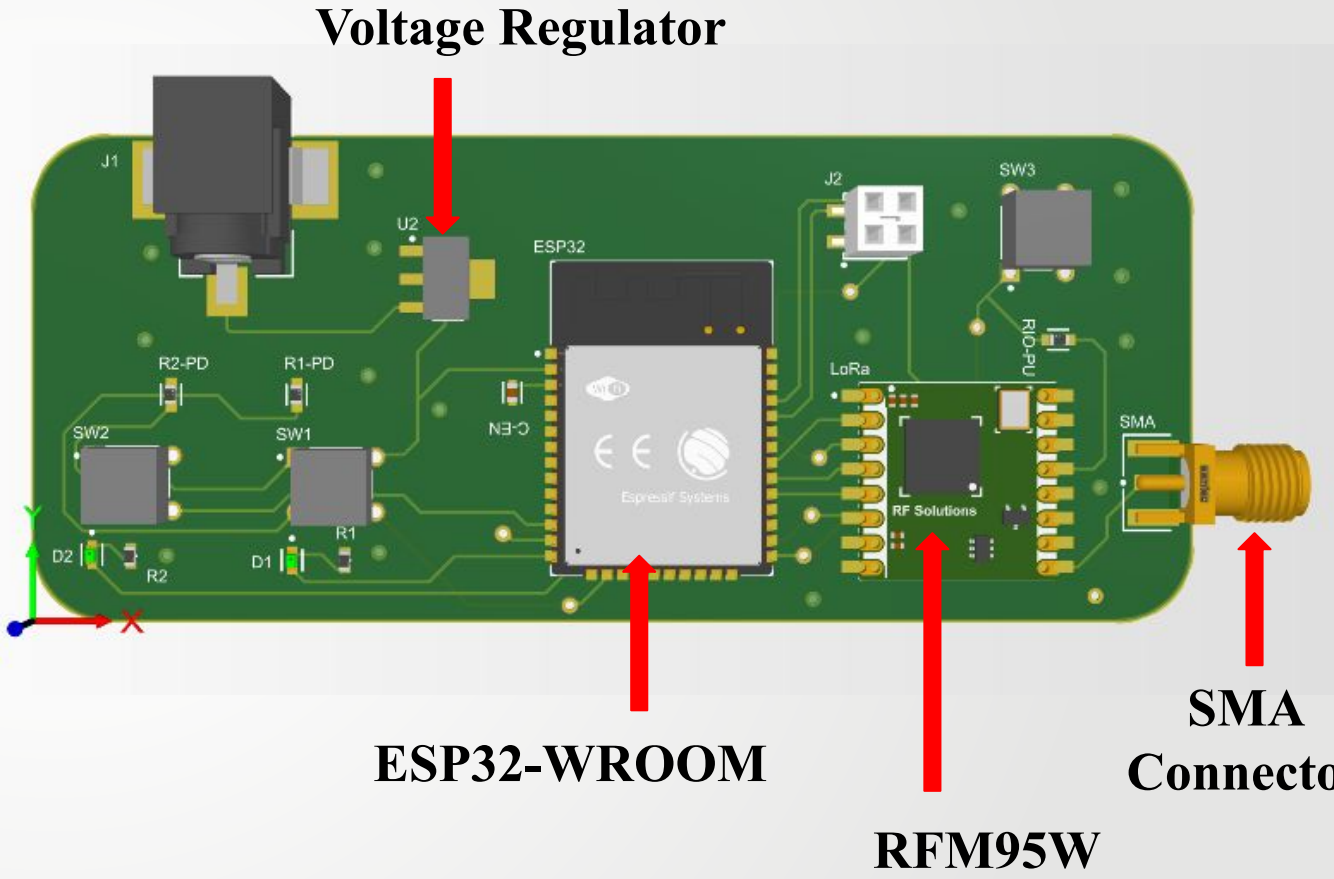

Charge Controller IC
Voltage Regulator
J1
C-BAT
U2
P1
J2
SW3
ESP32
R4
RIO-PU
CP
U1
R1-PD
LoRa
SW2
R2-PD
SW1
DP
C-EN
SMA
D2
R2
D1
RF Solutions
ESP32-WROOM
RFM95W
SMA
Connector

Base Station Schematic



Base Station PCB





NeverLost Demo Plan

Subsystems:

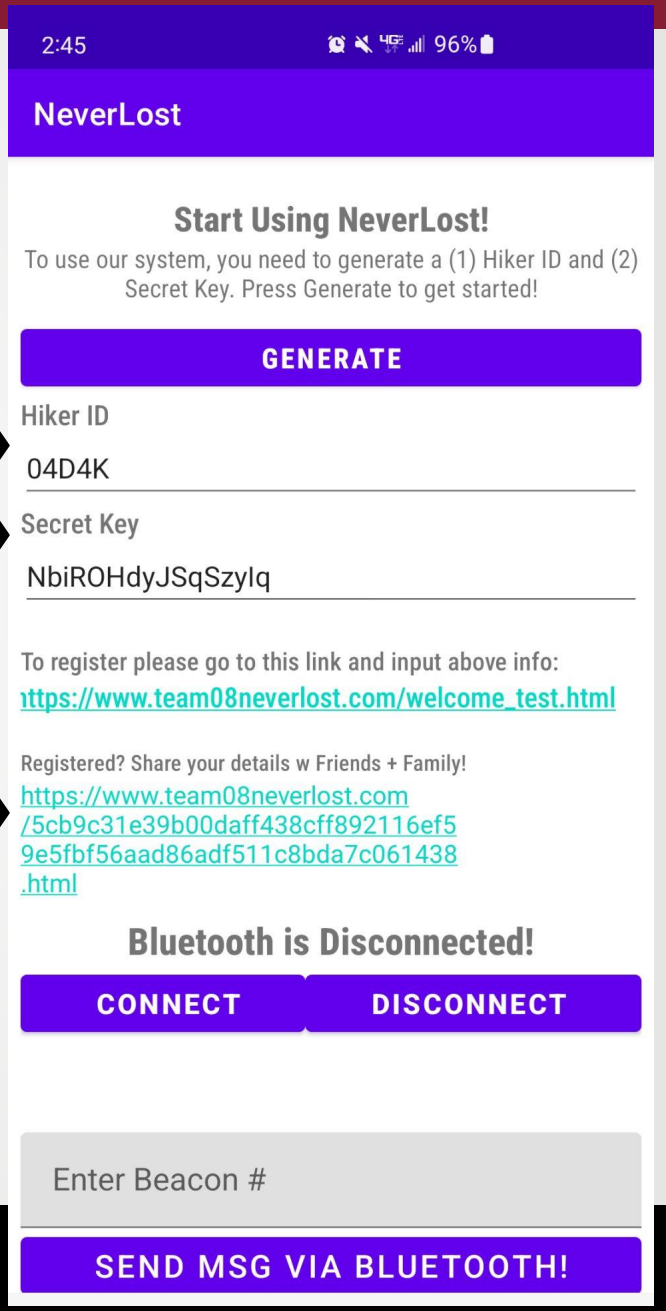
- Hiker Registration
- Simulate Check-In(s) → Hiker Log Table
- Simulate Emergency Signal Transmission → Location Coordinates via SMS
- Solar

“SOFTWARE SYSTEM” DEMO - Backup

NeverLost Mobile Application Demo

User-Facing

(1) Press *"Generate"* to output
   (a) HikerID: 5-char nonce
   (b) SecretKey: 16-char nonce
(2) Welcome Page for registration of (a), (b)
(3) Begin connecting to bluetooth / checking-in with input of *Beacon #*
   (a) Share check-in information with friends & family!



NeverLost Mobile Application Demo

Back-end

(1) Generates (a), (b) upon *"Generate"* click

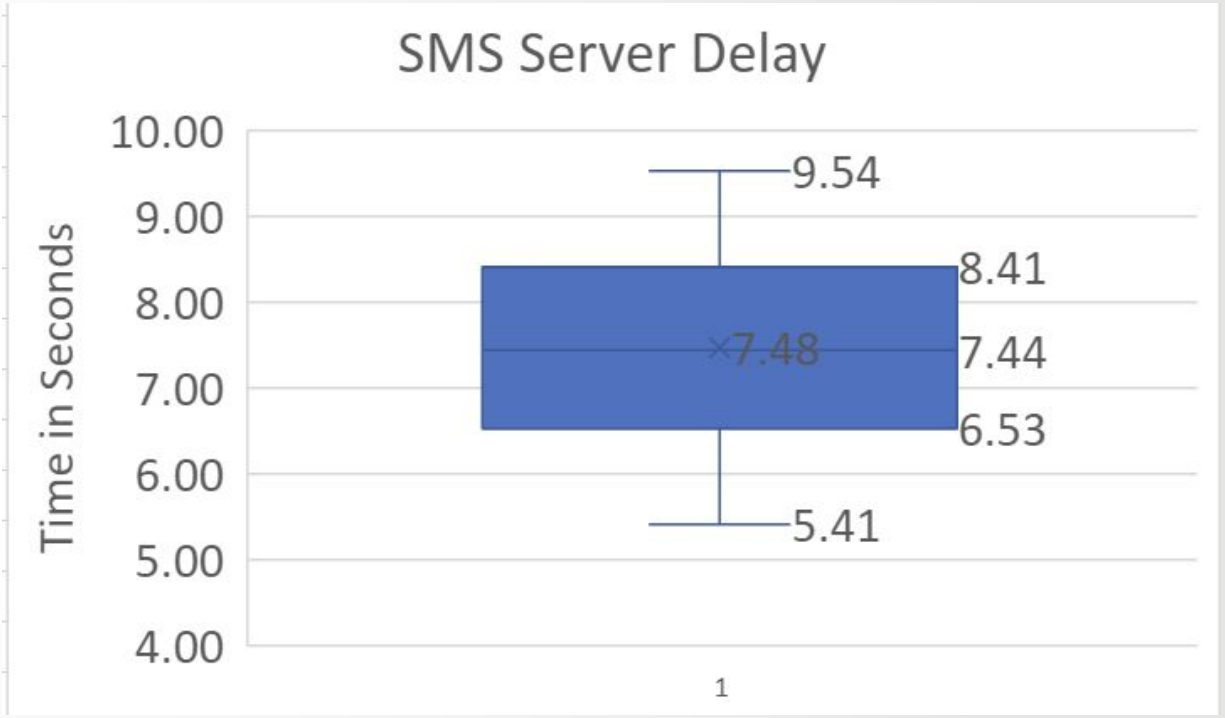
(2) Concatenates
HikerID + *"Success"* + *Check-In DateTime(MMddyyyyHHmm)* + *Input(Beacon #)* + Padding = plaintext

(3) msgToTransmit = AES(plaintext)

(4) htmlAccess = sha-256(secretKey)

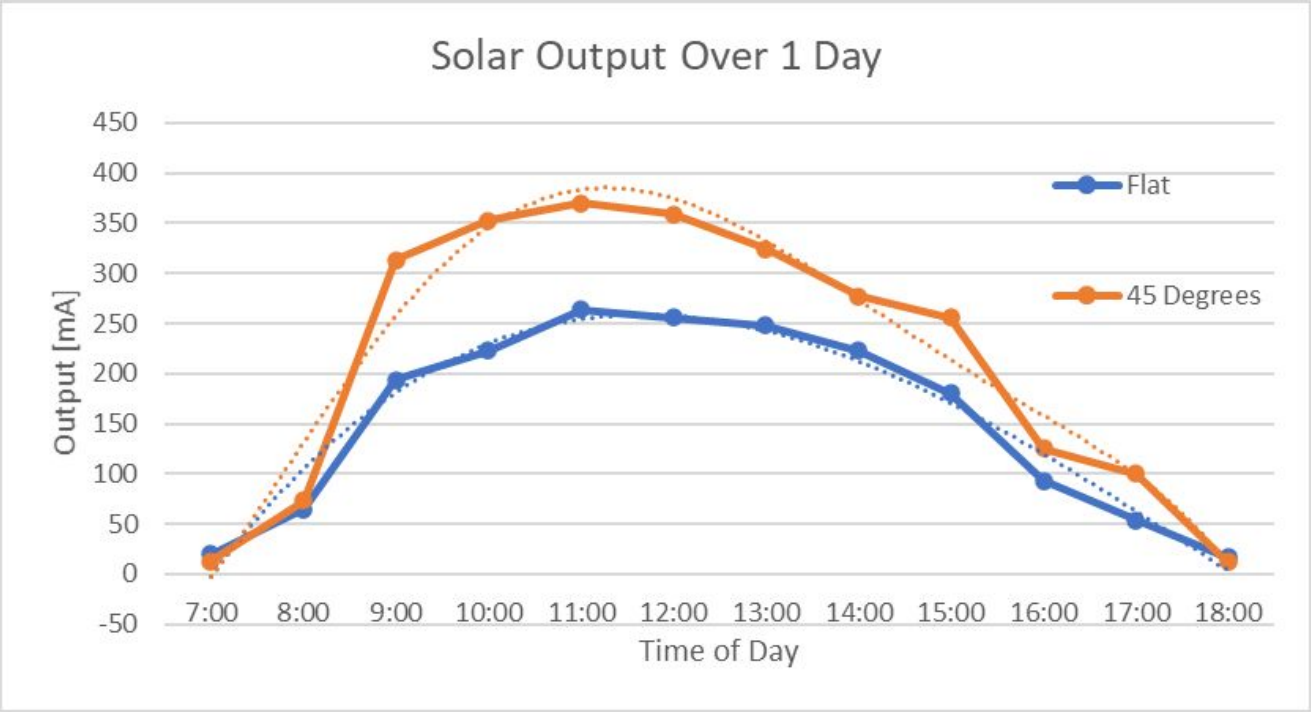
Contact Emergency Services <5 Minutes

- SNS provides durable storage of all messages
- Multiple copies of the message across multiple AWS Availability Zones
- 1000 emergency signals sent from the base station
- 100% Delivered
- 7.48 Average server delay



“BEACON SYSTEM” DEMO @ DISTANCE 500m

Solar Output



- Plot of current output of solar panel to find total power produced in a day
- Measured using solar panel pointed straight to sky and compared at 45° angle

- Integrating over best fit line for output at 45° angle gives **2600 mAh** per day

- With solar panel flat produces **1850 mAh** per day

Power Consumption - Worst Case

Worst Case power consumption is beacon closest to base station - We will call this Beacon 1

- Beacon 1 must transmit and receive (number of beacons) * (number of hikers) times per day
- 1 message consumes **8 µAh**
- total power consumed is:

  (# Hikers)*[(# Beacons)*(8 µAh) + (1.5 mAh)] + Sleep Power

- Power by bluetooth - 88 mA at 1 minute per connection and check in consumes **1.5 mAh**
- 1 bluetooth connection per hiker
- Using estimate when solar panel is flat we can support **100 beacons and 495 hikers in a day**
- On one full battery charge, we can support **100 beacons and 780 hikers**

Improving Reliability

- Testing at our maximum range we found the probability of a successful transmission in 1 attempt is **94.9%**
  - data was collected over **1000** transmissions at various locations on campus

To improve this we use: $P = 1 - (1-p)^N \rightarrow P - 1 = (1-p)^N$ where N is number of retries and (P - 1) is failure rate and p is success rate of a single transmission

We use 2 types of transmissions, each has different level of importance

- For Check-In Data to reach **99.99% success**, we calculate 3 retries - through testing this gives **98.5% success**
- For Emergency Signal to achieve **failure rate below 10^{-8}** we calculate 7 retries - through testing this gives **98.99% success**

FPR Plan

Software

- Visual Improvements to web / mobile User Interface
  - *Website update to include Check-In Map*
- Automatic Data Entry Pipeline
  - from *NeverLost* Mobile App directly to Cloud
- 3D print enclosure

Hardware

- PCB Revisions
- PCB Population
- PCB Testing

NeverLost's FPR Plan

1. User's will download NeverLost's mobile application, generating a HikerID + Secret Key
   a. These specs will be *automatically uploaded* to our AWS DynamoDB instance and their *Hiker Log Webpage* will be generated
2. The user will be able to share their Hiker Log with Friends and Family securely
   a. This hiker log will have desired, *updated UI/UX elements* (interactive map)
3. Hiker will embark on their adventure!
   a. NeverLost's Beacon system will be in a *3D Printer Enclosure*
   b. Send check-in LoRa packet to next beacon/base station
   c. Check-ins sent and updated within 5 minutes
   d. In case of Emergency, Button on beacon allows for EMS transmission (sent via SMS)

Neverlost FPR Demo

2 Beacons, 1 Base Station

1. Emergency Button Press → Through Linear Hop Network → Emergency SMS
2. Check In System Demo
   a. User Registers
   b. Encrypted Msg sent → Through Linear Hop Network → Decrypted and Viewable at Hiker's Log.html
3. Solar Cell charging, indicated by LED

Post MDR Expenditures

Item	Quantity	Unit	Total
Charge Controller	3	0.72	2.16
DIP SMT Adapter	3	2.69	8.07
Order ship			6.99
Extra LiPo Battery	2	14.95	29.9
Order ship			9.93
Power Jack	4	2.3	9.2
ESP32 WROOM	3	3.6	10.8
Voltage Regulator	4	0.5	2
SMD Resistor 10K Ohm	10	0.163	1.63
Switch	10	0.113	1.13
Capacitor	1	0.1	0.1
SMD Resistor 470 Ohm	10	0.017	0.17
Green LED	10	0.0309	0.309
Rectangular Connector	4	0.89	3.56

Item	Quantity	Unit	Total
RFM95W	3	14.44	43.32
SMA Jack Connector	3	3.07	9.21
Header Connector	3	0.41	1.23
Charge Controller	3	0.69	2.07
10 UF Capacitor	3	0.19	0.57
4.7 UF Capacitor	10	0.043	0.43
Order ship			6.99
Tariff			5.84
Stencil	2	7	14
Base Station PCB	10	0.62	6.2
Beacon PCB	10	0.79	7.9
Order ship			39.82
AWS SNS	1500	0.0025	3.75
Custom Domain			12
Grand total			**239.28**

Total Current Expenditures

MDR Expenditures: $274.69

CDR Expenditures: $239.28

Total Expenditures: $513.97

Future Expenditures

PCB Revisions:

Team Responsibilities

Shelby Anderson
- Team Manager
- Application Development / Security

Eric Anderson
- Budget
- Cloud Lead

Louis Gencarelli
- Long/Short-range Communication
- Embedded System Lead

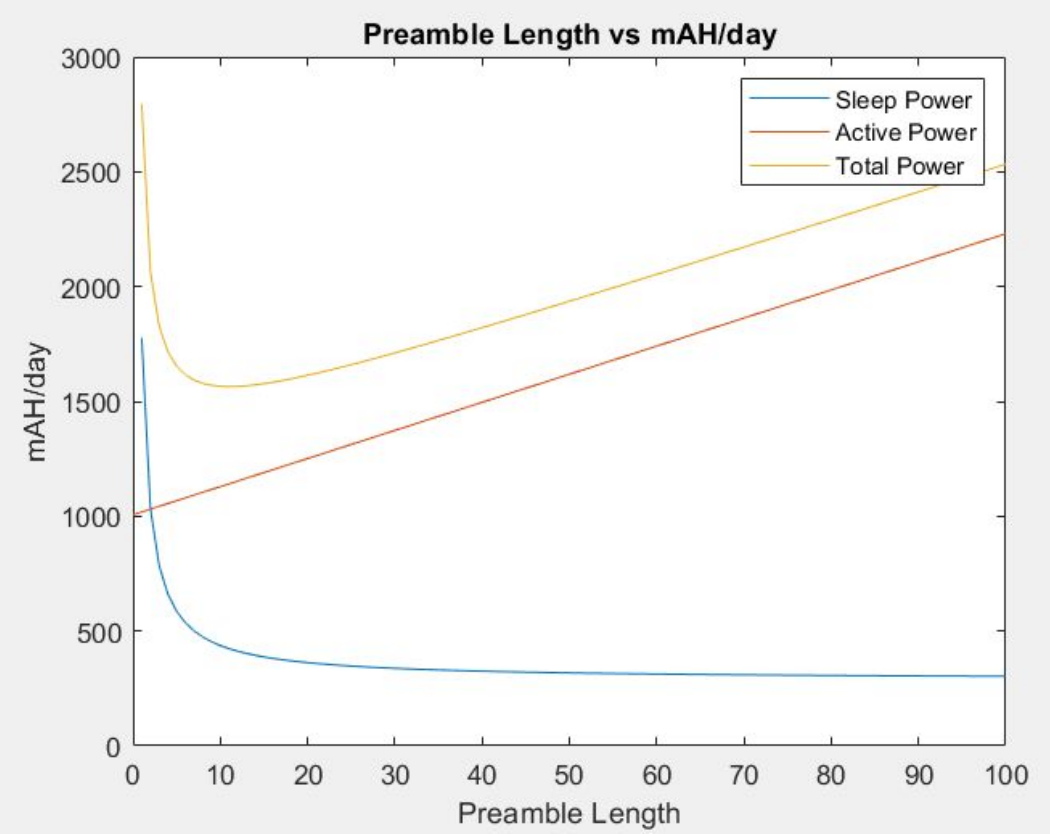
Eric Sutherland
- PCB Lead
- Power Consumption

Gantt Chart

	Task Name	Start Date	End Date	Members	3/21 - 3/25					3/28-4/1					4/4-4/8					4/11 - 4/15					FDR
					M	T	W	TH	F	M	T	W	TH	F	M	T	W	TH	F	M	T	W	TH	F	
Hardware																								
	PCB Revisions	21-Mar	15-Apr	ES + L																				
	Populate PCB	28-Mar	8-Apr	ES + L																				
	Test PCB	30-Mar	15-Apr	ES + L																				
Software																								
	Pipeline from Android to AWS	21-Mar	1-Apr	S+EA																				
	Additional UI Elements	31-Mar	8-Apr	S+EA																				
	3D Modeling / Print / Revise Enclose	4-Apr	15-Apr	S+EA																				
Both																								
	SDP Report	28-Mar	8-Apr	ALL																				
	FPR Prep	11-Apr	15-Apr	ALL																				

Thank you!
Any Questions?

Appendix - Power / Scheduling Justification

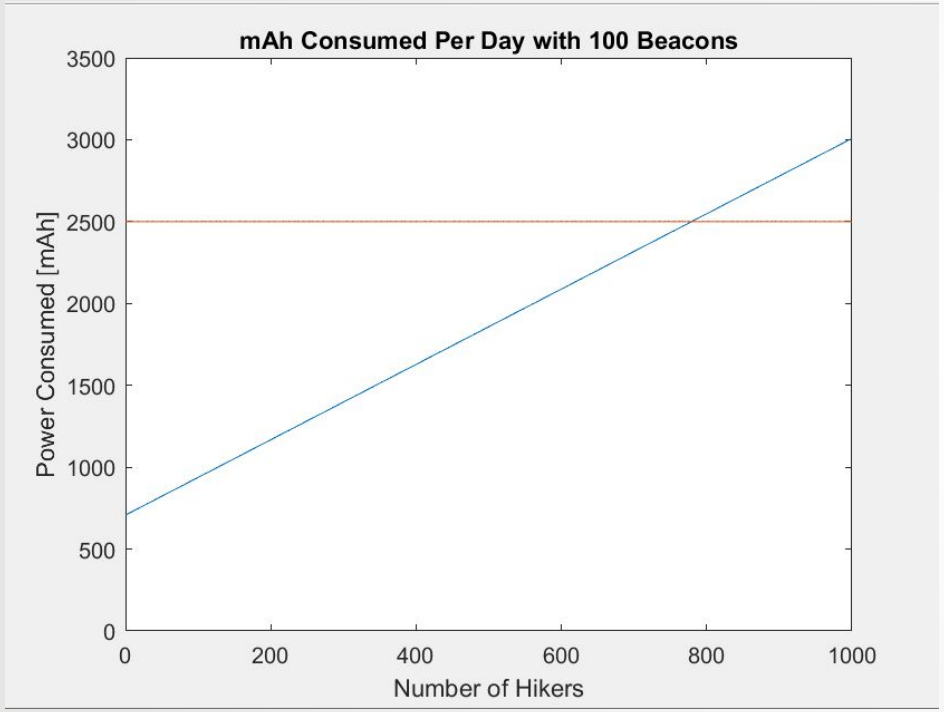


- Created equation for total power related to preamble length
  - equation is based off of worst case scenario (first beacon from base station which will see a message from each hiker and each beacon)
- minimized equation to find optimal preamble length

- 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]
```

Power Consumed per Day



- Plotting power consumed at Beacon 1
- Using a line of 100 Beacons, we can support 780 hiker check-ins / emergency transmissions per battery charge

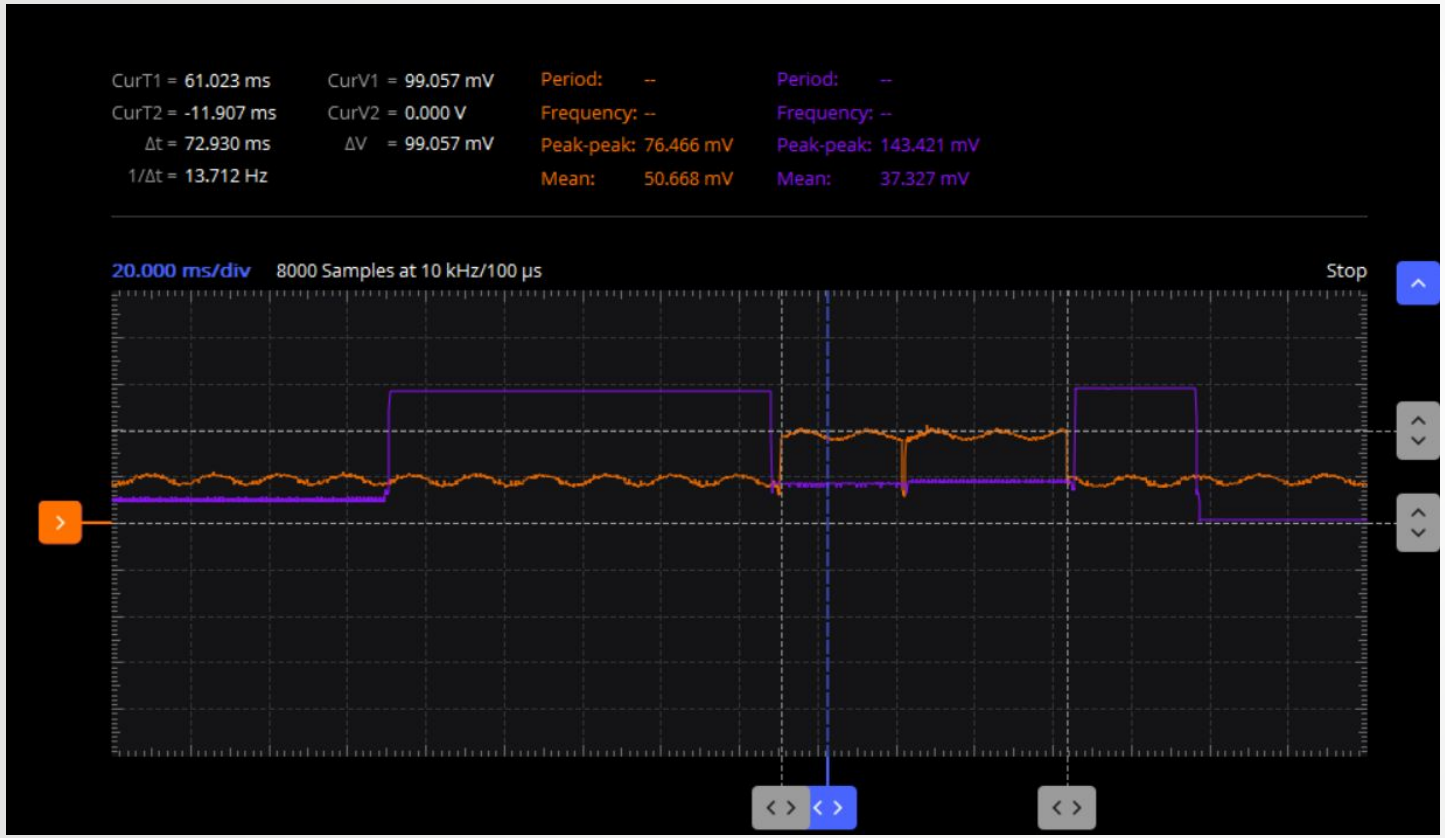
```
p = hikers .* (beacons*m + ble) + (s*percent) + (rx*(1-percent));  % power in mAh
```

Appendix - Power Measurements

Peak Transmit

Appendix - Power Measurements

Peak Receive



Appendix - Power Measurements

Acknowledgement