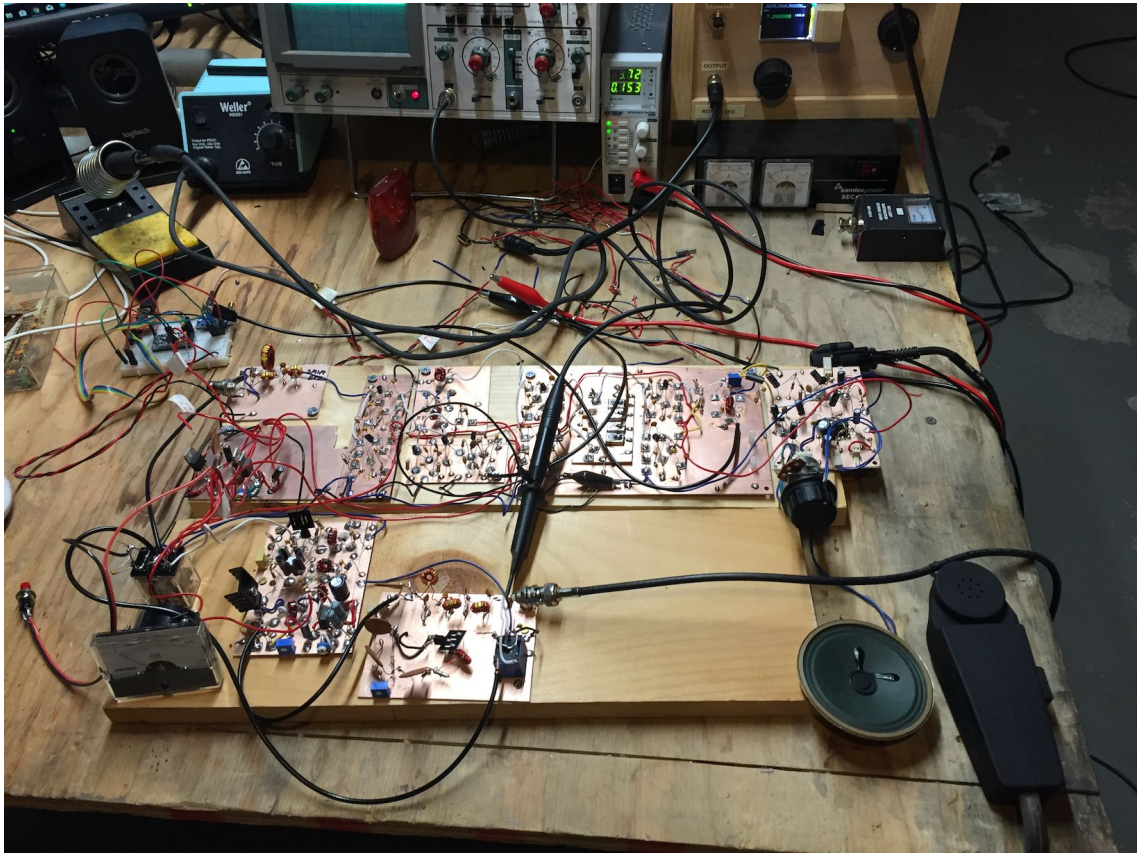
Wellesley Amateur Radio Society

LoRa Birdhouse Mesh Network Project

HamXposition 2022

Bruce MacKinnon KC1FSZ

Homebrew HF Rig

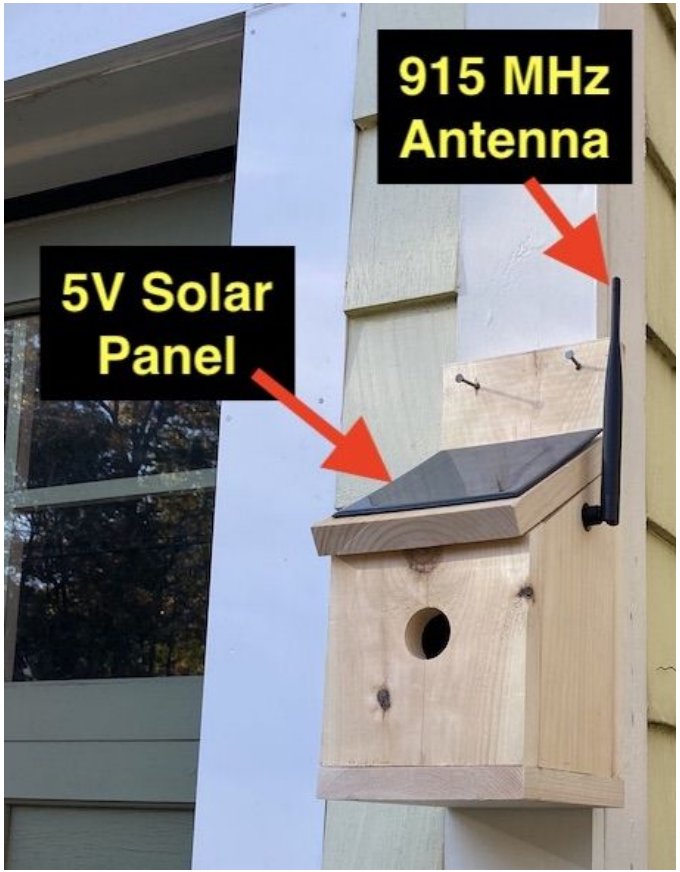


Homebrew HF Rig

Project Goals

Project Overview

LoRa Mesh Birdhouse Station



LoRa Mesh Desktop Station

Why Birdhouses?

Packaging Study - Focus Group

Focus Group Question #1

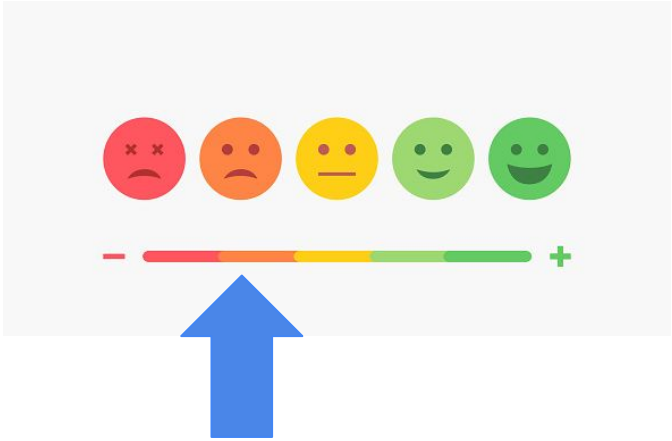
Focus Group Question #1

1. Birds
2. Shelter
3. Cute

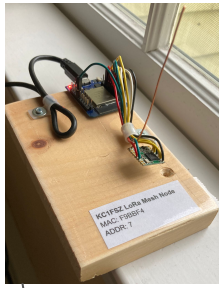
Focus Group Question #2

Focus Group Question #2

1. Controller
2. Surveillance
3. Ham Radio



Simplified Topology Diagram



LoRa Mesh Network

Birdhouse Station

Birdhouse Station

Birdhouse Station

Birdhouse Station

LoRa

LoRa

LoRa

LoRa

LoRa

LoRa

Desktop Station

Gateway Station

Desktop Station

USB Serial

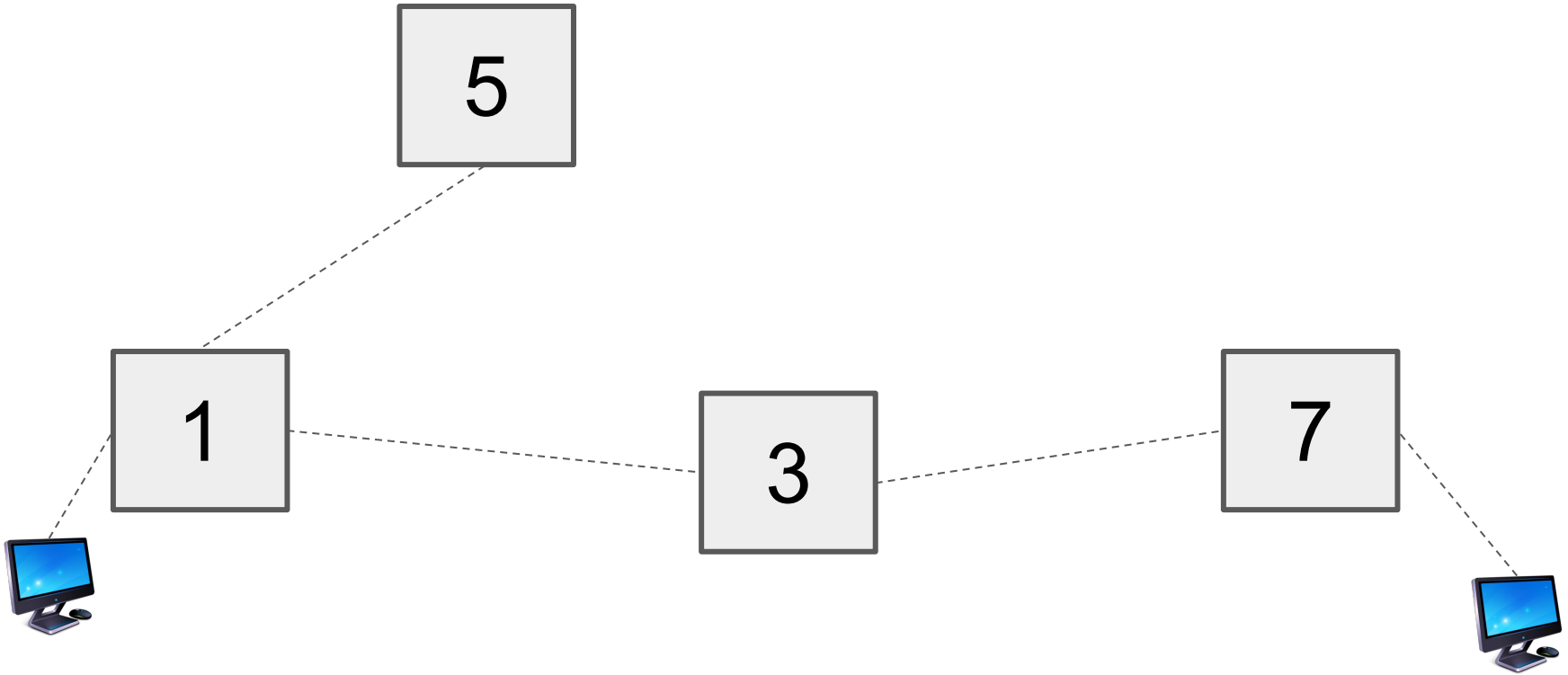
USB Serial

Public Internet

What Can The Network Do? (+/-s)

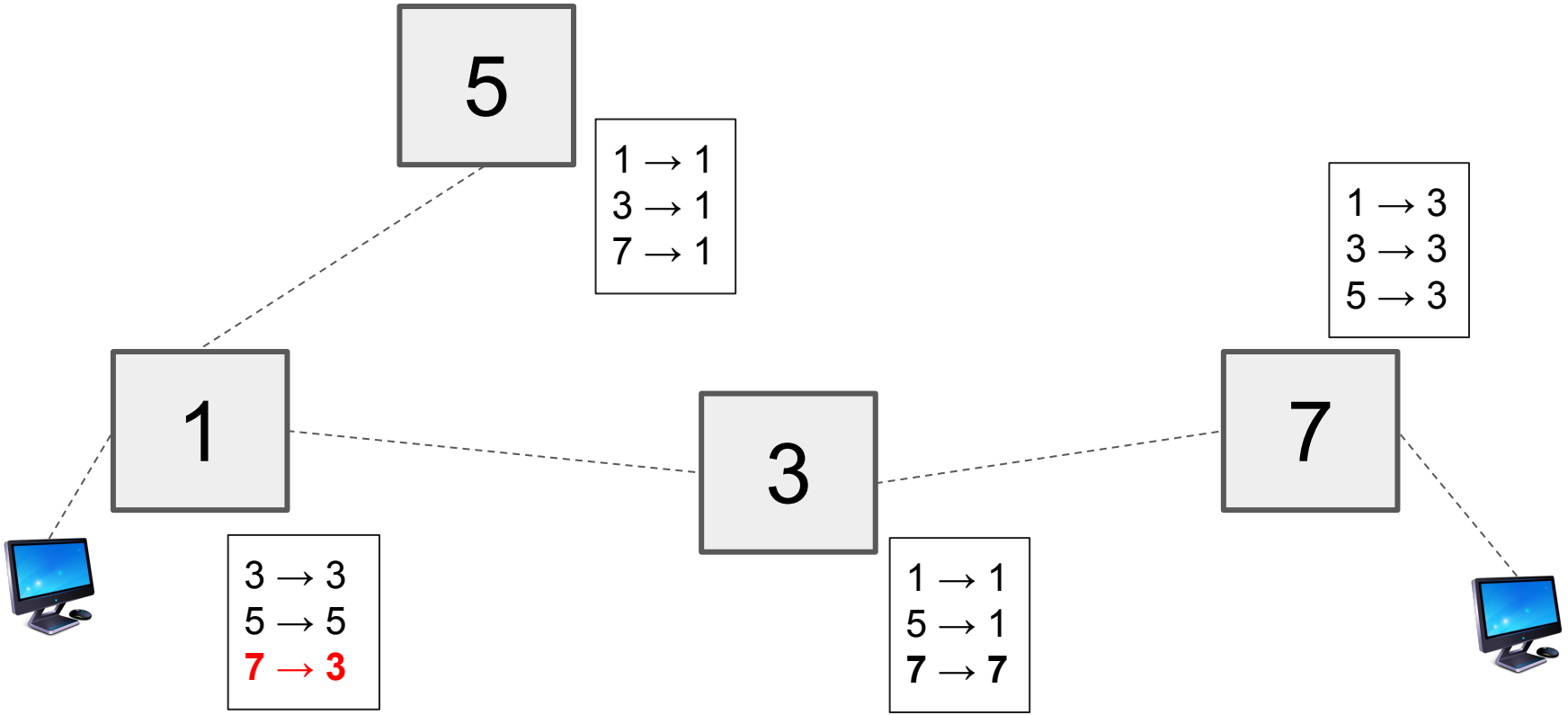
Mesh Networking Basics

Simple Topology



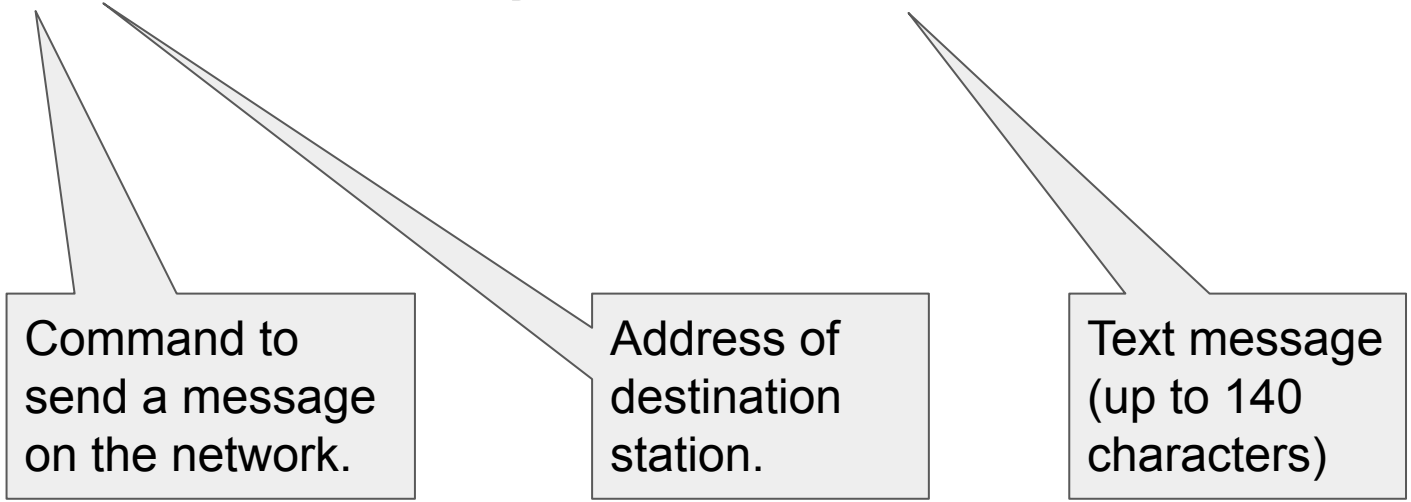
Routing Table Configurations

(Configured in advance)



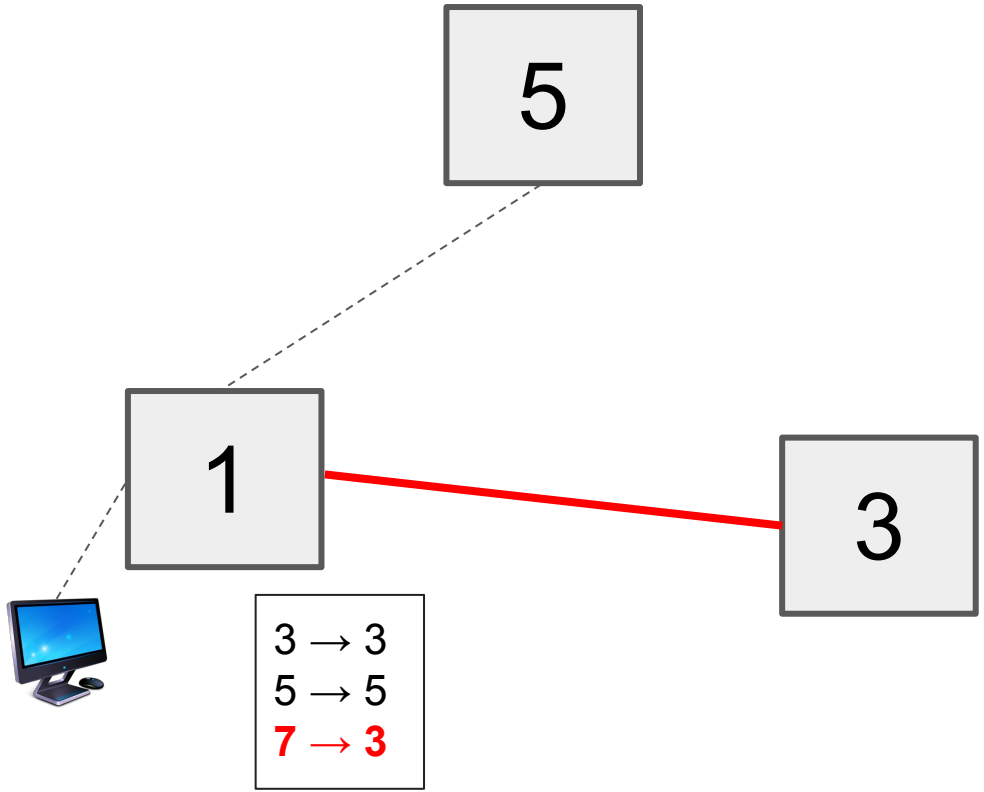
Command to Send Message

```
t 7 “Good morning Charlie, how’s the weather over there?”
```

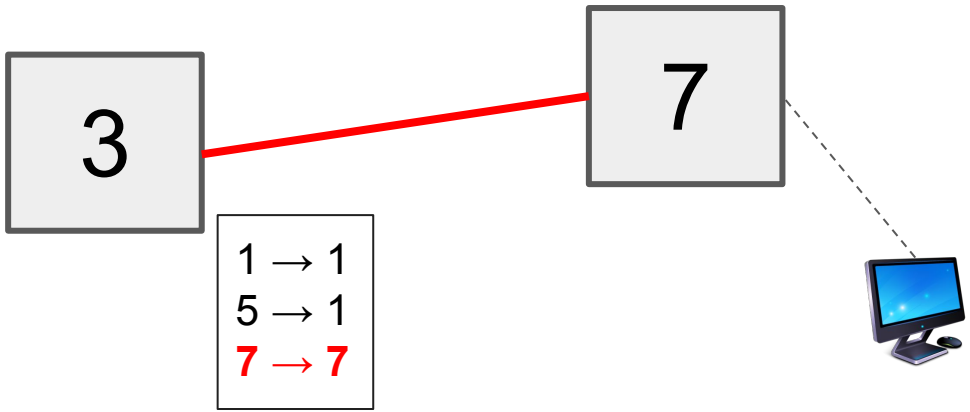


First Hop

Station 3 is used to handle traffic for station 7. Station 5 hears, but ignores traffic.

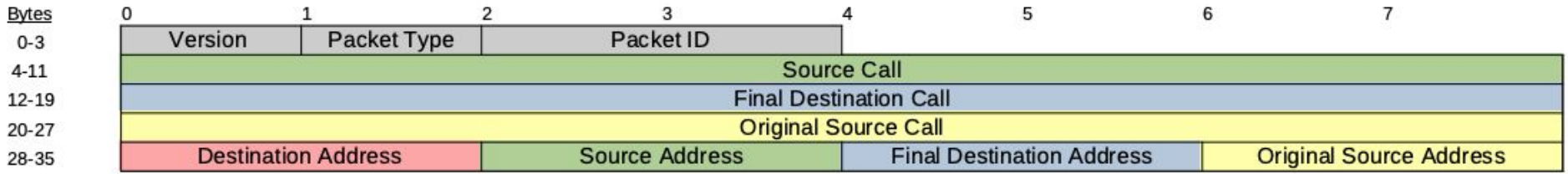


Second Hop



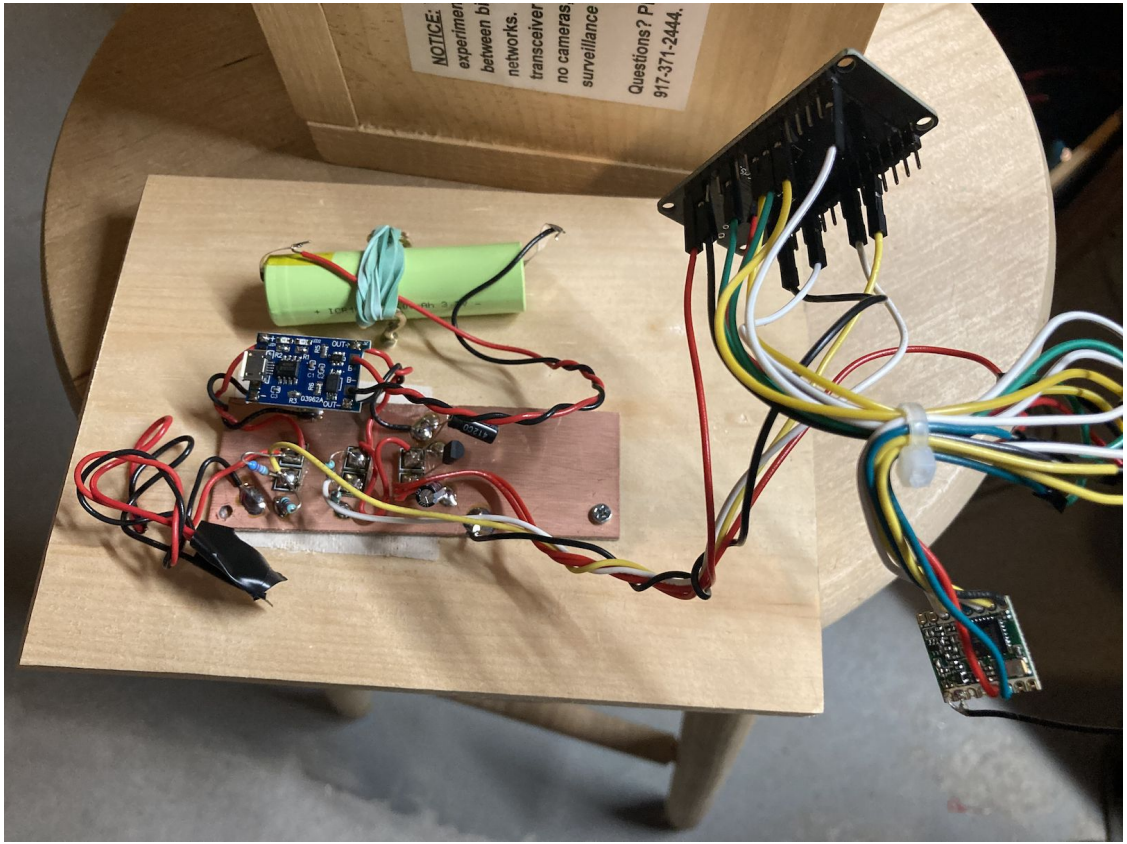
Packet Format

WARS Birdhouse Mesh Packet Header Format (V2)



Radio Stuff

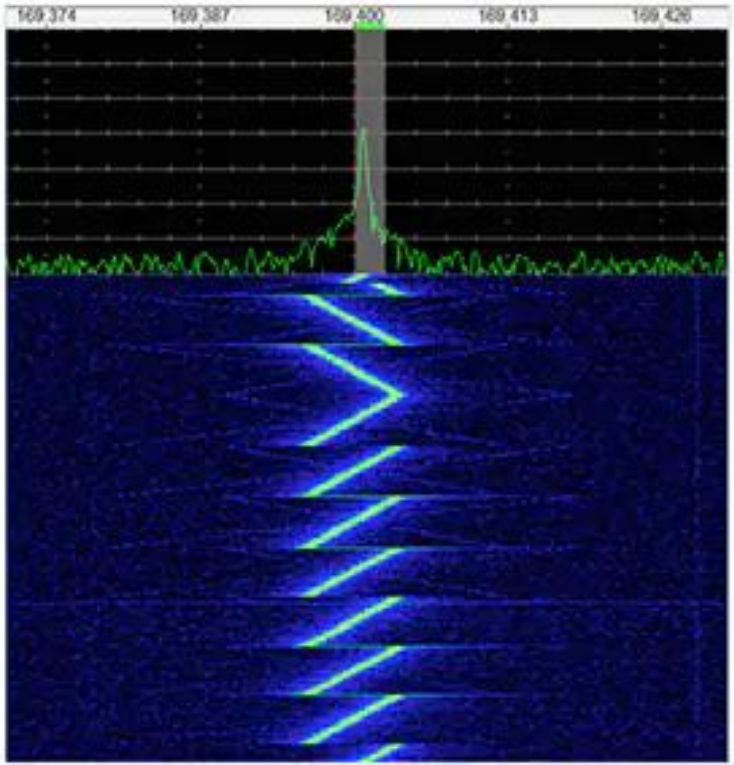
V1 Prototype Hardware

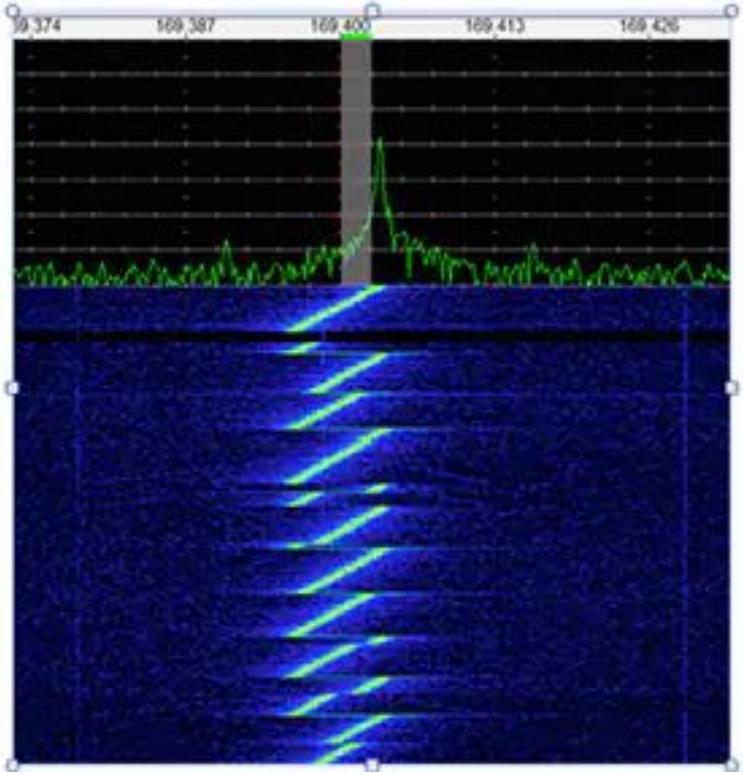


V2 Integrated PCB

Introduction to LoRa™

LoRa Waterfall

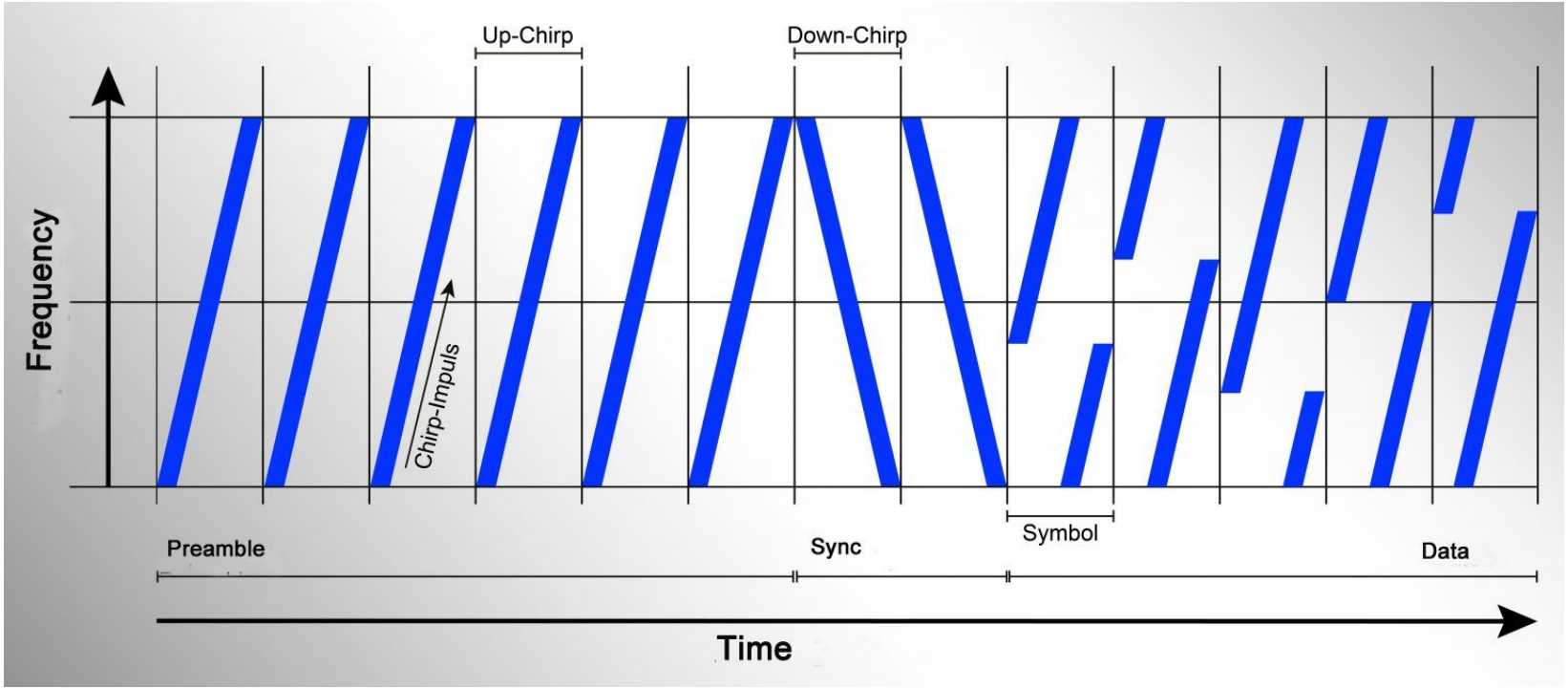




LoRa Modulation/Encoding Details

- Important Parameters
  - Modulation
    - Bandwidth (narrower = slower, more noise immunity)
    - Spreading Factor (higher = slower, more noise immunity, more power required)
  - Coding Rate (controls how much coding redundancy is in the message, data/FEC ratio)
- We are using:
  - 125 KHz
  - SF9
  - CR 4:5
  - Implies a data rate = 1,760 bits per second

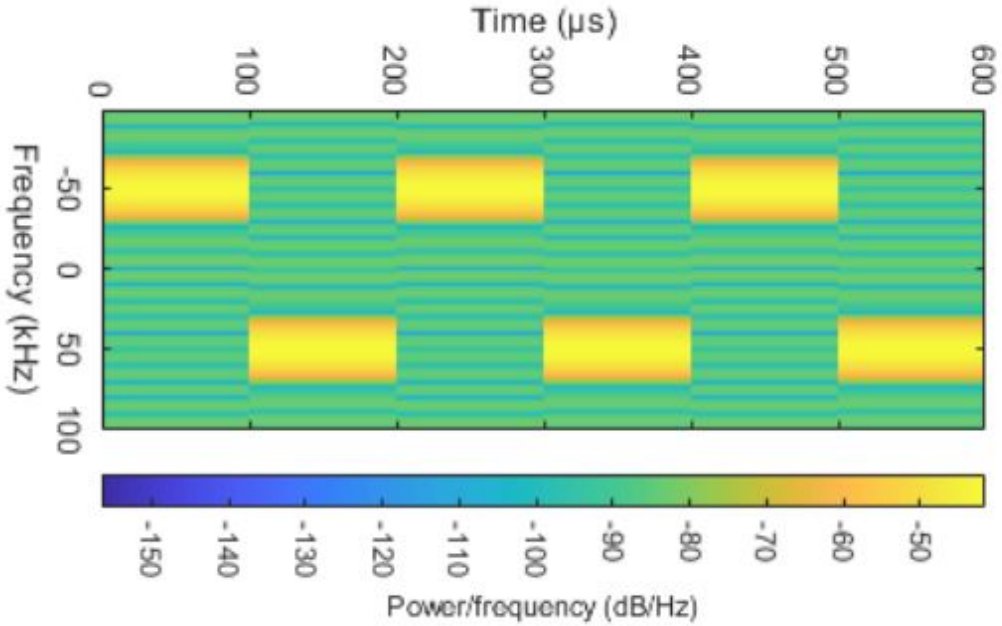
Chirp Modulation



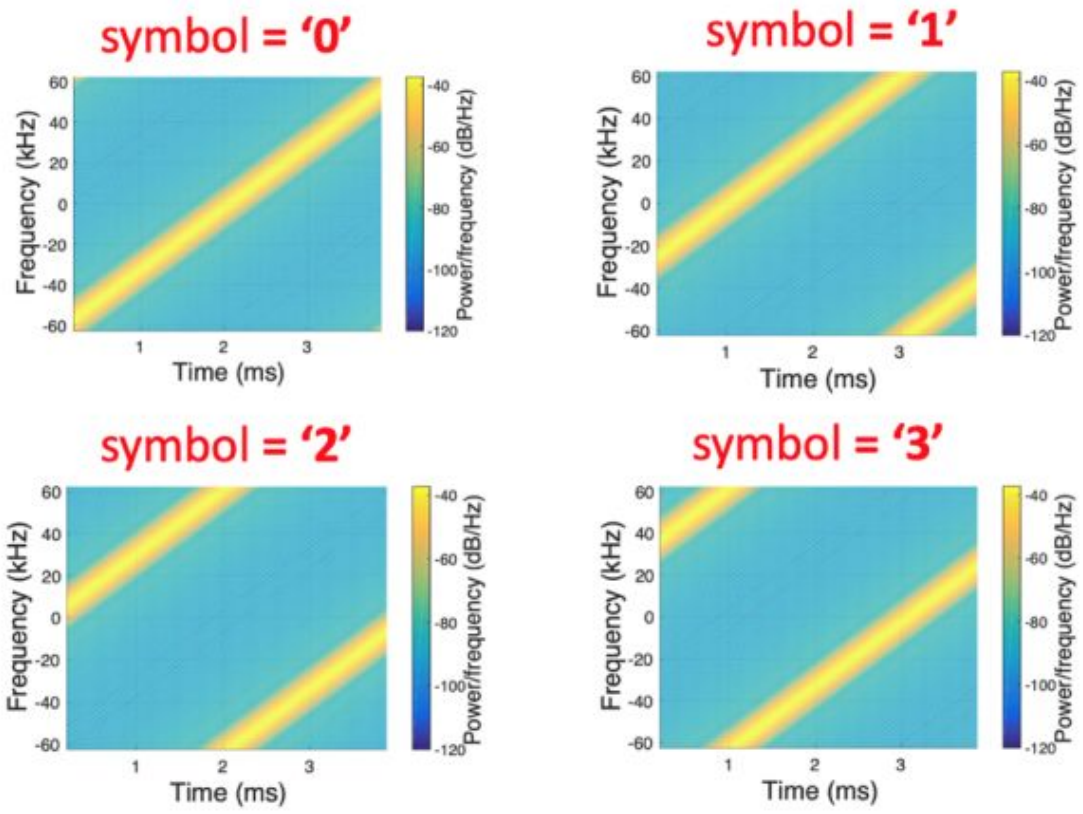
FSK Symbols (this is not LoRa!)

symbol=’0’

symbol=’1’



LoRa Chirp Symbols



LoRa Reverse Engineering

Matt Knight, security researcher

Presented in 2016 at DEFCON and the JailBreak Security Summit

Used GNU Radio

A good paper was also written by grad students at EPFL (École polytechnique fédérale de Lausanne) in Switzerland. Swiss Federal Institute of Technology.

LoRa/SX1276 Physical Layer

(Very little structure, extremely versatile)

Hardware Details

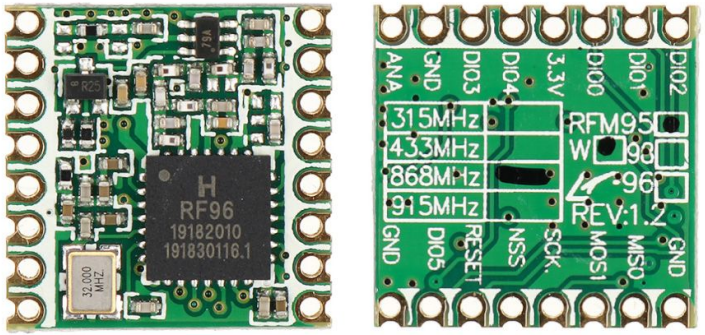
(Champagne Capabilities at Beer Prices)

Semtech SX1276

- Semtech’s first LoRa product
- QFN28 package (SMD)
- +20 dBm (100mW) power amplifier
- 3.3V part
- ~10 mA receive
- ~140 mA transmit
- SPI interface (Serial Peripheral Interface)
- More than 100 internal reigsters
- $7 in 100 units on DigiKey **(Thank you municipal water systems!)**

HopeRF RFM95W Module

- Chinese (Shenzhen) IoT manufacturer
- Integrates Semtech SX1276 with crystal oscillator and power conditioning
- Castellated/through-hole package for ease of mounting
- 3.3V supply
- Approximately $10



Commodity Antennas

- Turns out that cheap 900 MHz antennas are widely available **(Thank You LoRaWAN and Helium Network!!)**
- Most likely colinears: +3dBi

ESP32

Developed by Espressif Systems, Shanghai

32-bit, dual-core, 240 MHz, fully integrated WIFI/BLE

SMD package

Cost ~$2.00 in 100 units on Digikey (**Thank you mass-market IoT!**

ESP32-WROOM Module

ESP32 + flash memory + support components + WIFI/BLE antennas

Fully integrated module (SOIC)

Castellated pads (SMD)

About .5 MB RAM, 1 MB of Flash ROM

+3.3V supply

Cost: ~$3.50 **(Thank you IoT market!)**

ESP32 D1 Mini Module

WROOM module + voltage regulator + USB interface + LEDs

Convenient through-hole package

Cost: ~$7.00 **(Thank you maker mass-market!)**

One of many similar development modules

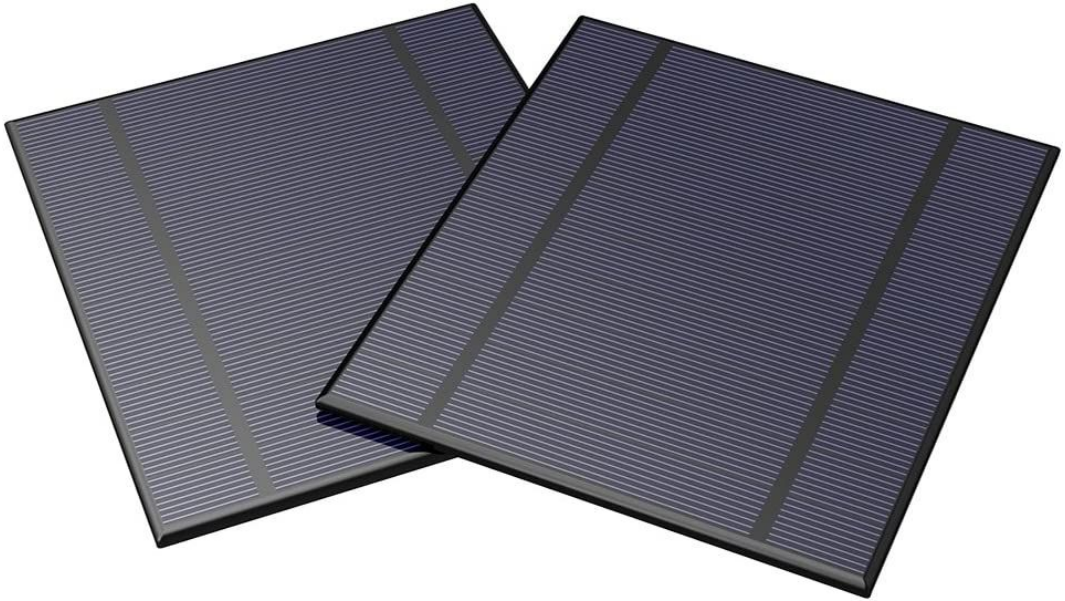
Power is a problem

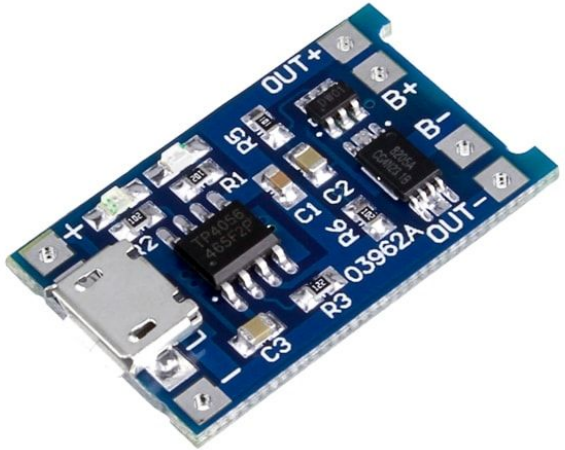
- Full default: ~240mA
- WIFI/BLE disabled: ~120mA
- Clock reduced, LEDs removed, LDO reg: ~40mA
- Deep sleep: ~8mA

Solar Panel and Charge Controller

2.5W, 4V solar panel, $6.50 each

TP4056 Li-Ion charge controller, $0.75 **(Thank you cheap walkway lights @HD!)**





Battery

18650 Li-Ion battery

~3.7V, ~2,600 mAh

Widely used, commoditized, ~$6.00 **(Thank you E-Cigarettes Smokers!!)**

Forest Products

Douglas Fir

Inexpensive, biodegradable, and fully renewable, through good forest management.

(Thank you Mother Nature!)

Power Management

Snow Birds

Software Notes

Future Directions

14’ Tower - Height Matters!

Thank You For Your Interest!