

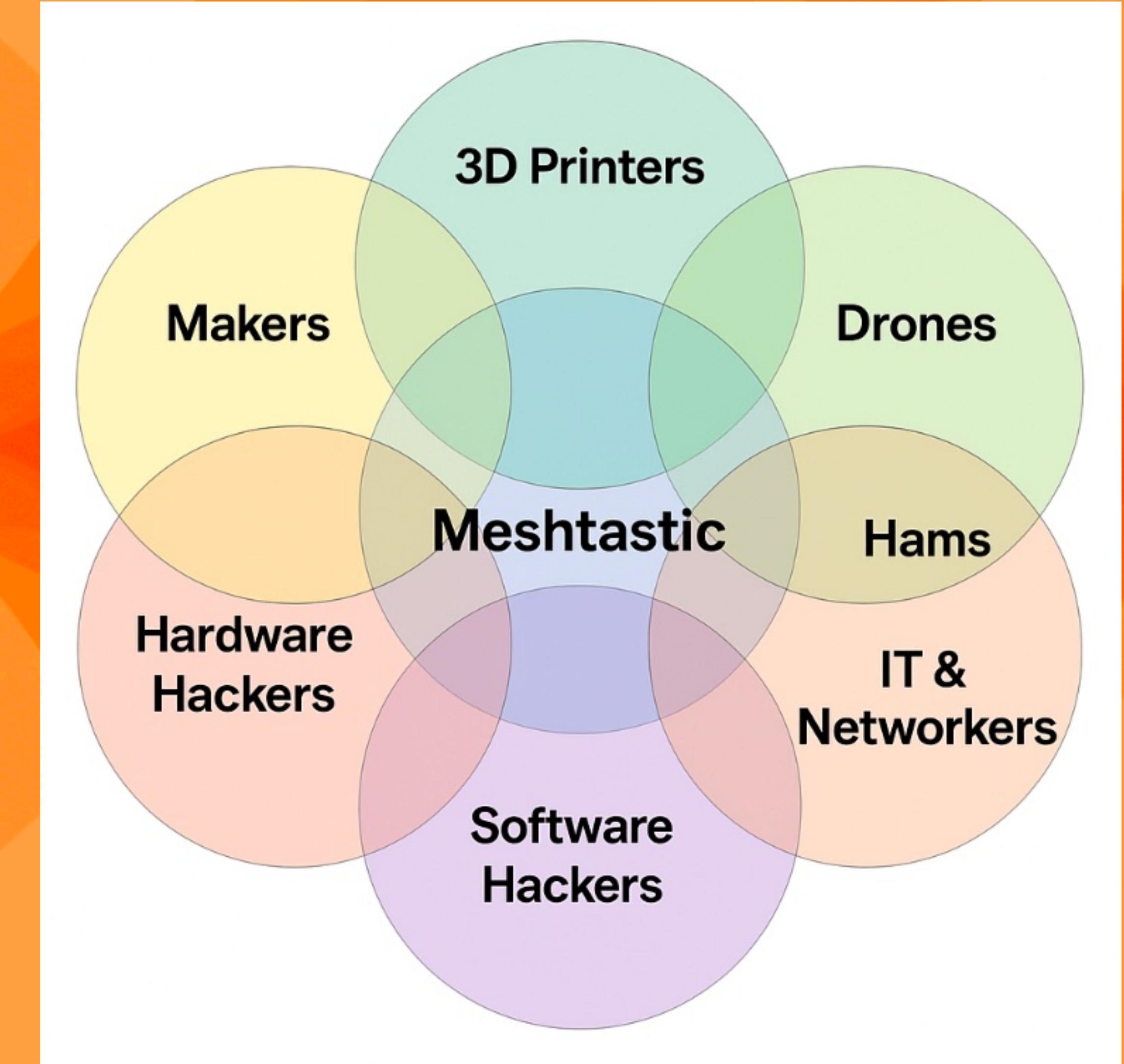
# **Meshtastic: What's In It For Me?**

**Bob Van Valzah, ke9yq, February 23, 2026**

**For DuPage Amateur Radio Club**

# What's In It For Me?

- Discover 900MHz!
- Sense of community
- Feels like a “new thing”
  - Innovation at Internet speed
- Easy and inexpensive to get started





# Architecture & Lingo

**Transports**

LoRa Radio

MQTT over IP

UDP Multicast

Meshtastic Firmware Running on a “Node”

**Streams**

Bluetooth

IP Over WiFi

Serial Over USB

**Meshtastic Clients**

Web Client

iOS Client

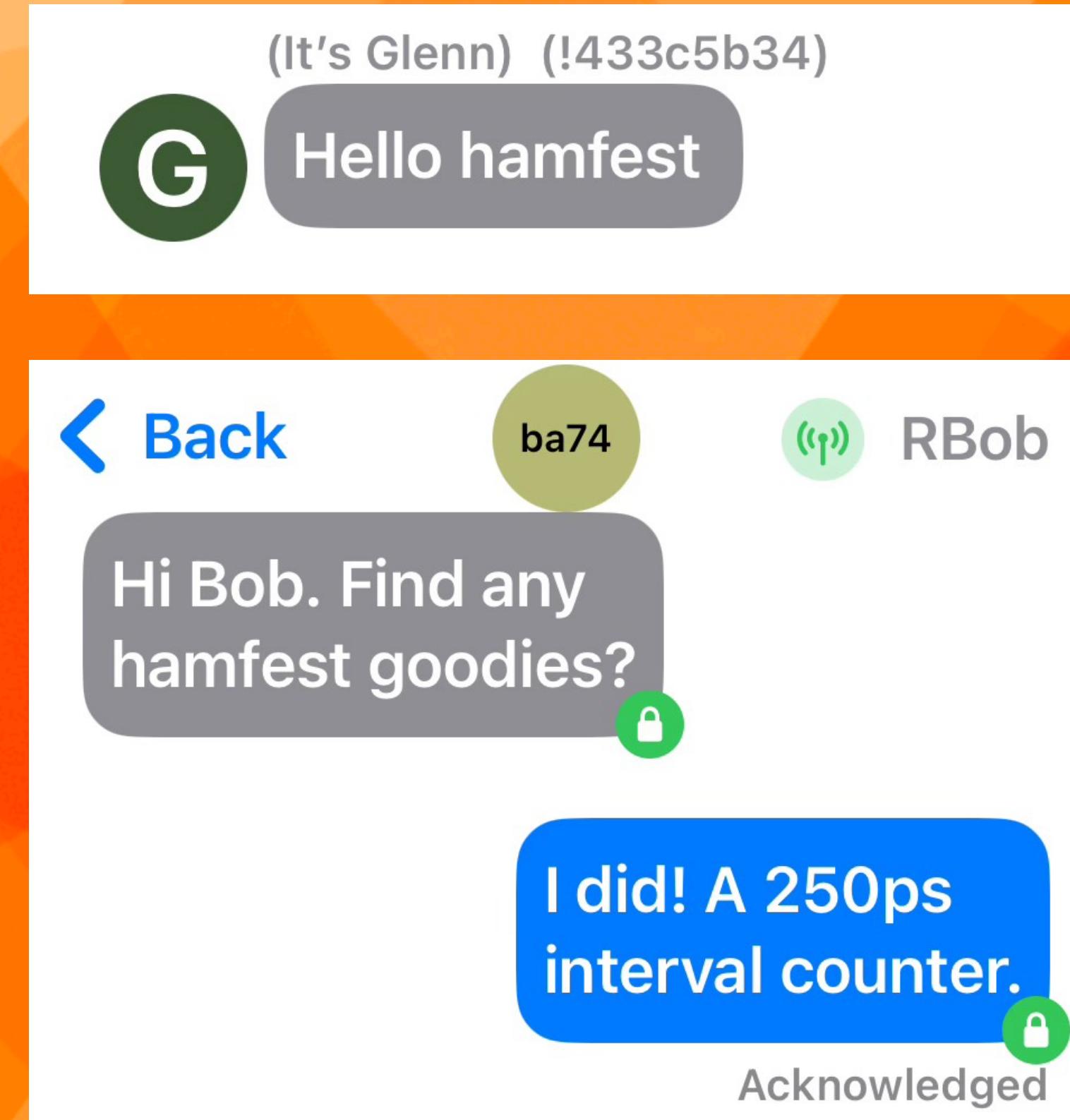
Android Client

Python CLI Client

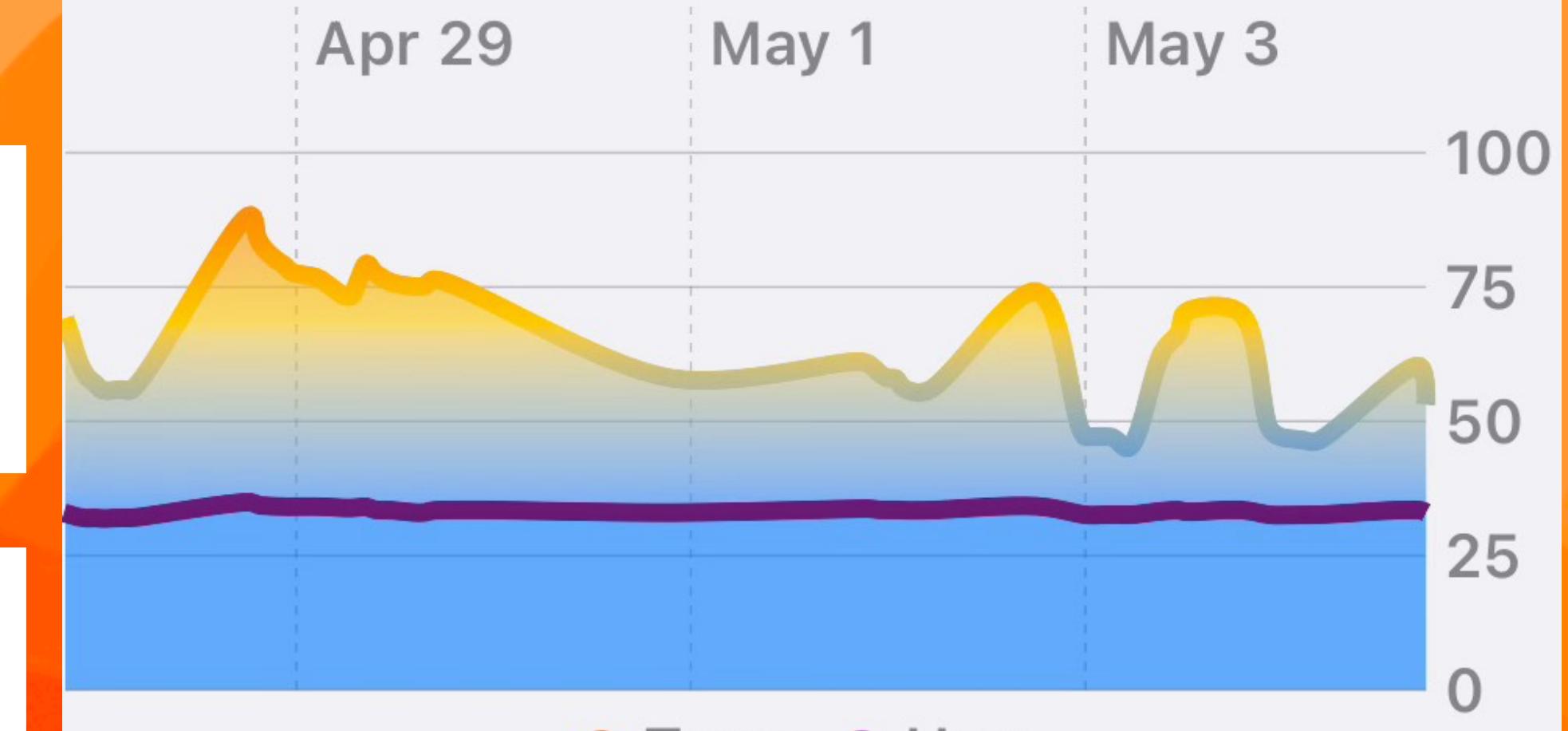
# What Can Meshtastic Do?

## Client Functions

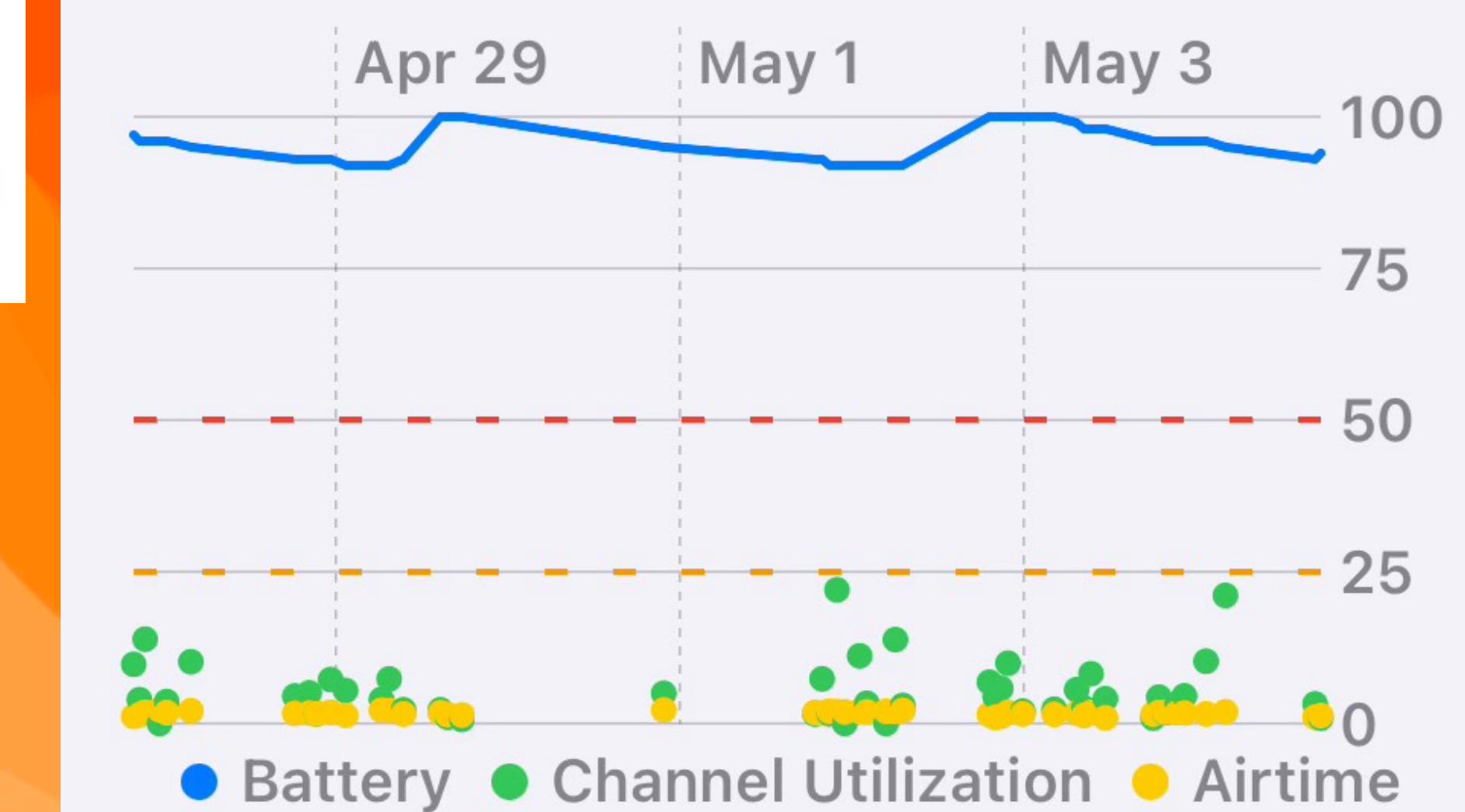
- List Nodes
- Channel Messages
- Direct Messages
- Traceroute
- Node Configuration
- Show Node Metrics, Telemetry, and Position
- IoT sensors and control



103 Readings Total



88 Readings Total



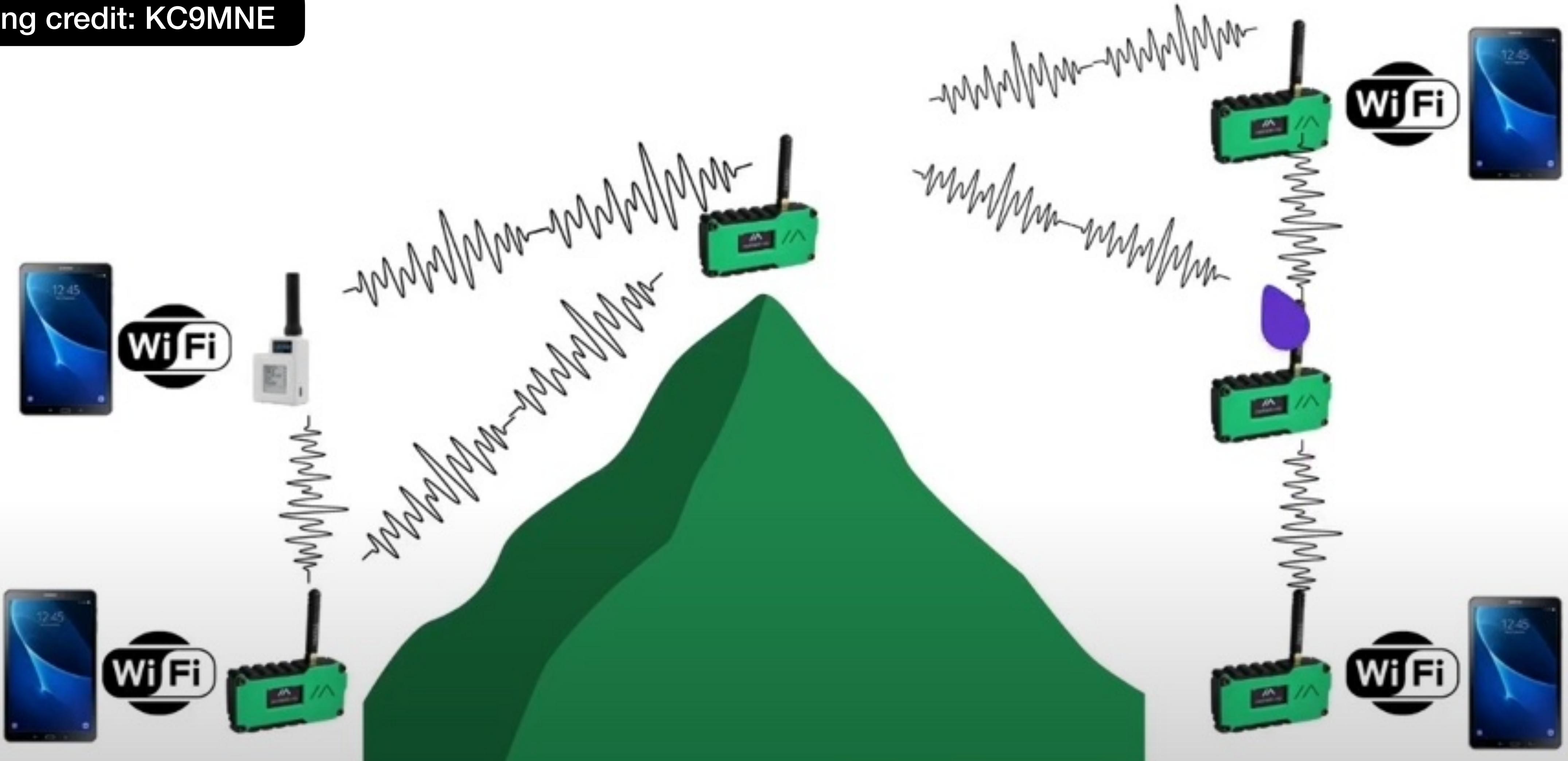
# What's In A Node?

- MCU or CPU with Meshtastic firmware
  - ~200MHz CPU, fewGB ROM, 200KB RAM
  - WiFi sometimes, Bluetooth frequently
- Semtec SX1262 LoRa transceiver chip
- Antenna
- GPS or other sensors sometimes
- Small display sometimes, keyboard sometimes
- Battery, solar, or other power source
- Case, maybe 3D-printed?



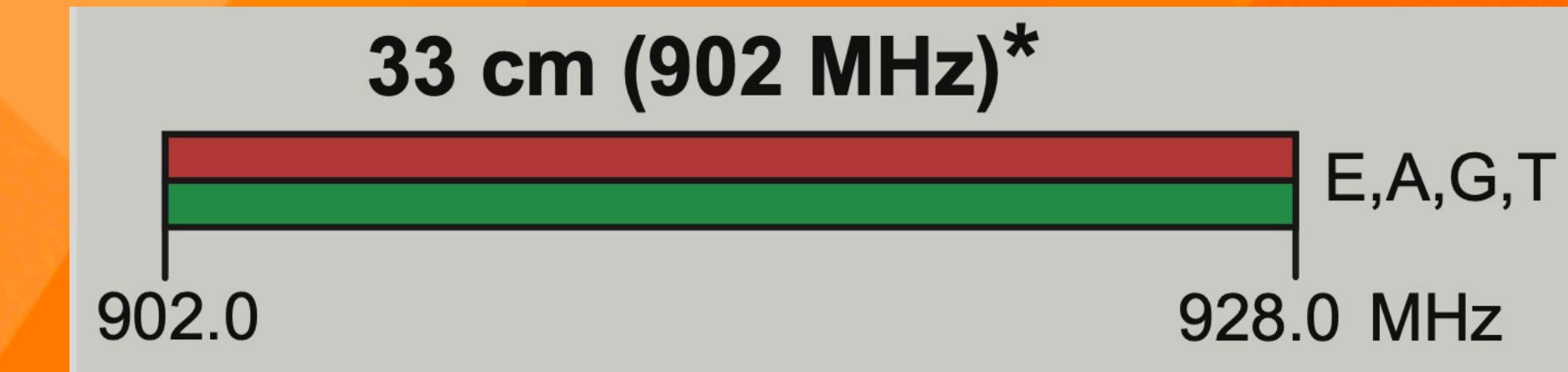
# What's A Mesh? What's a Hop?

Drawing credit: KC9MNE



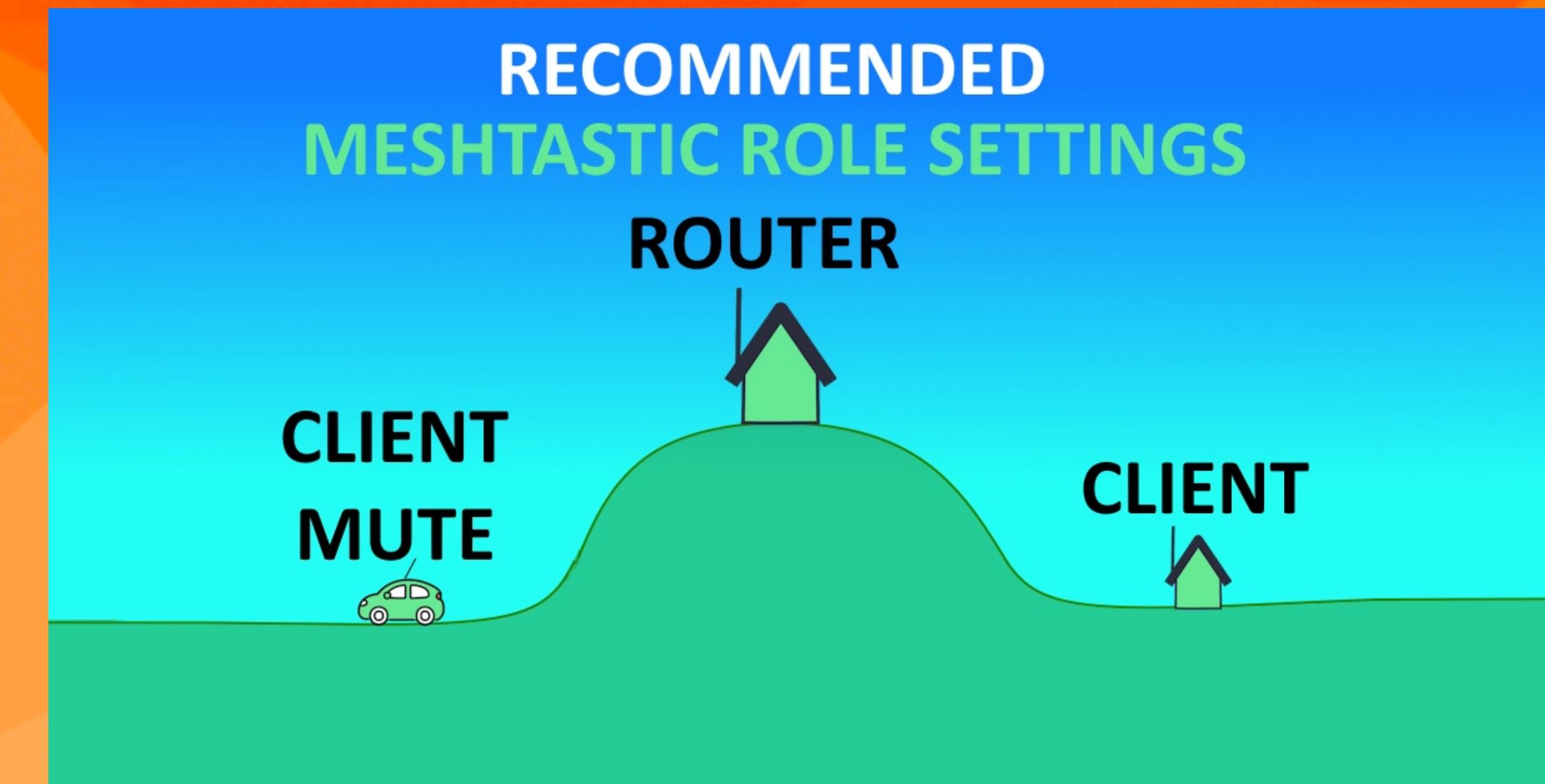
# Characteristics

- Unattended digital mode, no voice
- Uses 900MHz ISM band
- Largely line-of-sight propagation
- No centralized authority or infrastructure, *ad hoc* organization
- Works when everything else fails
- Your choice of Part 15 (unlicensed, encrypted) or Part 97 (amateur, unencrypted)
- LoRa spread spectrum modulation
- Receive with -20 dB SNR



# Node Roles

- **Client:** Join mesh, rebroadcasting for others
- **Client Mute:** Join mesh, no rebroadcasting
- **Router:** Prioritizes rebroadcasting, power hungry, discouraged
- **Router Late:** Rebroadcasts if other nodes don't go first
- **Tracker:** Prioritizes position updates
- **Sensor:** Prioritizes sensor data



# When to Transmit?

- TX & RX on same frequency, so RX is deaf while TX is on
- Neither node that transmits on top of another can find out
  - That would be CSMA/CD Collision Detection like old coaxial Ethernet
  - Half-duplex radios can only do CSMA/CA: Collision Avoidance
  - Random backoff when your RX hears another node has started
  - No help with other nodes you can't hear
- Rebroadcast limited by above, plus more

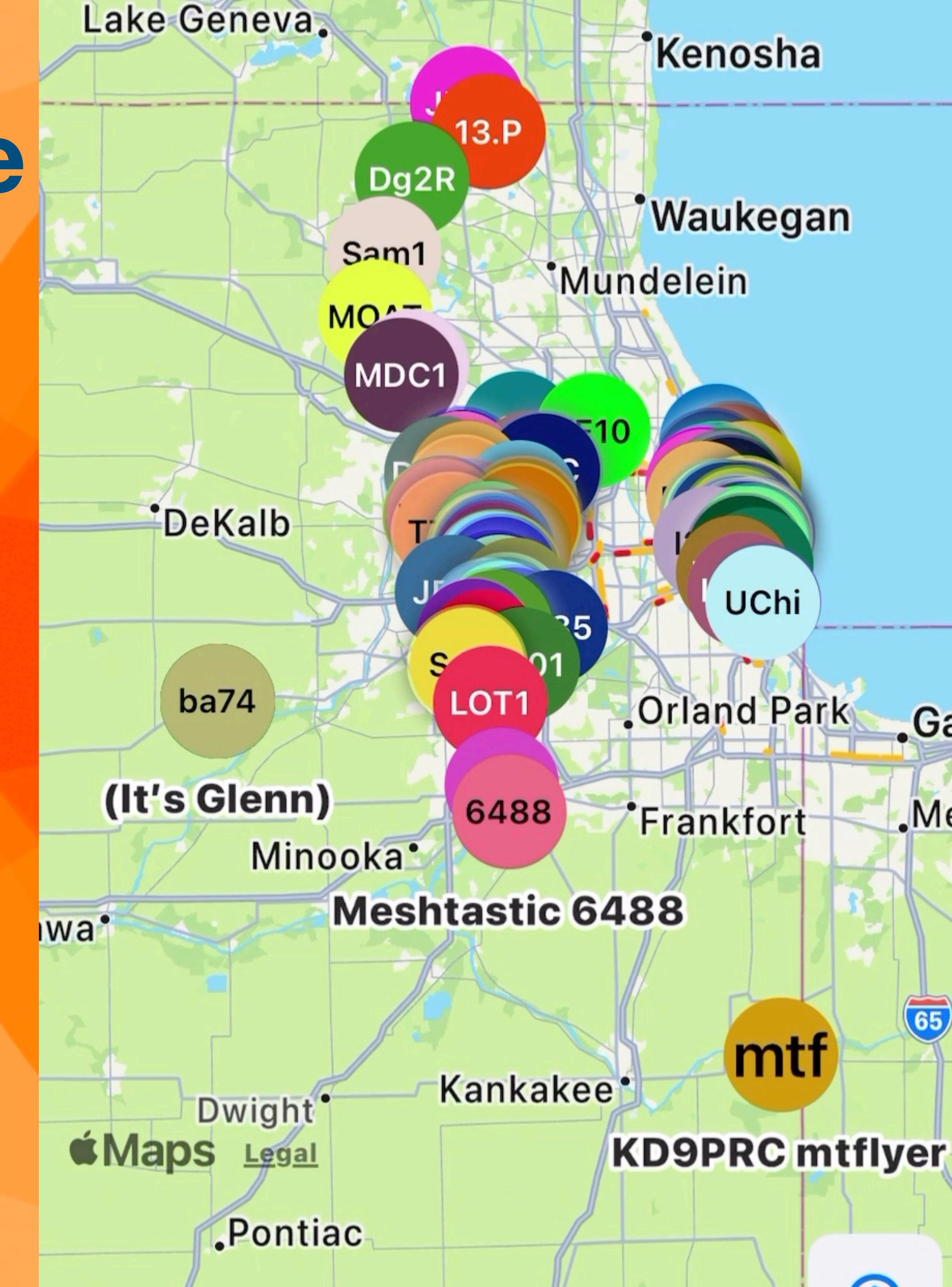
# When to Rebroadcast?

- No routing table! No unicast!
  - Nondeterministic routing
- Rules
  - Don't rebroadcast if message heard before or message at hop limit
  - Randomized rebroadcast delay inversely proportional to received signal strength (RSSI)
- Messages from far-away nodes more likely to be rebroadcast
- Near nodes hold off if they hear a rebroadcast from others
- Efficient flooding, avoiding unneeded rebroadcasting



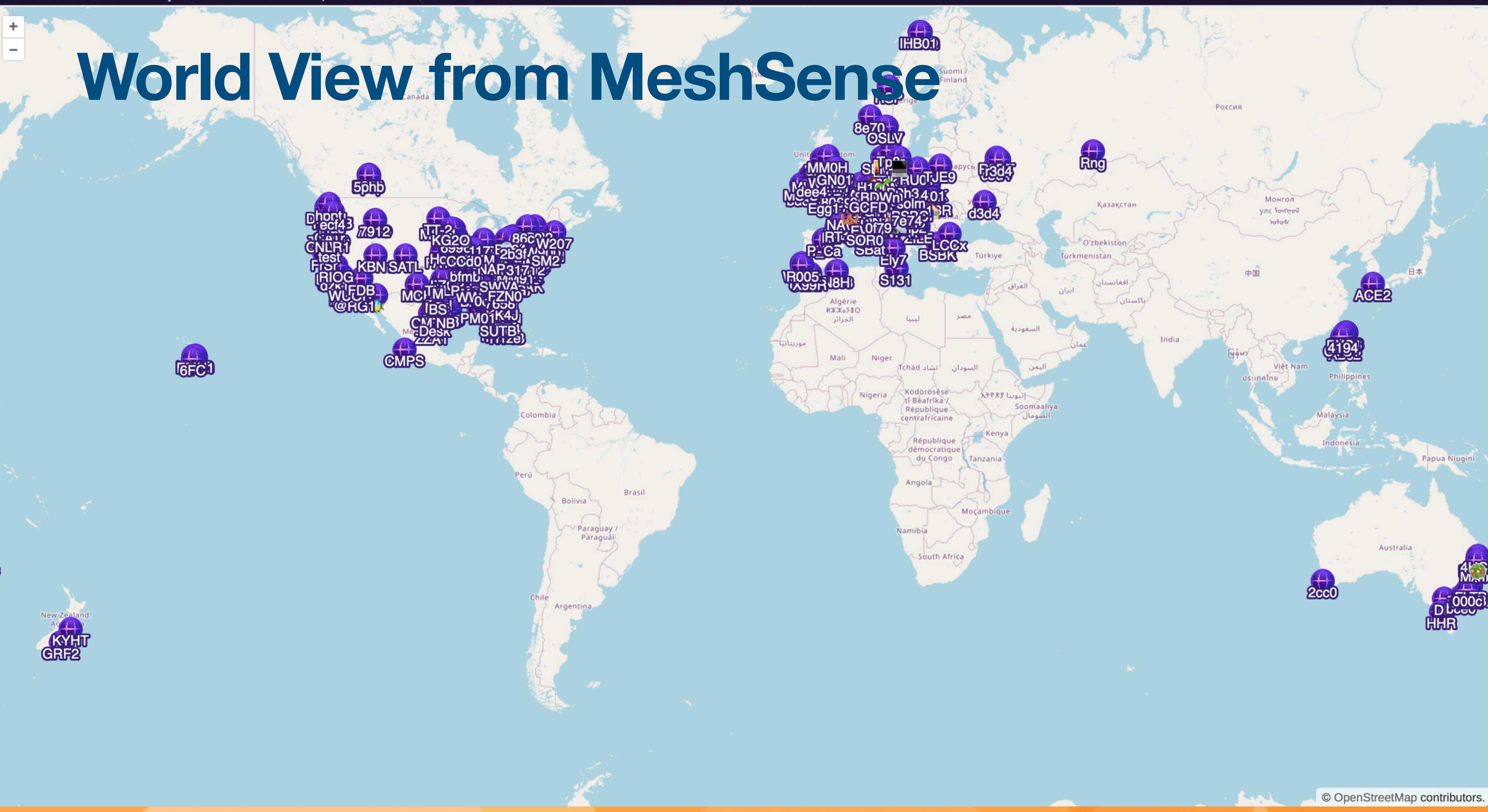
# Mesh Map on Bob's Phone

- Map only shows nodes reporting position
  - Some nodes move
    - Send new positions with GPS
  - This map doesn't show relationships
  - We know they can't all hear each other
  - Likely multiple mini-meshes



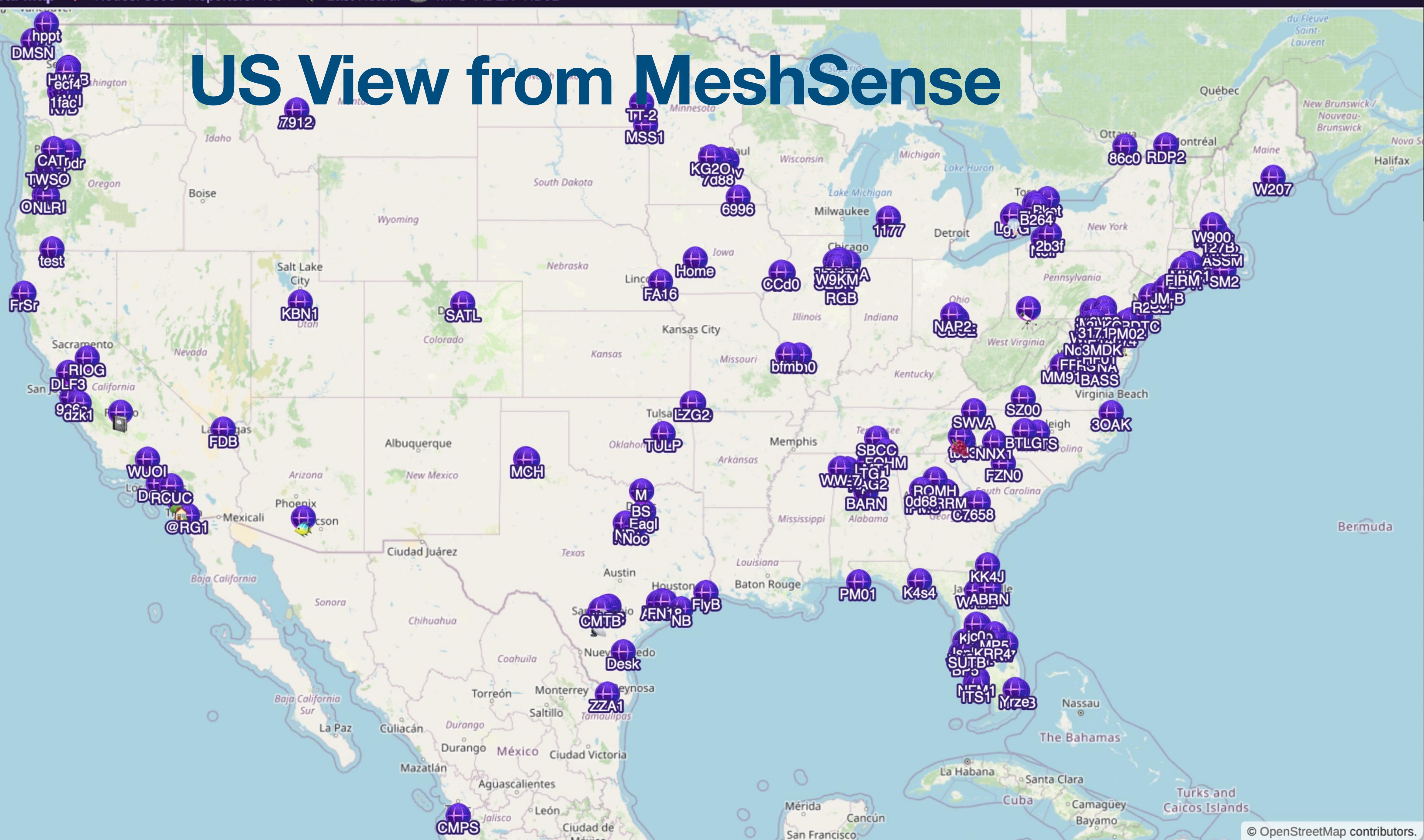


# World View from MeshSense



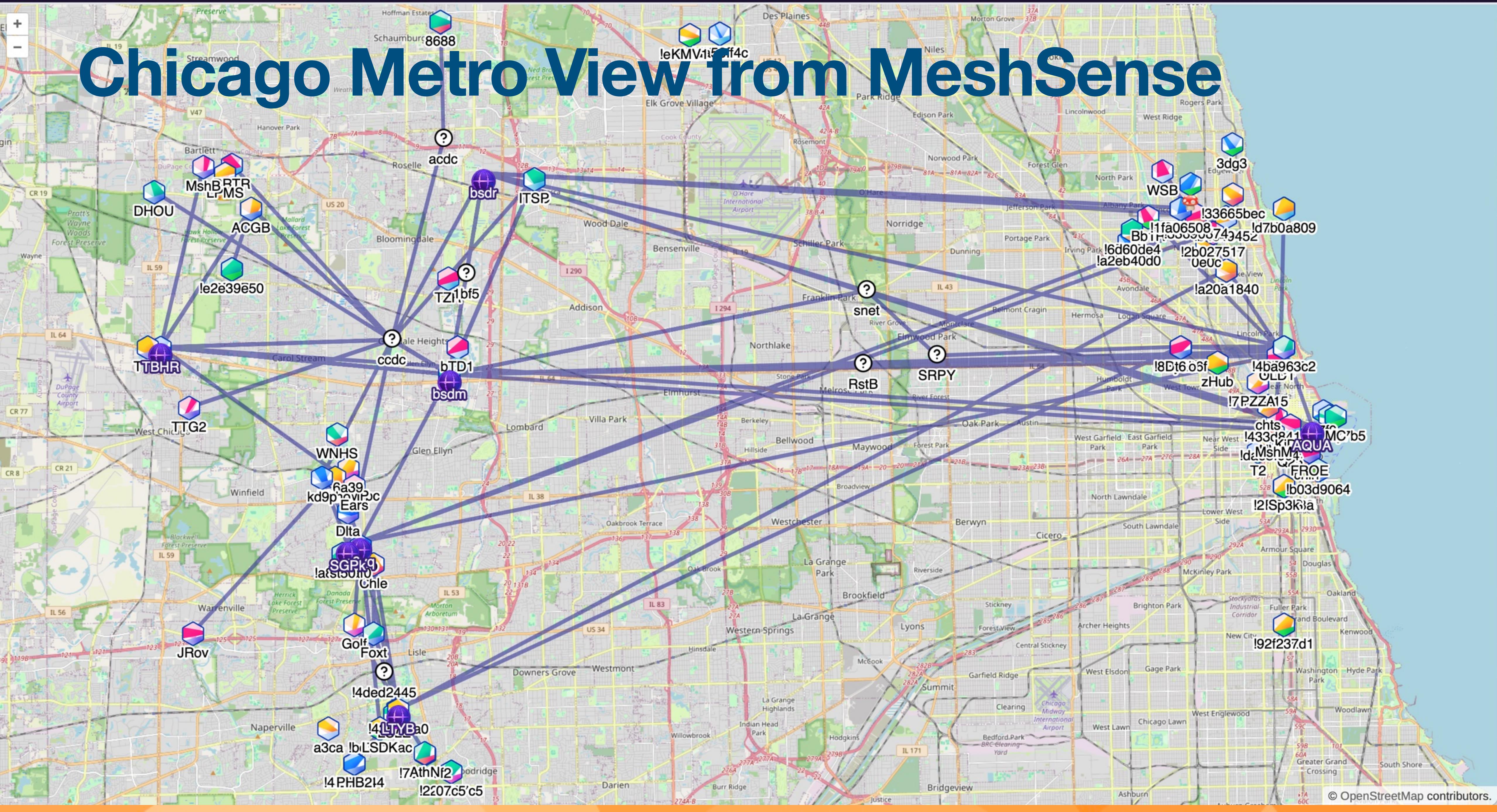


# US View from MeshSense

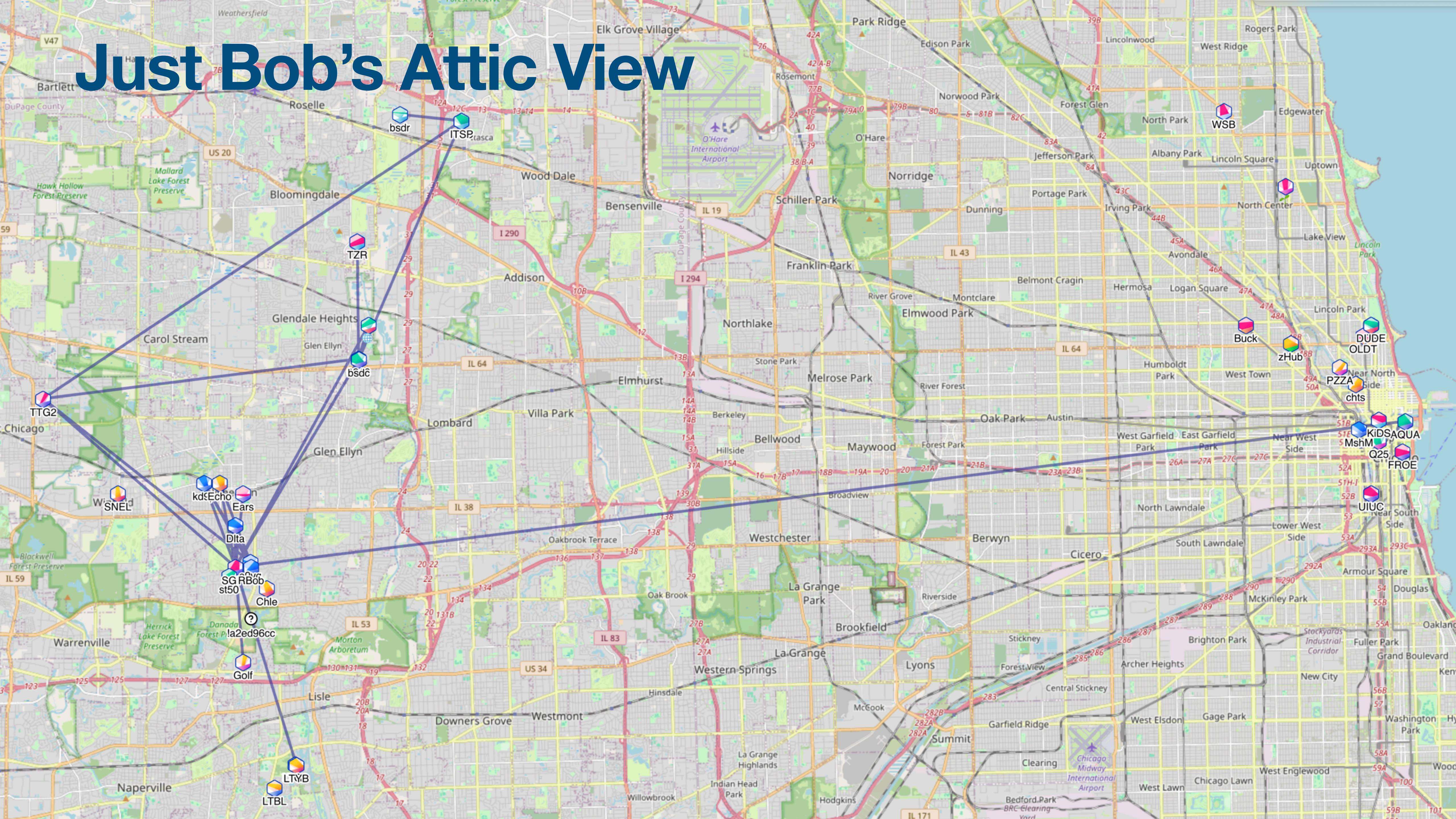




# Chicago Metro View from MeshSense



# Just Bob's Attic View



# Traceroute

- Somewhat similar to Internet traceroute
  - But records route there and route back
  - Not often symmetric
  - Records signal-to-noise ratio, not latency
- Traceroute is like a message passing QSO
  - Confirms two-way connectivity and provides signal report
  - SNR range is about -20dB (noise floor) to 13.25dB (“full quieting”)

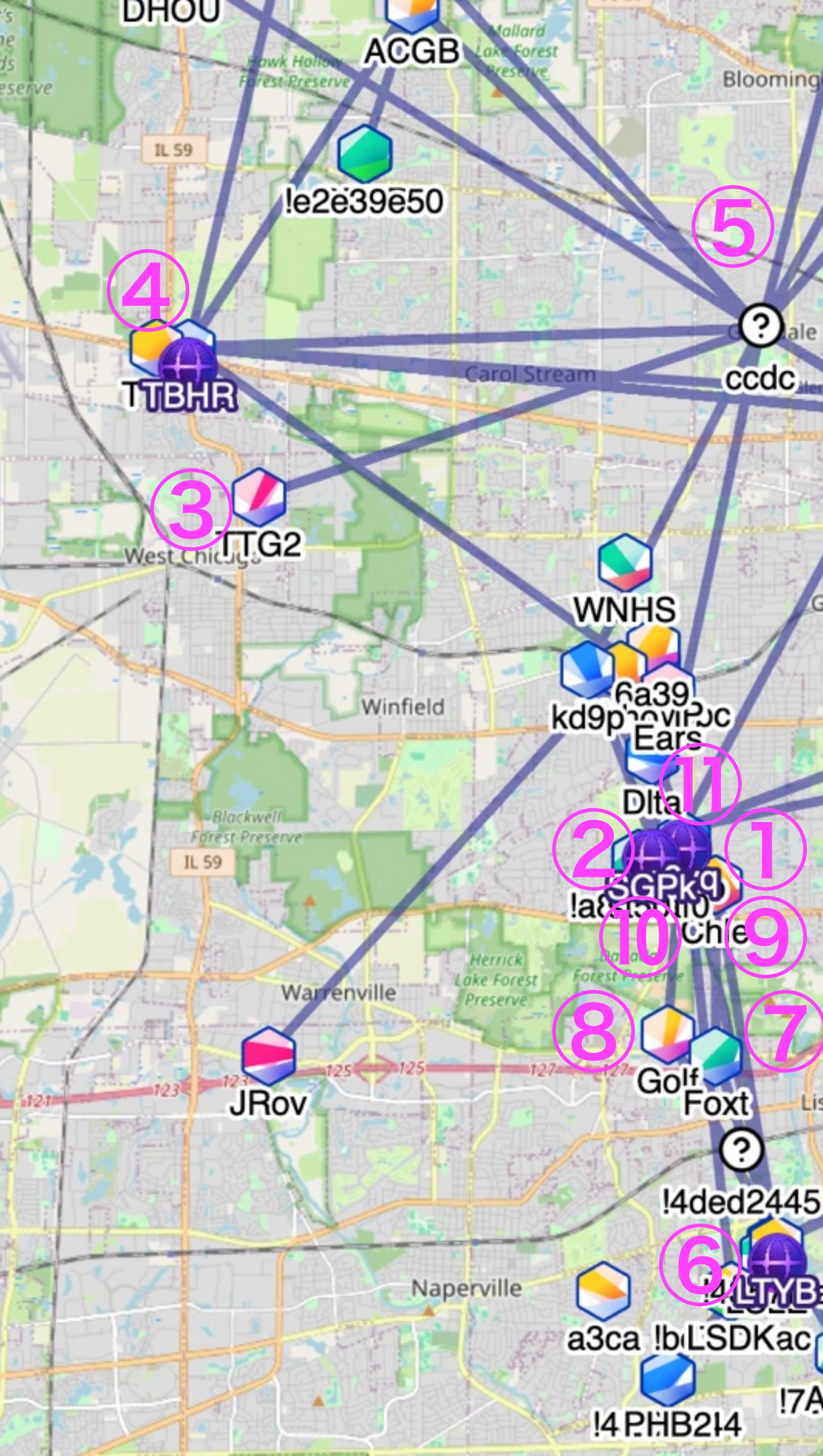
➡ Route: All Ears --> ke9yq (ChiMesh.Org) (6.25dB)

--> Waypoint Echo !8f929380 (-12.0dB)

➡ Route Back: Waypoint Echo !8f929380

--> ke9yq (ChiMesh.Org) (-5.25dB)

--> All Ears (13.25dB)



➡ Route: All 1 Ears --> ke9yq@ChiMesh.Org (6.0dB)

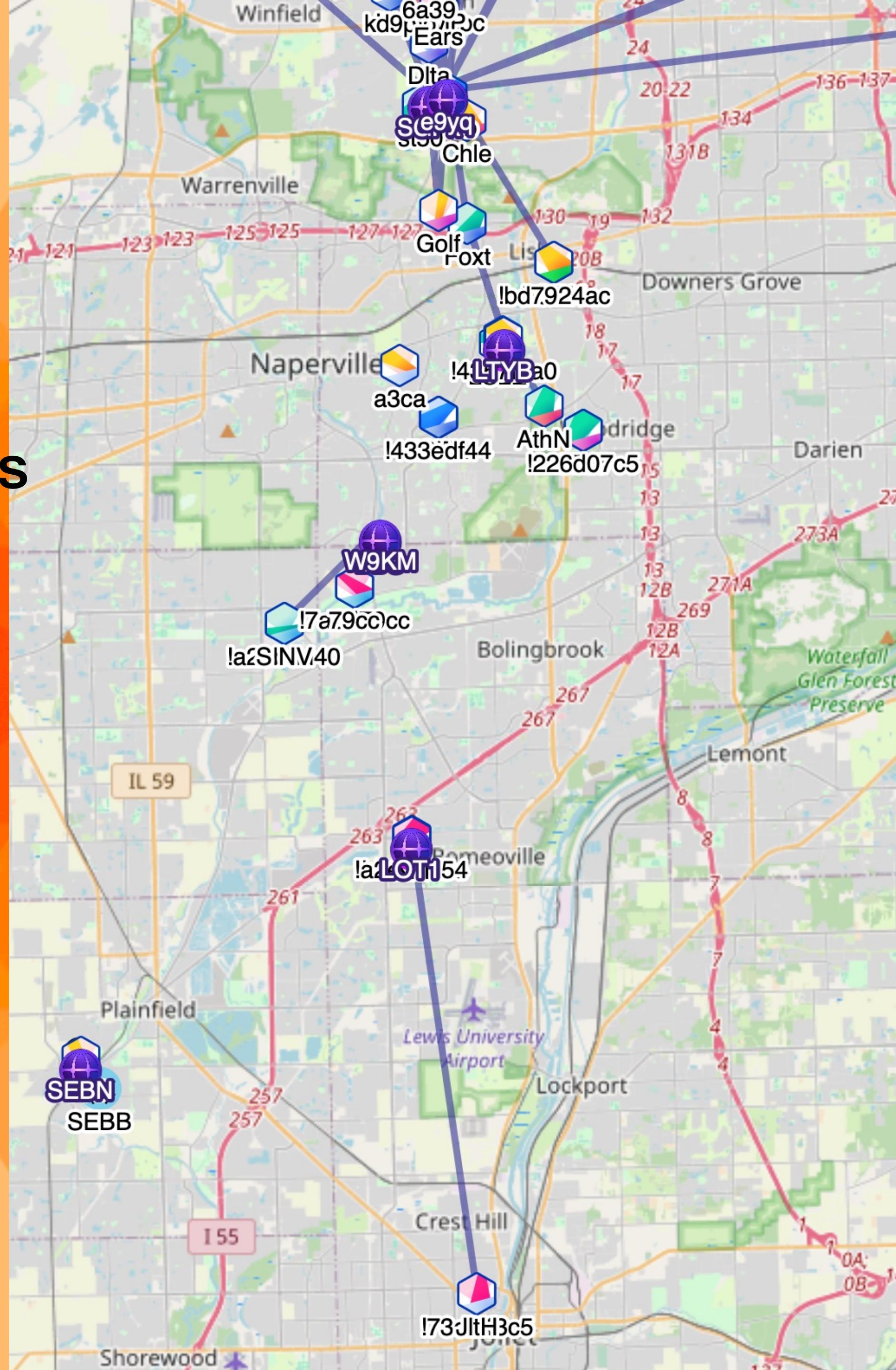
- ③ --> Tegan's Tavern Station G2 (-7.25dB)
- ④ --> TBH Router - West Chicago (no9g.us) (-10.75dB)
- ⑤ --> Meshtastic ccdc (-8.75dB)
- ⑥ --> Lisletastic-Yagi-Beam !4357f0a0 (-12.0dB)

➡ Route Back: 6 Lisletastic-Yagi-Beam !4357f0a0 --> Waypoint Foxtrot (-10.0dB)

- ⑦ --> Waypoint Golf (-2.5dB)
- ⑧ --> Waypoint Charlie (1.5dB)
- ⑨ --> Roving Bob (-15.75dB)
- ⑩ --> All Ears (11.75dB)

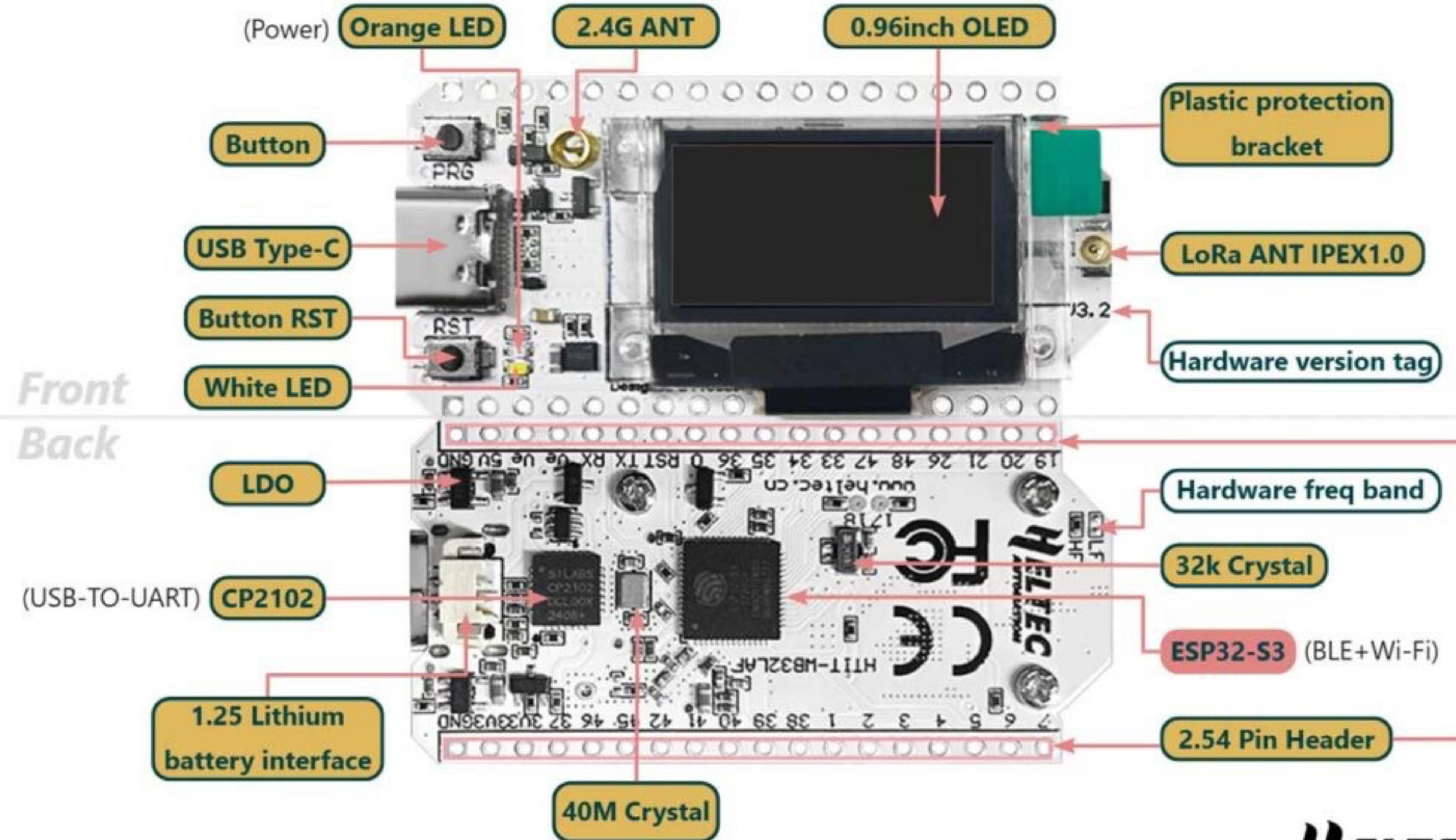
# Argonne Area

- LTYB Adrienne: 7.7 miles
- SGPK Bob: 11.6 miles



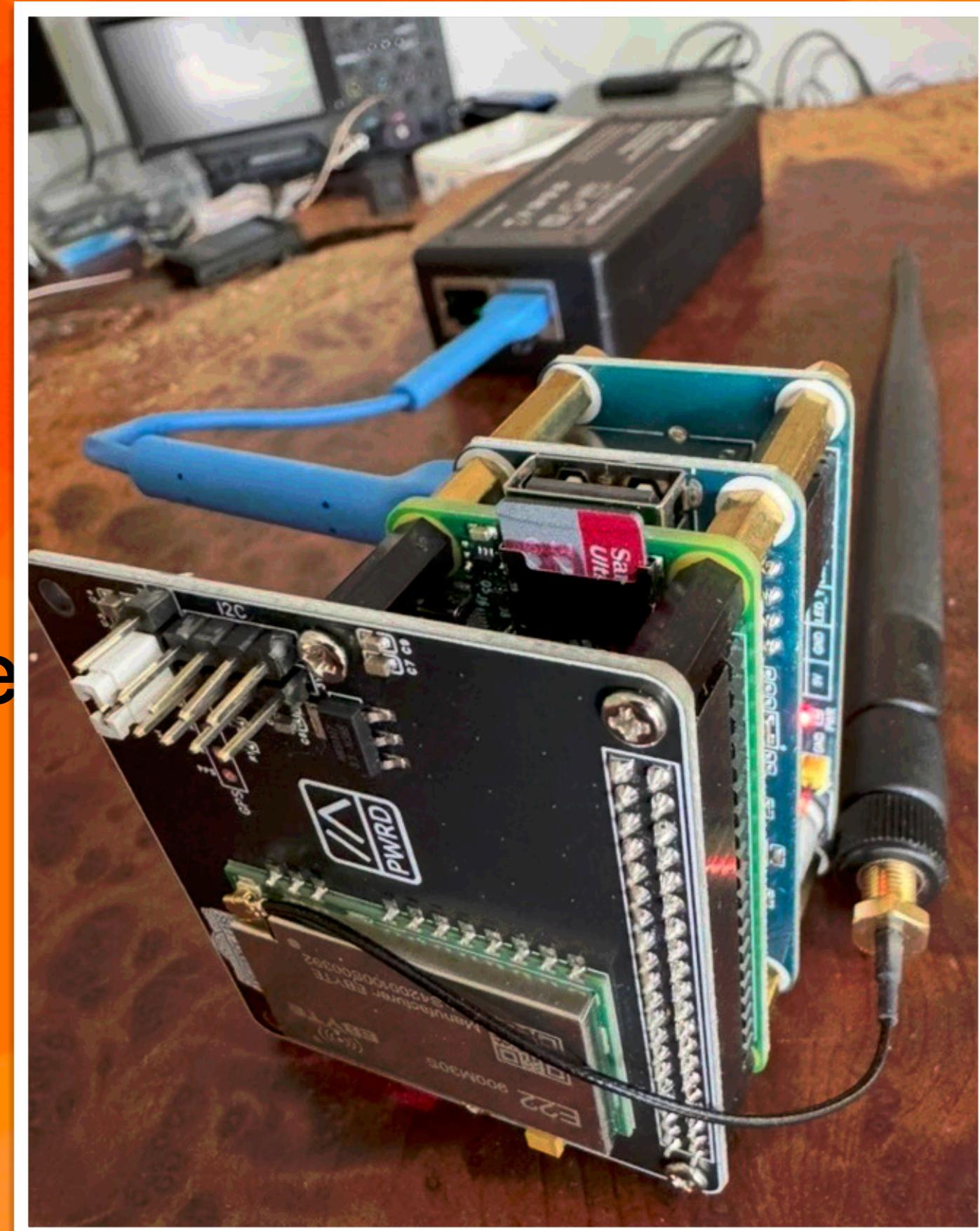


# WiFi LoRa 32 V3



# Energy Budgets

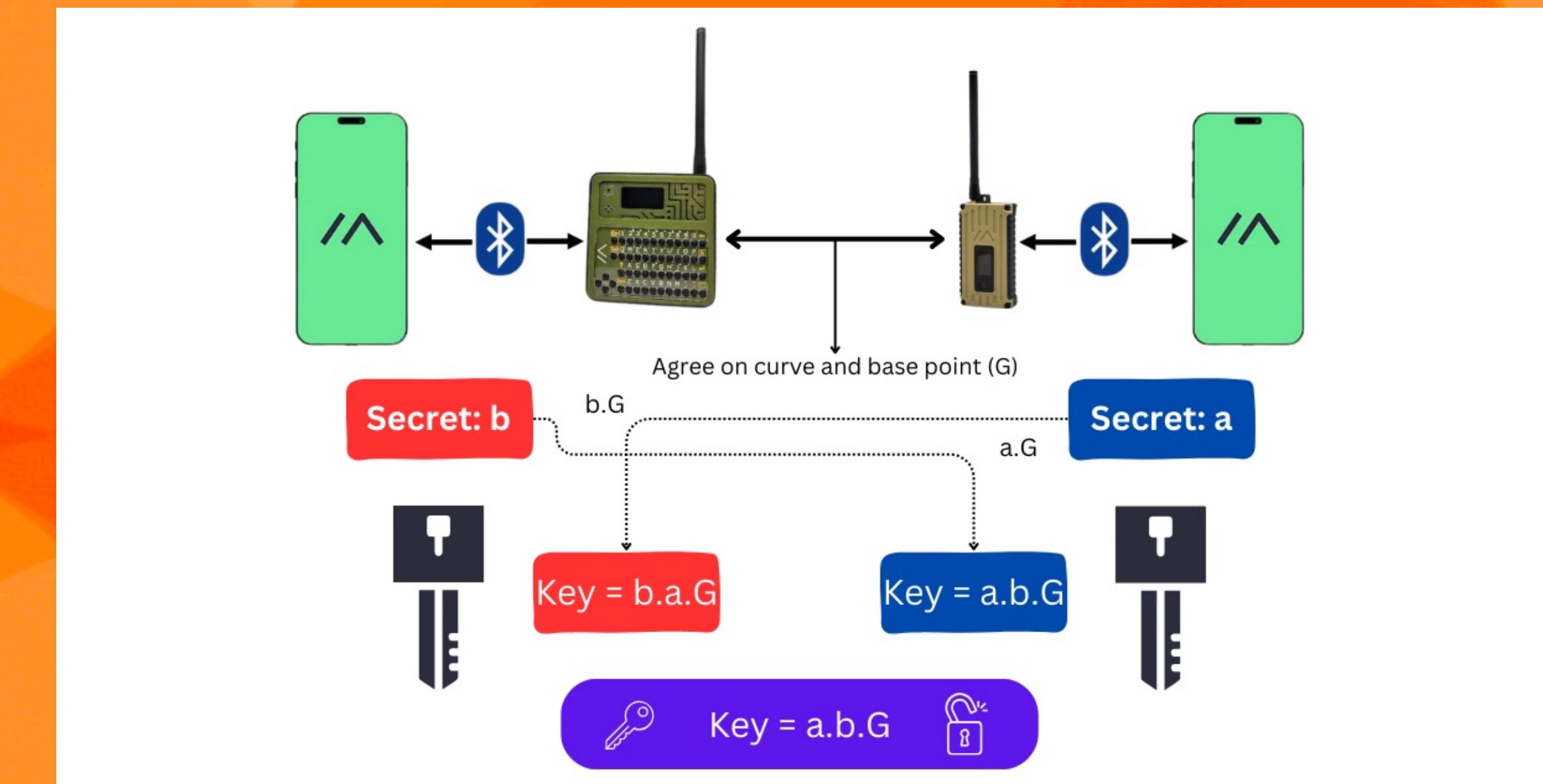
- Typical ESP32 nodes will drain batteries in a few days
  - Good with daily charging or fixed power
- 5" solar panel can power a node with better MCU
  - Best MCU for job: nRF52840
- I home-brewed a Power over Ethernet node for Argonne
  - Raspberry Pi, PoE Hat, 2-Watt LoRa Radio Hat



# Licensed Amateur Use (Part 75 vs Part 15)

IANAL, but . . .

- Privileges
  - Up to 10W TX power
  - Higher gain antennas
- Restrictions
  - No encrypted messages
  - Must ID, effectively giving your location
  - Doesn't exchange messages with unlicensed mesh



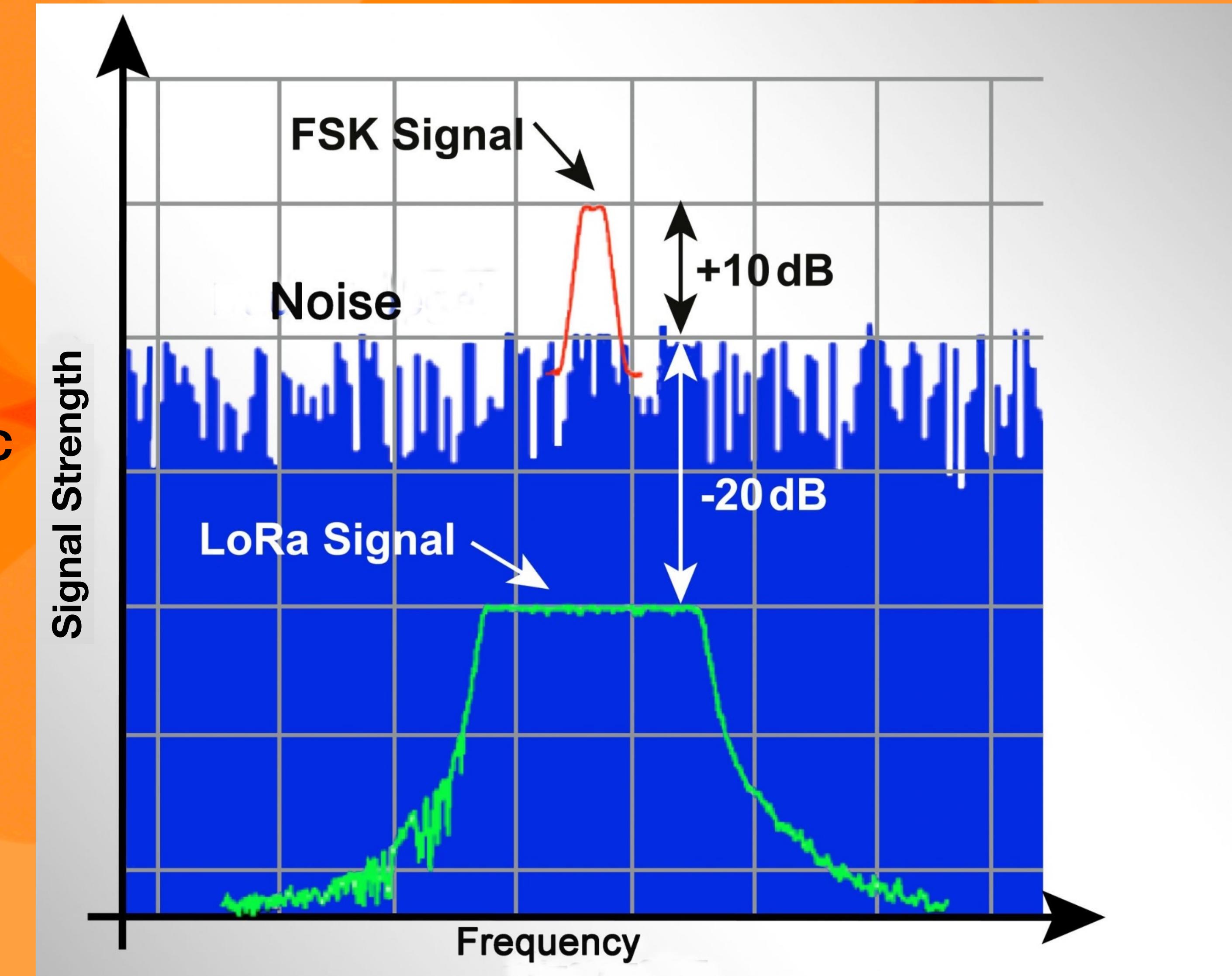
# Other 900 MHz Users

- Cordless phones
- Hams: FM repeaters, ATV
- Walkie talkies
- Industrial, Scientific, Medical
- My water meter!

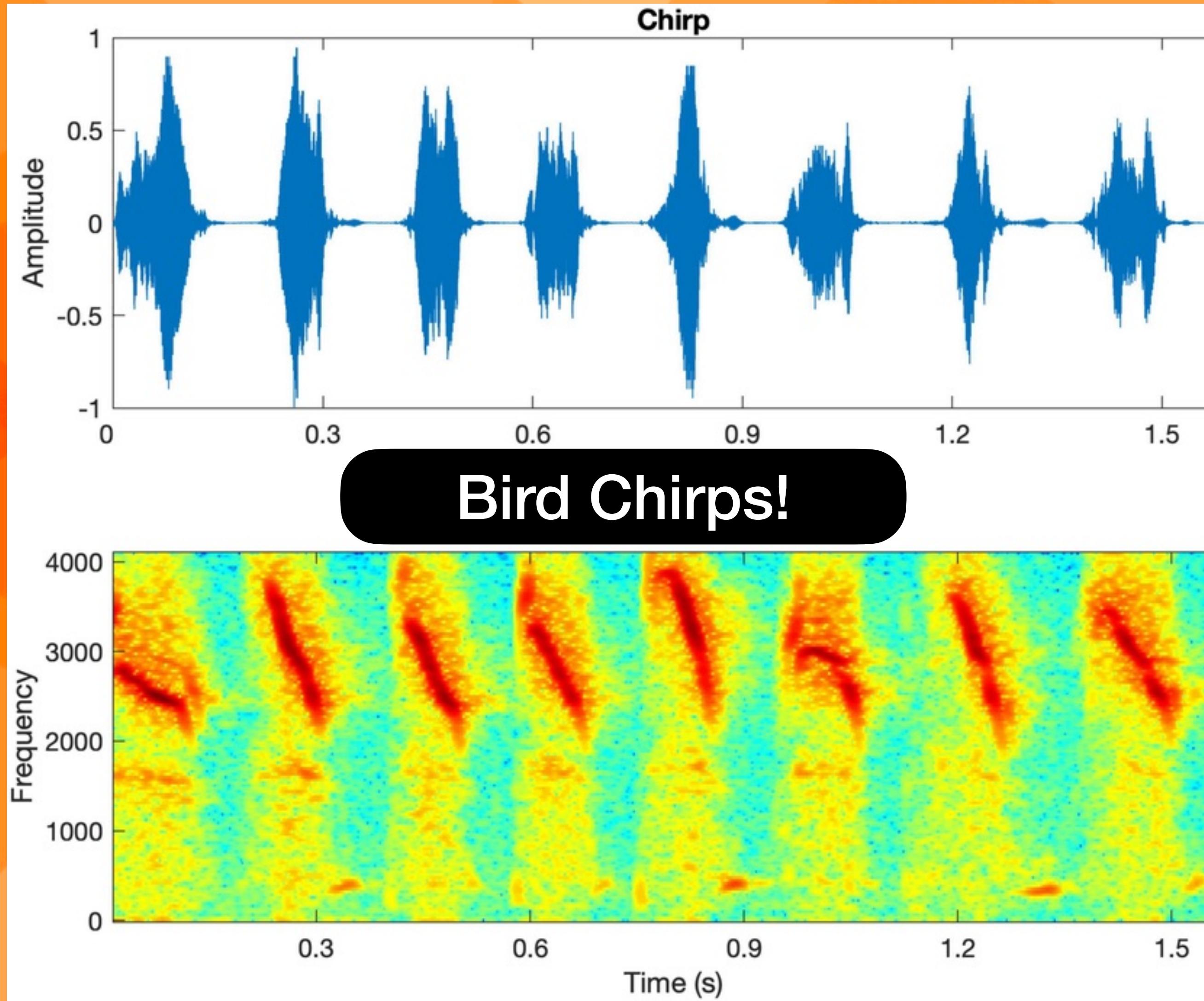


# Getting Below the Noise Floor

- ke9yq
- K-E-9-Y-Q
- Kilo Echo Niner Yankee Quebec
- Correlation-based decoding
- \_eelo Eck\_ \_ner Yan\_ \_bek



# Evolution Invents Spread Spectrum Modulation



This mean value is not zero, implying that there are lines in the spectrum [21], [22]. More precisely, since the modulation is memoryless, we have for  $0 \leq t < T_s$

$$\begin{aligned} \mathbb{E} \{x(t; A_0)\} &= \frac{1}{M} \sum_{\ell=0}^{M-1} x(t; \ell) = \frac{1}{M} \sum_{\ell=0}^{M-1} \sum_{k=0}^{M-1} x(t; \ell) \\ &\times g_{T_c}(t - k T_c) = \frac{1}{M} \sum_{k=0}^{M-1} g_{T_c}(t - k T_c) \sum_{\ell=0}^{M-1} x(t; \ell) \\ &= \frac{1}{M} \left\{ g_{T_c}(t) \sum_{\ell=0}^{M-1} x(t; \ell) + \sum_{k=1}^{M-1} g_{T_c}(t - k T_c) \sum_{\ell=0}^{M-1} x(t; \ell) \right\} \end{aligned}$$

where  $T_c = 1/B$  is the chip rate. From (5) we have

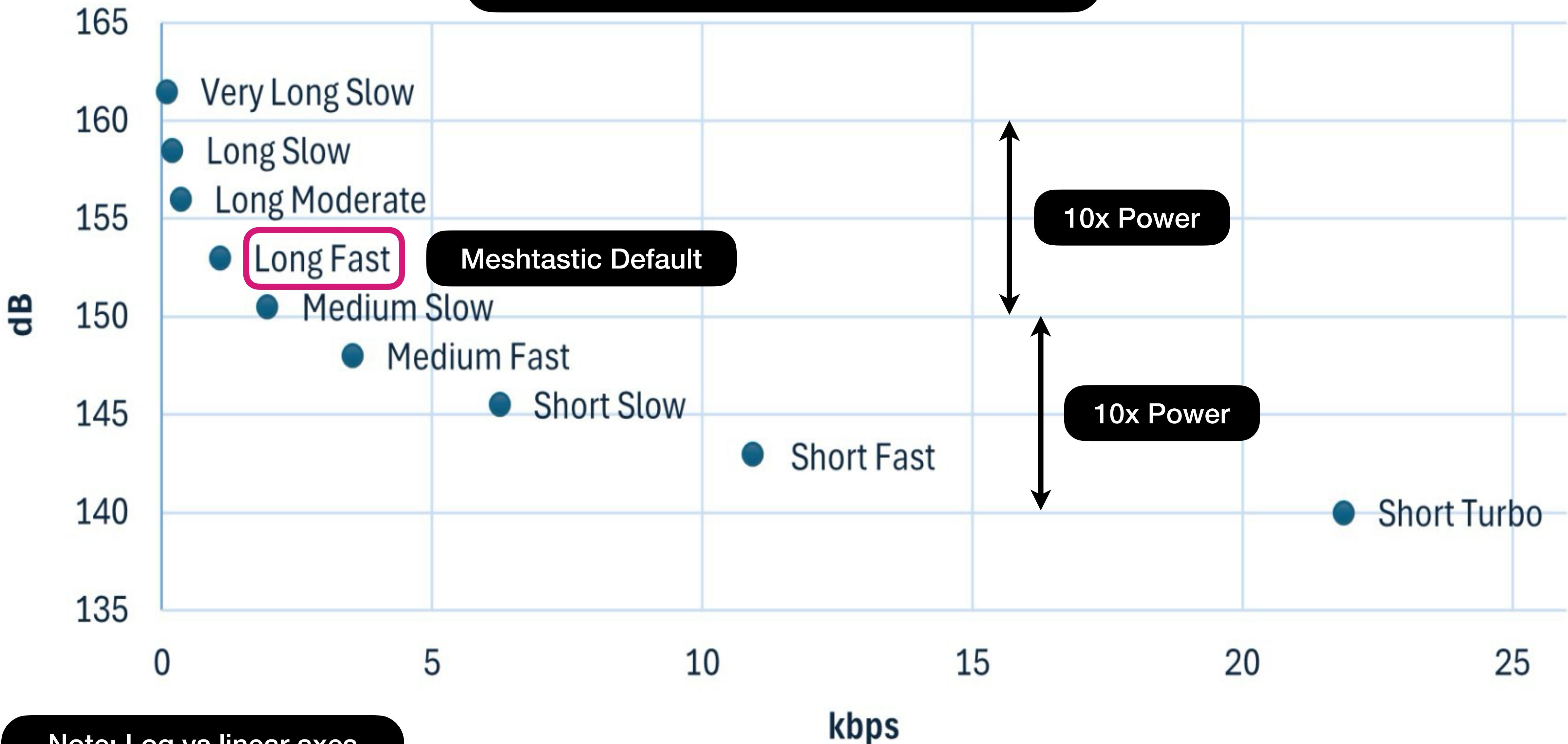
$$\begin{aligned} \mathbb{E} \{x(t; A_0)\} &= \frac{1}{M} e^{j2\pi \frac{B}{2T_s} t^2} \left\{ g_{T_c}(t) \sum_{\ell=0}^{M-1} e^{j2\pi \frac{B}{M} \ell t} + \right. \\ &\left. \sum_{k=1}^{M-1} g_{T_c}(t - k T_c) \left[ \sum_{\ell=0}^{M-k-1} e^{j2\pi \frac{B}{M} \ell t} + \sum_{\ell=M-k}^{M-1} e^{j2\pi \frac{B}{M} \ell t} e^{-j2\pi Bt} \right] \right\} \\ &= \frac{1}{M} e^{j2\pi \frac{B}{2T_s} t^2} \left\{ g_{T_c}(t) \frac{1 - e^{j2\pi Bt}}{1 - e^{j2\pi Bt/M}} + \sum_{k=1}^{M-1} g_{T_c}(t - k T_c) \right. \\ &\left. \times e^{j2\pi B(M-k)t/M} \frac{e^{-j2\pi Bt} - 1}{1 - e^{j2\pi Bt/M}} \right\}. \end{aligned}$$

After some manipulation we get

$$\begin{aligned} \mathbb{E} \{x(t; A_0)\} &= \frac{1}{M} e^{j\frac{\pi B t}{M} (B t - 1)} \frac{\sin(\pi B t)}{\sin(\pi B t / M)} \\ &\times \sum_{k=0}^{M-1} g_{T_c}(t - k T_c) e^{-j2\pi B k t / M}. \end{aligned}$$

# ~~Link budget~~ VS data rate

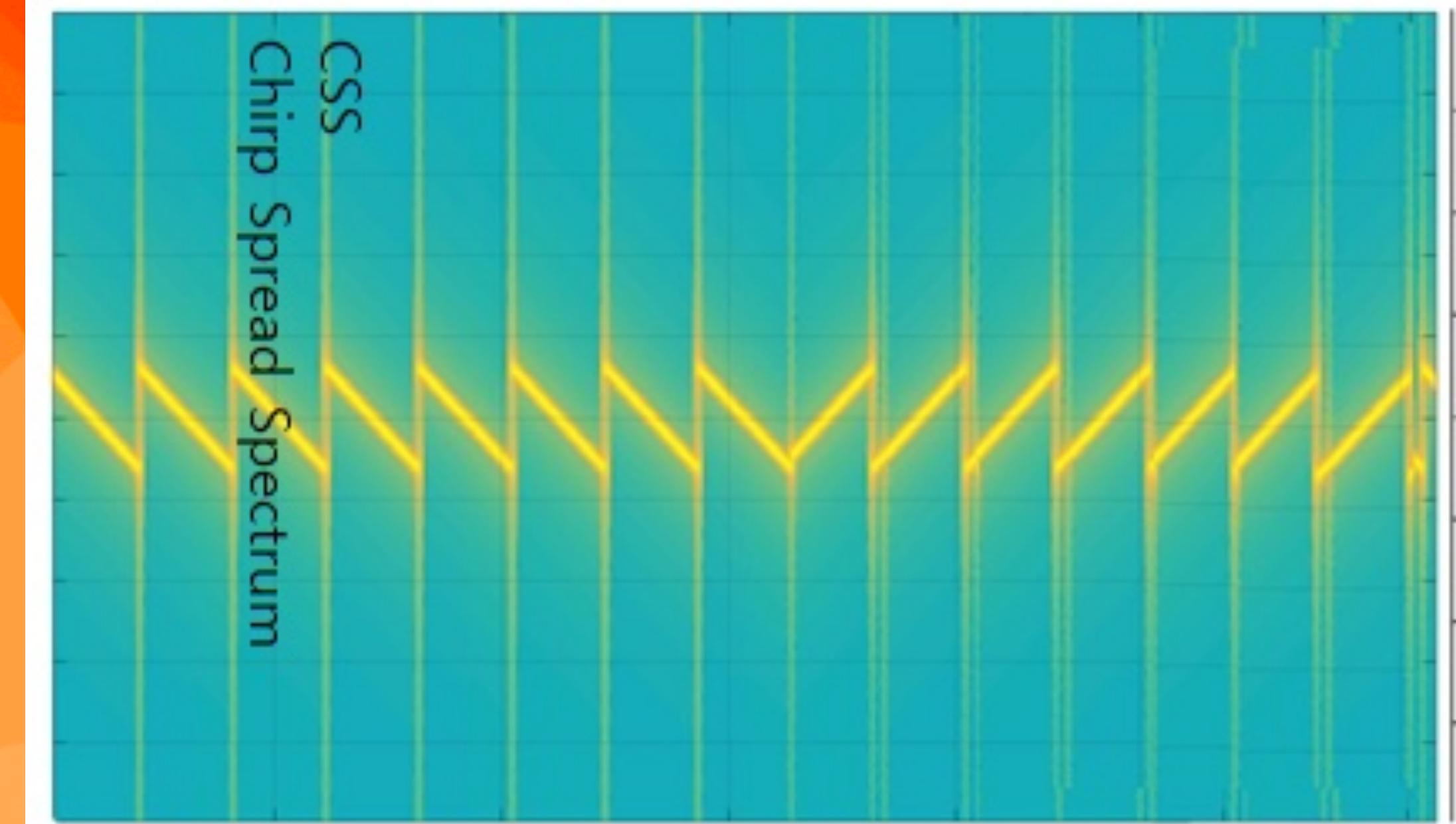
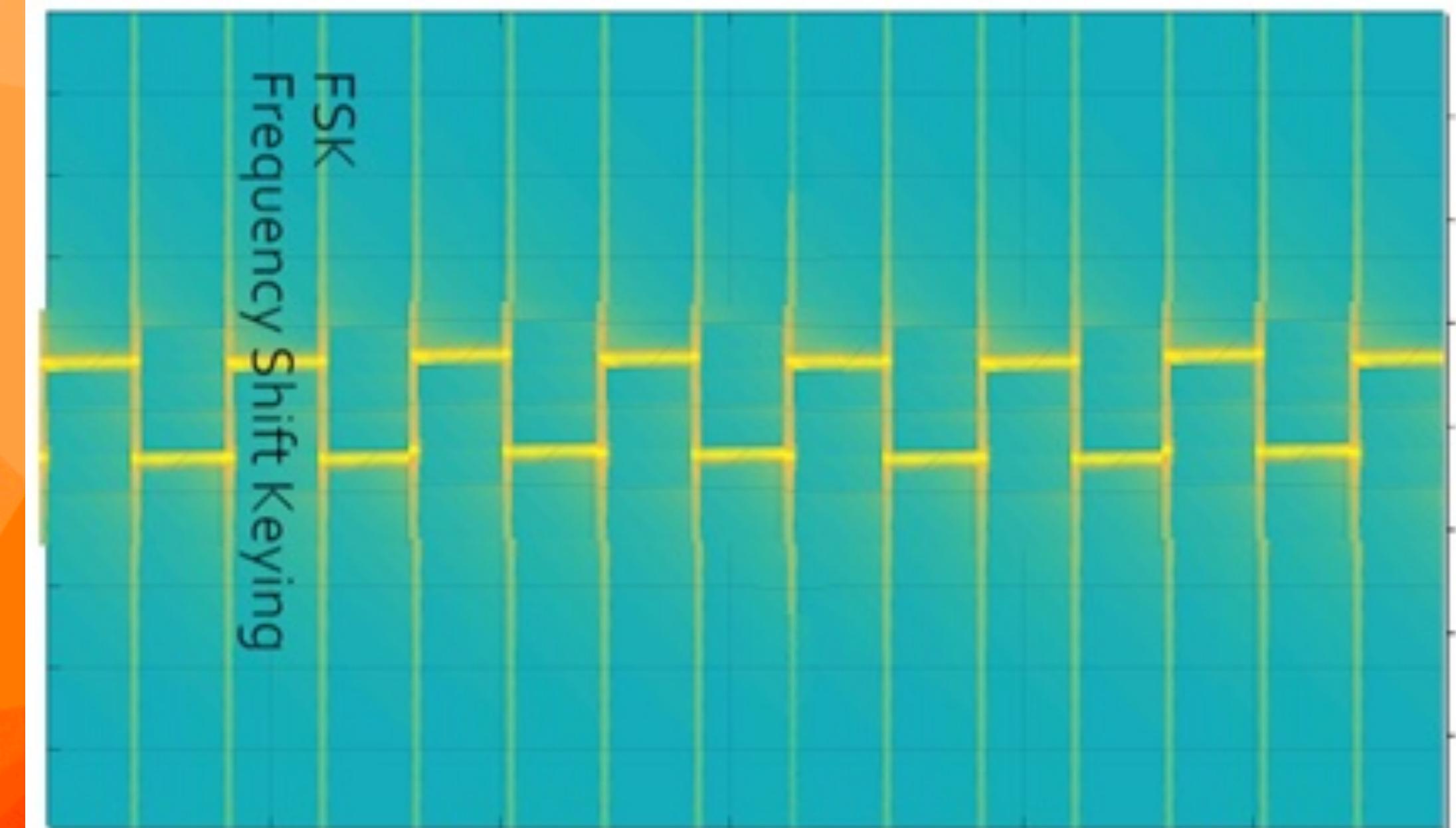
Range VS Data Rate



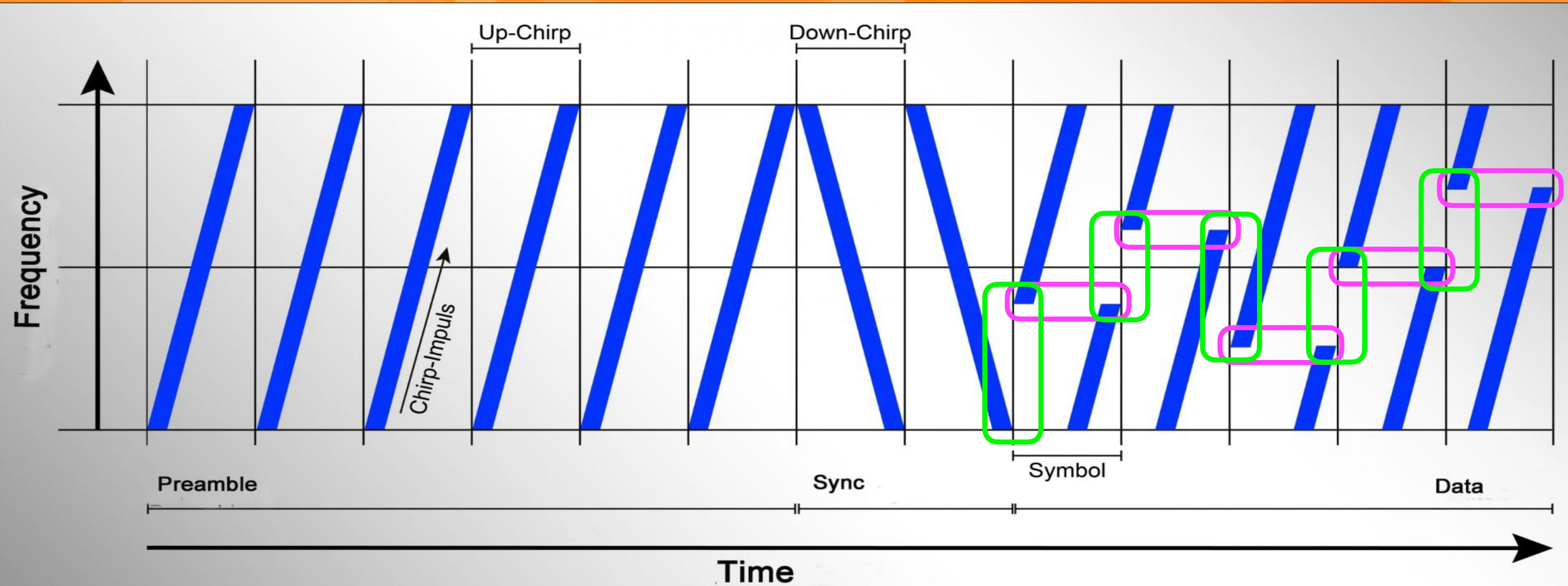
# Modulation Contrast

## FSK vs Chirp Spread Spectrum

- Audio Frequency Shift Keying (AFSK)
  - E.g. RTTY, AX.25, WSPR, APRS
- Frequency Shift Keying (FSK)
  - 9600-baud packet
  - Rarer, but preferred
- LoRa uses Chirp Spread Spectrum
- 3G cellular used CDMA SS
- 5G cellular uses OFDM

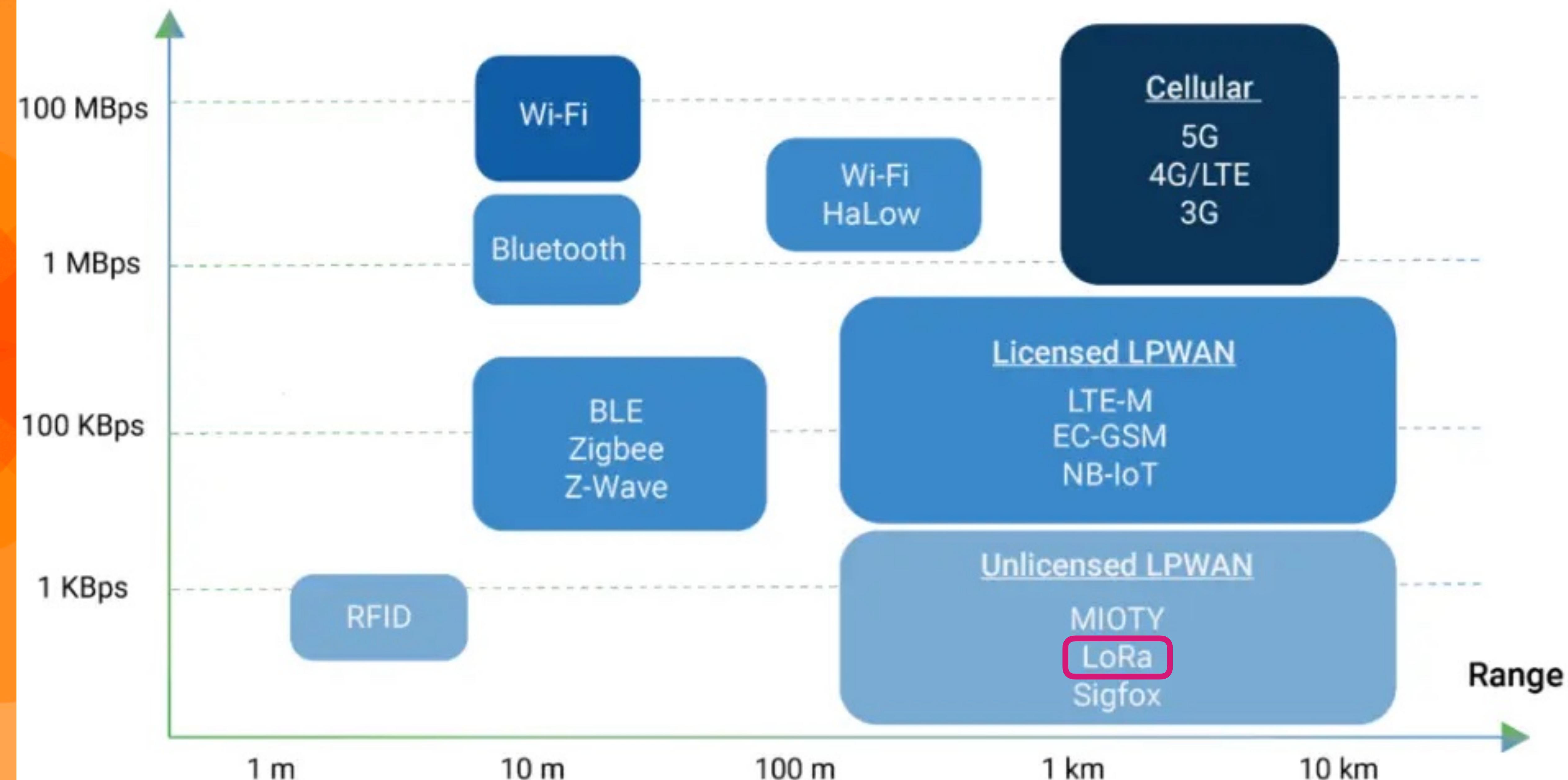


# Example Airframe (Packet over the air)



## Data rate & Power Consumption

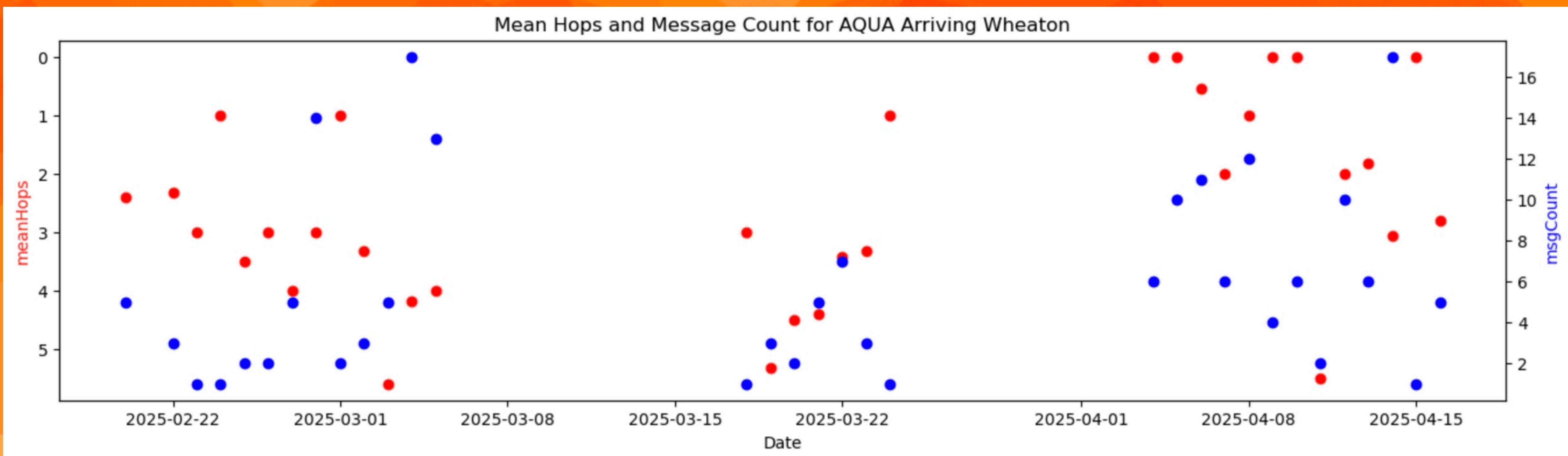
Cost: Low High



# Collecting Data

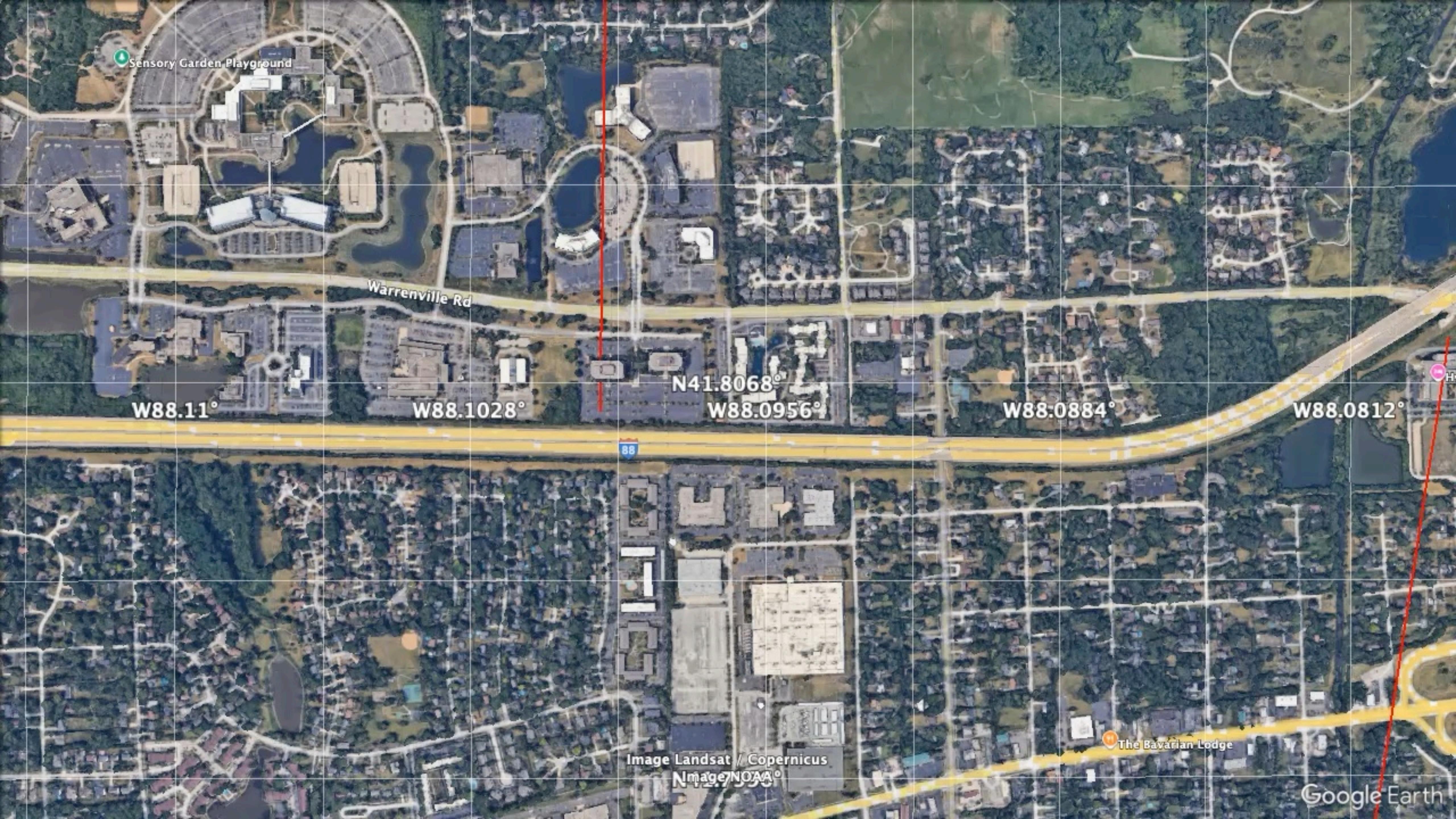
## AQUA upgrades his antenna

- Much more likely to hear AQUA direct (zero hops) after antenna upgrade



# Related Projects

- Meshcore
- Reticulum
- LoRaWAN
- Ham satellites use LoRa ~440MHz





# Fun for Bob

- Radios and antennas are small and inexpensive
- Build your own antennas
- Use 3D printing
- Data analysis
- Mechanical construction
- Easy to get started
- Cartography, topography, path planning
- Meetups

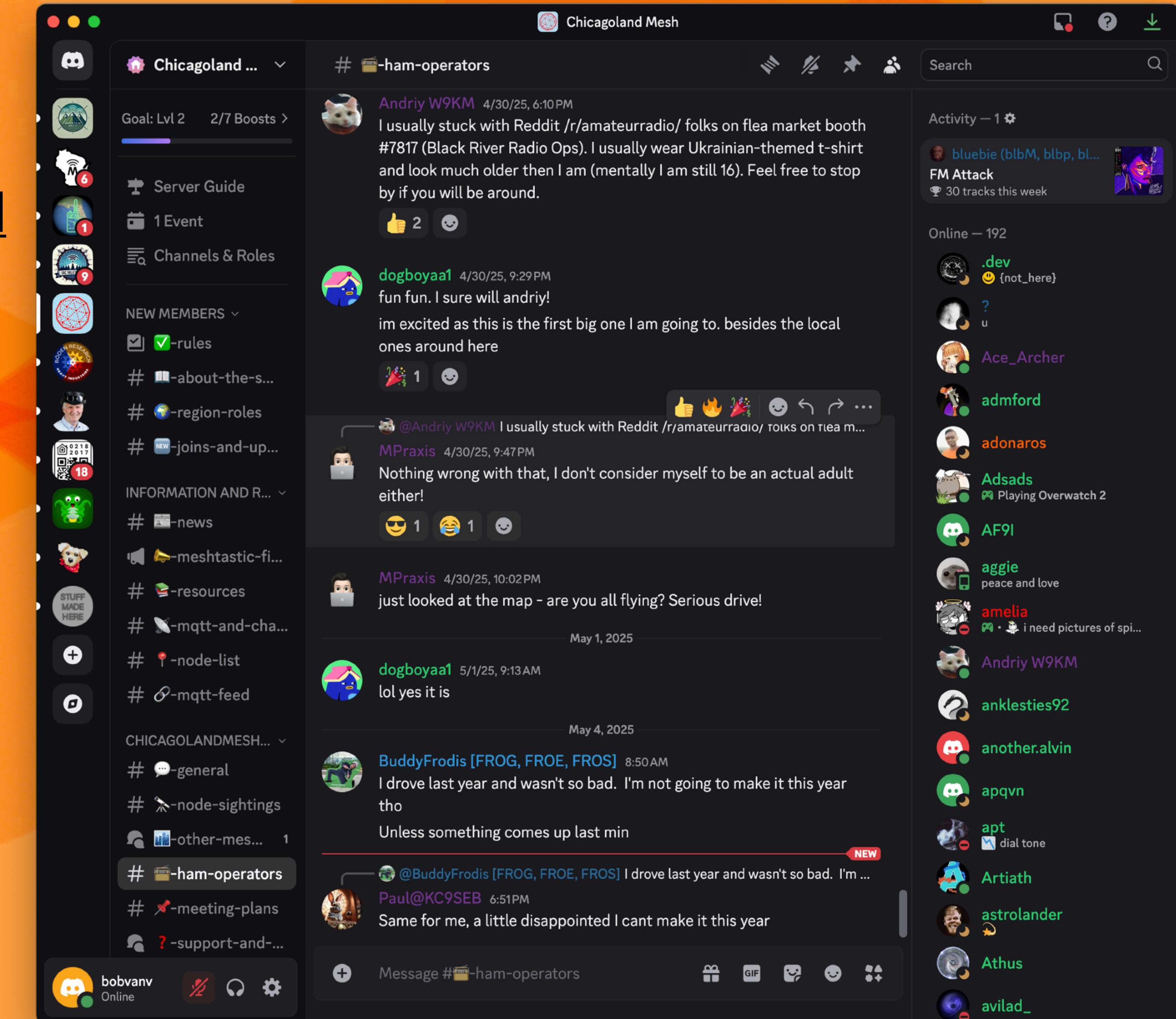
# Antenna Build

- Simple 1/4-wave
- Fun experimenting with VNA
- Trim carefully!



# Meshtastic Community

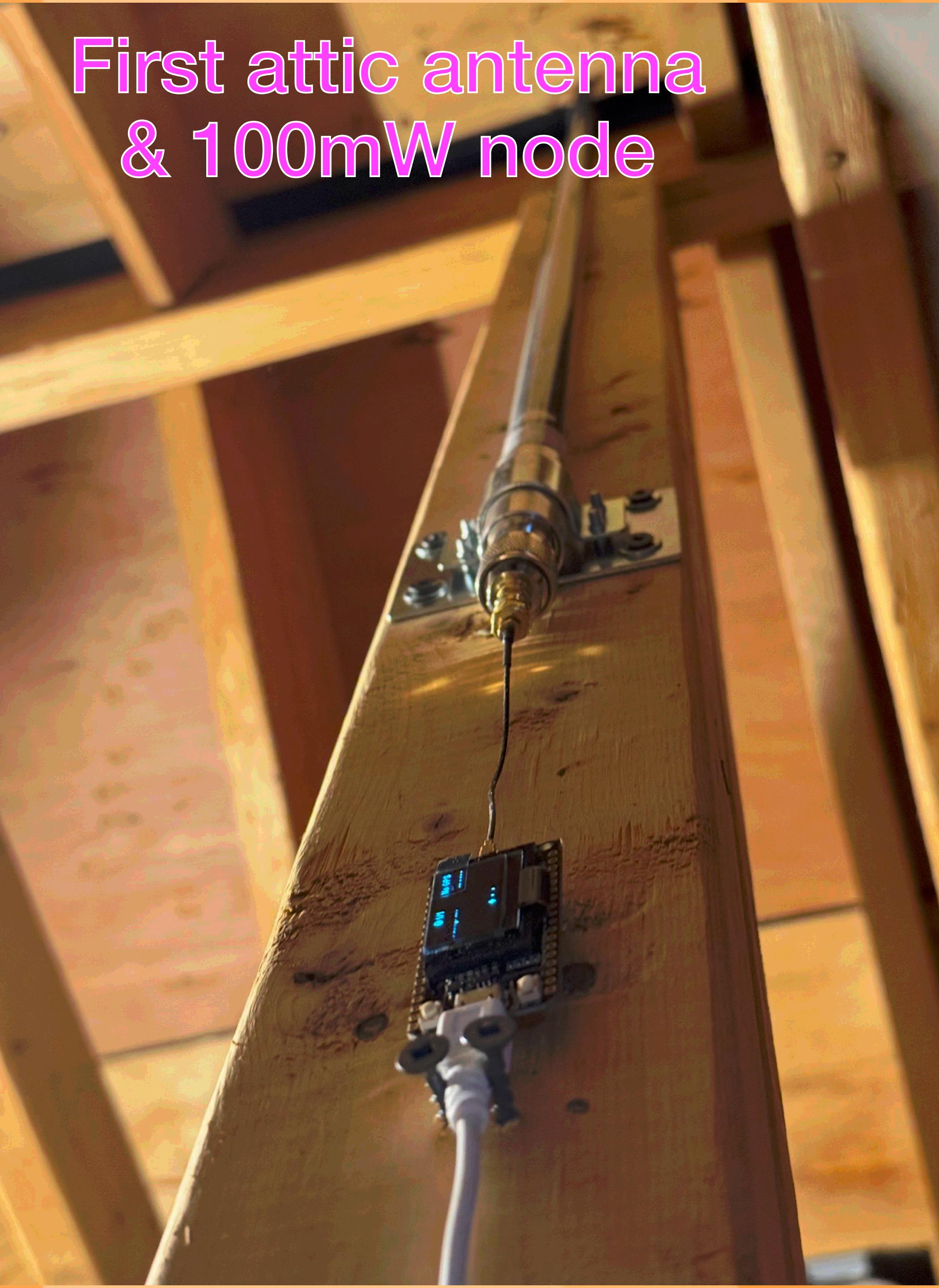
- Join: <https://ChiMesh.Org/discord>
- Channel #ham-operators
- Also see website
  - <https://ChiMesh.Org/>



# Bob Phases

- 11/24: Handheld node, surplus parts
- 12/24: Attic colinear antenna, 100mW radio
- 1/25: LNA, Cavity filter, 5W radio, 9-element Yagi experiments
- 2/25: 17-element Yagi, 2x 5W radios with LNAs, 2nd floor attic
- 3/25: Mobile nodes, solar nodes (“Waypoints”)
- 4/25: Airplanes, balloons

First attic antenna  
& 100mW node



Head-to-toe  
antenna

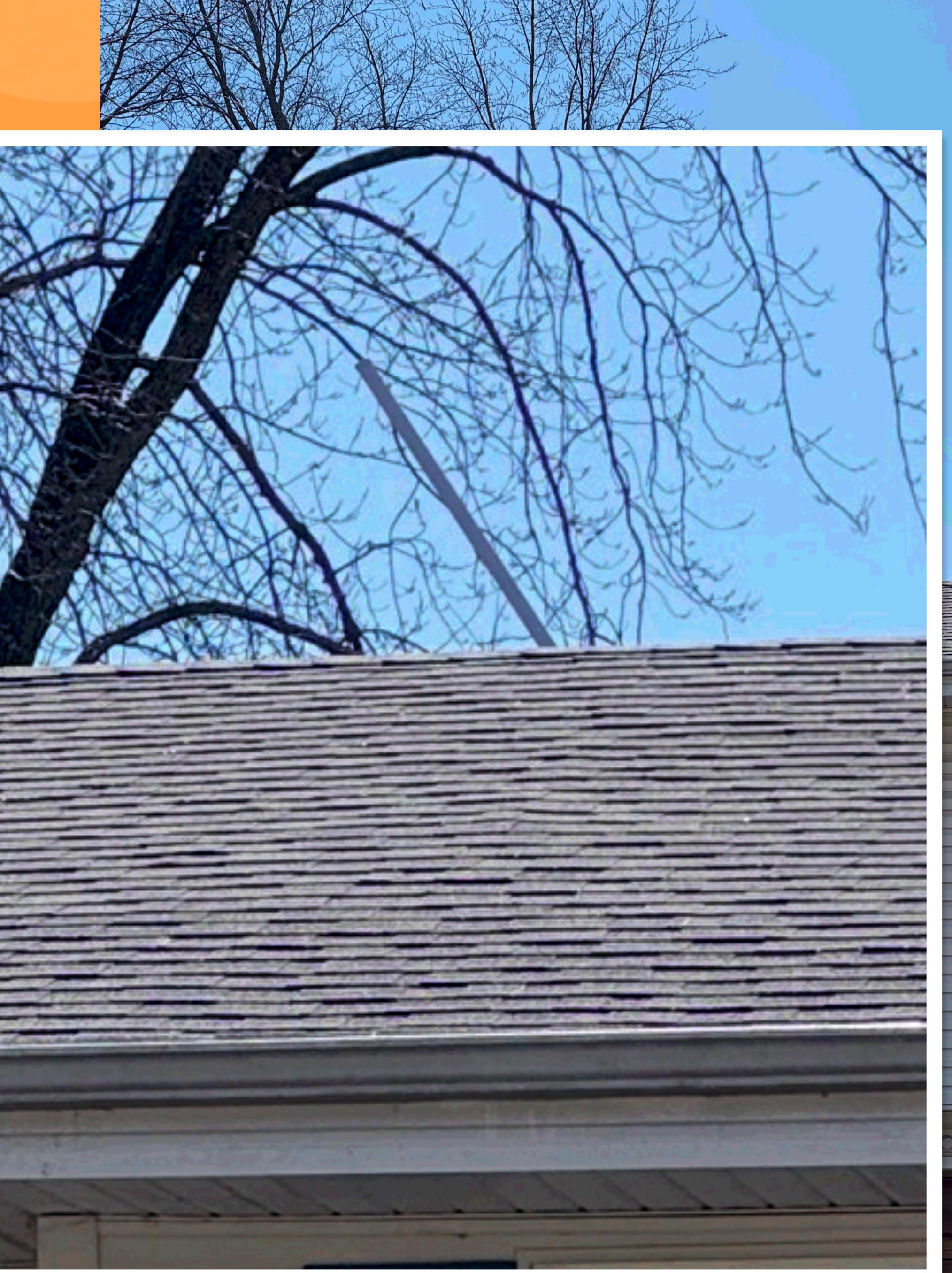




Current Attic Nodes

# Life at 900 MHz (33cm)

- A full wavelength is 13"
- A quarter wave is 3-1/2"
- Small antennas
  - Partner-friendly
  - Neighbor-friendly
- Inexpensive to buy
- Make your own!



# More Life at 900 MHz (33cm)

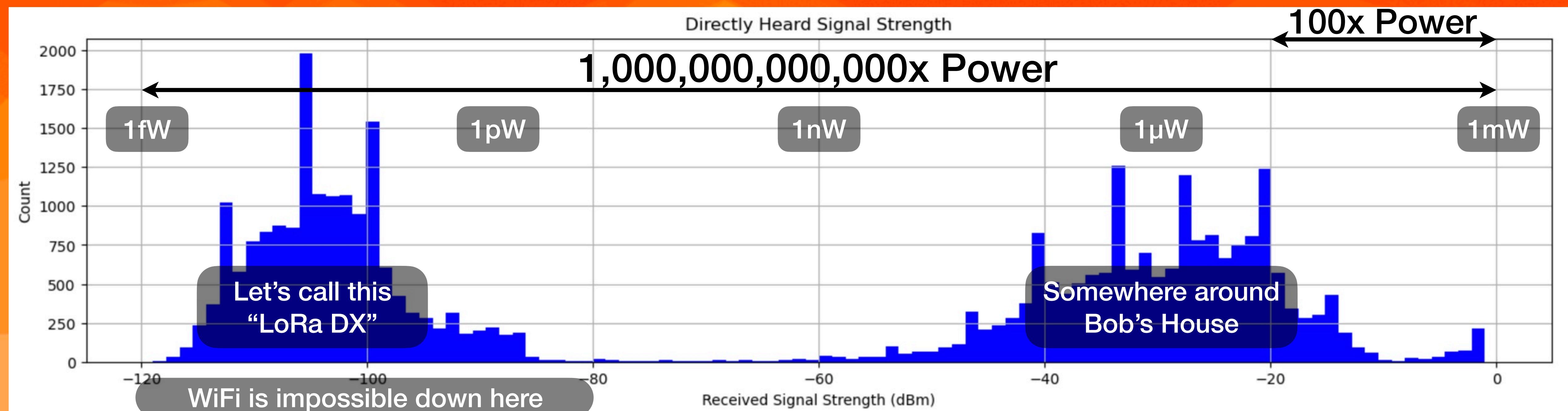


Who took my feed line?

- Integrate radio and antenna to avoid feed line loss
- Decent building penetration, so attic antennas can work well
- Radios and antennas inside or outside?
  - Inside pros: lightning protection, grounding, weather protection, easier wiring
  - Outside pros: Better signal
  - Different: Temperature swings

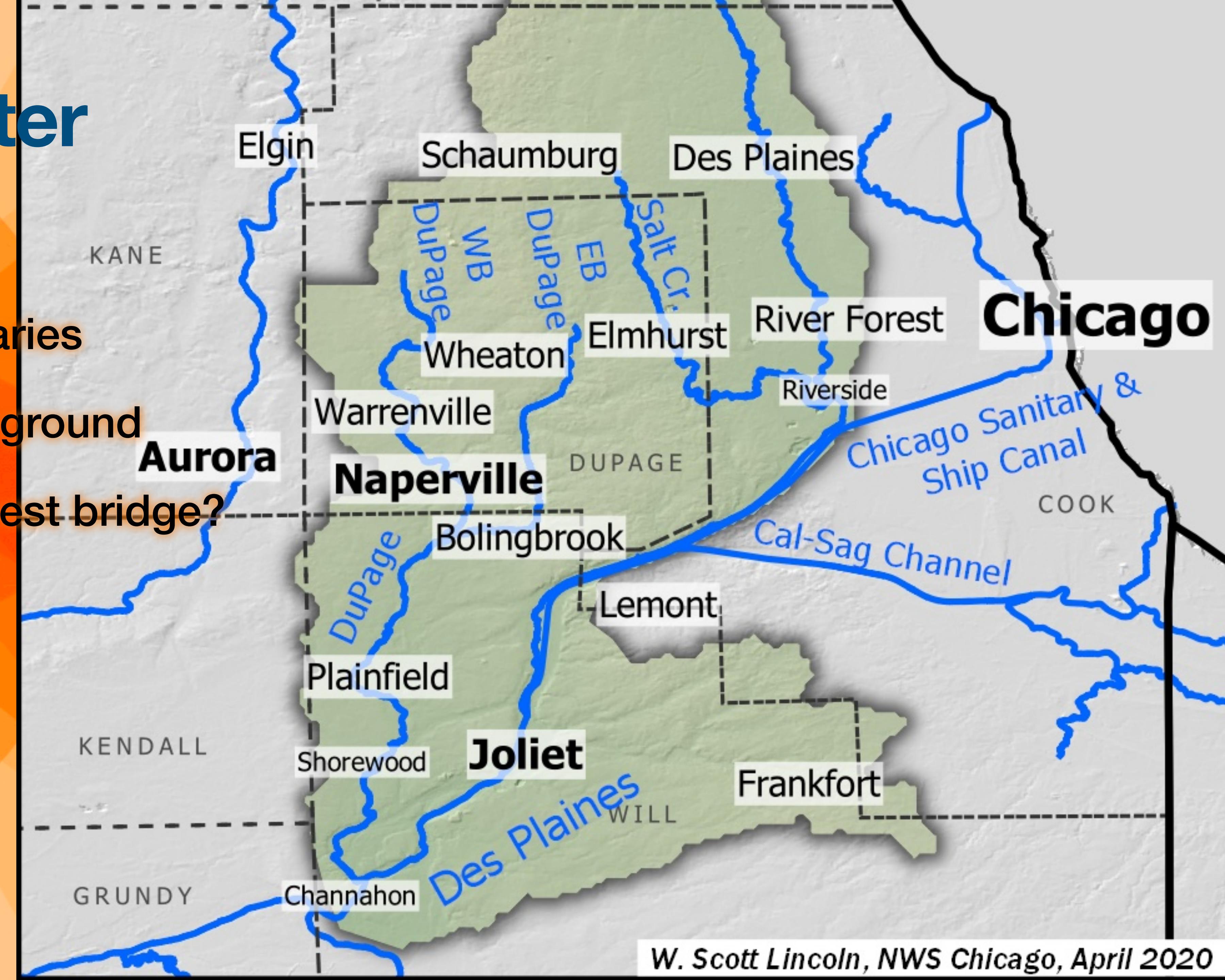
# Measured Signal Strength in Wheaton

- Over 35,000 directly-heard messages logged below
- Bimodal distribution
- Not much below -115 dBm
- Note: This is signal strength in dBm, not SNR in dB

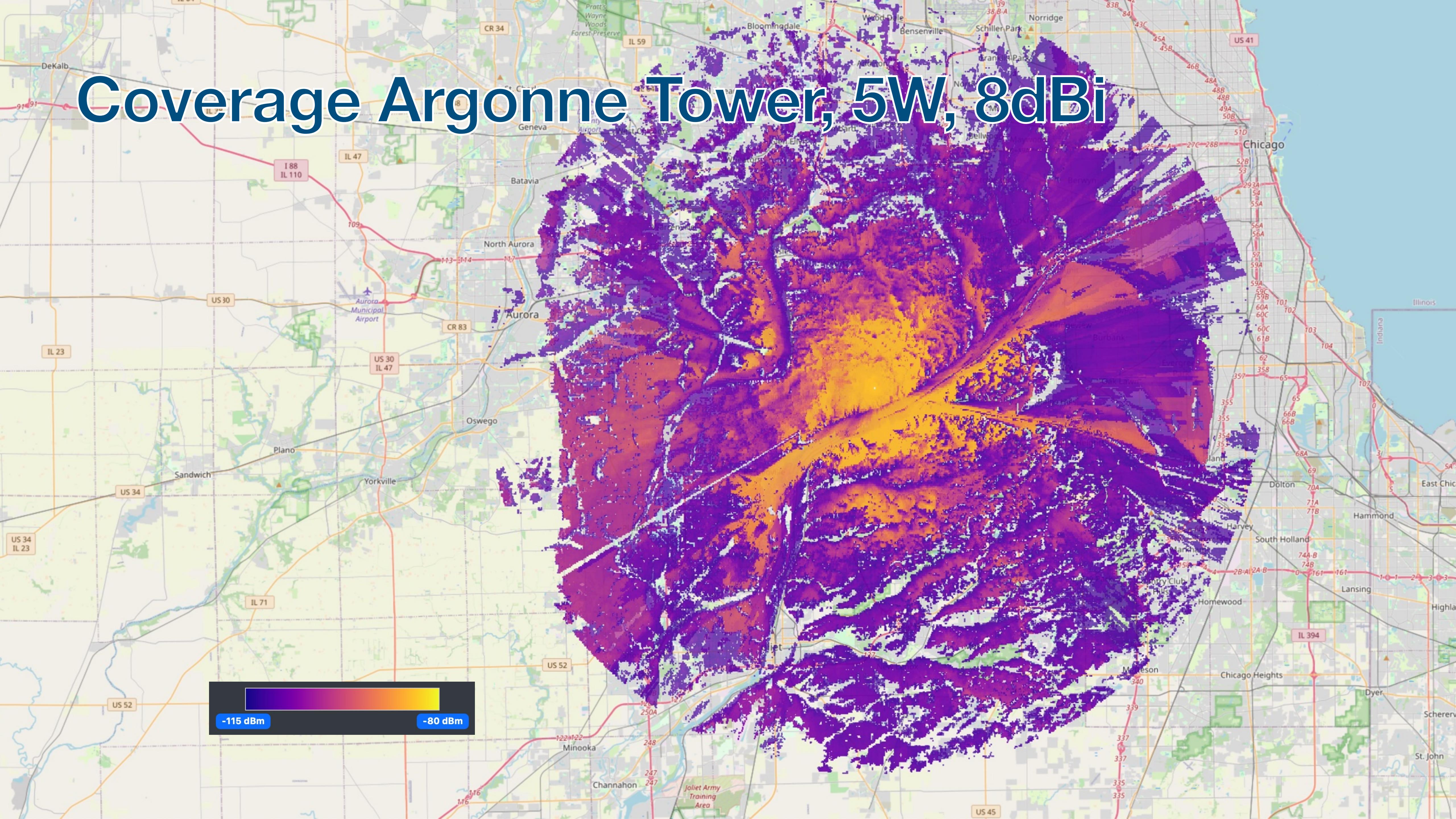


# Surface Water

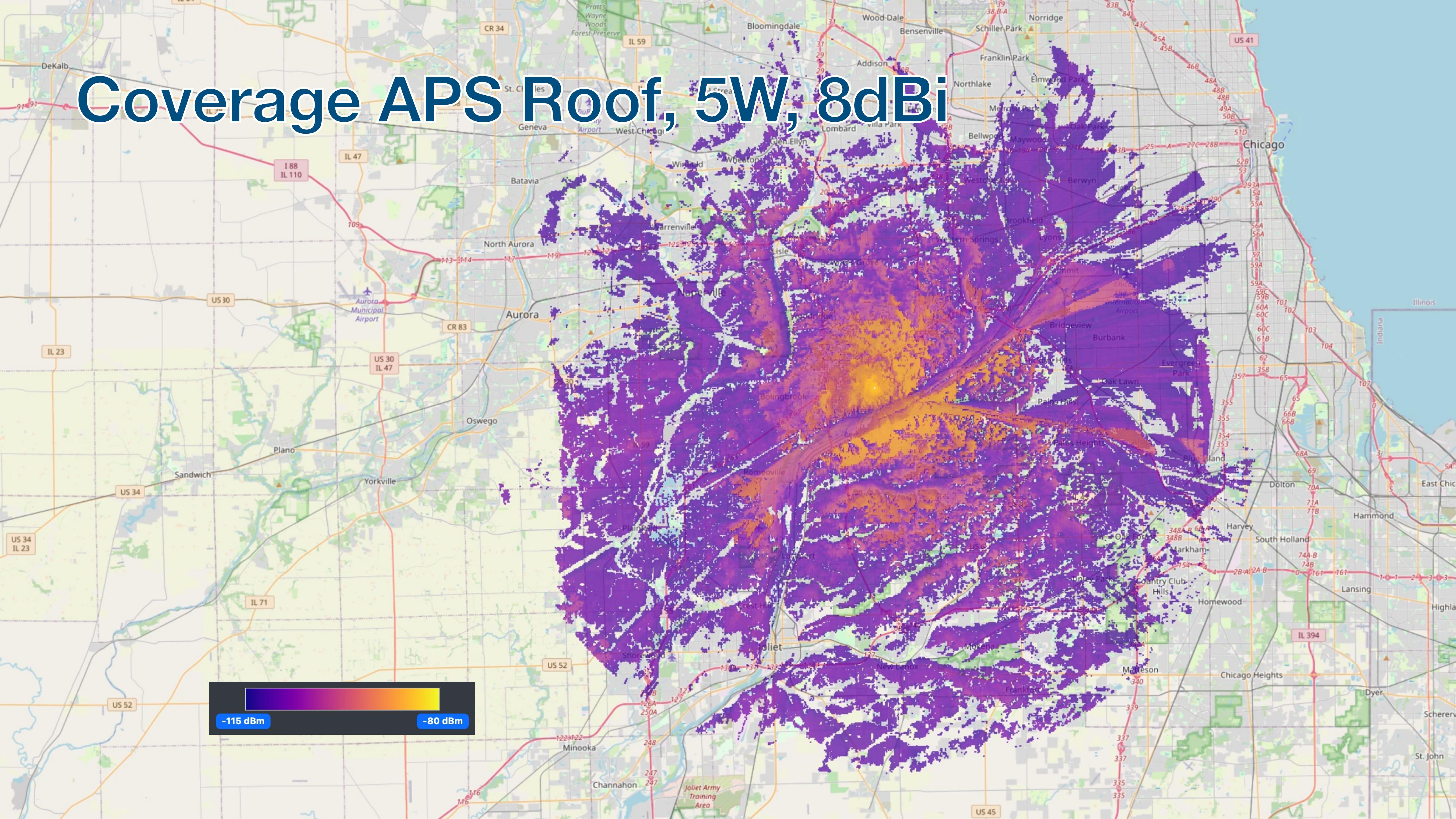
- Watershed boundaries
  - Defined by high ground
- Where is your closest bridge?



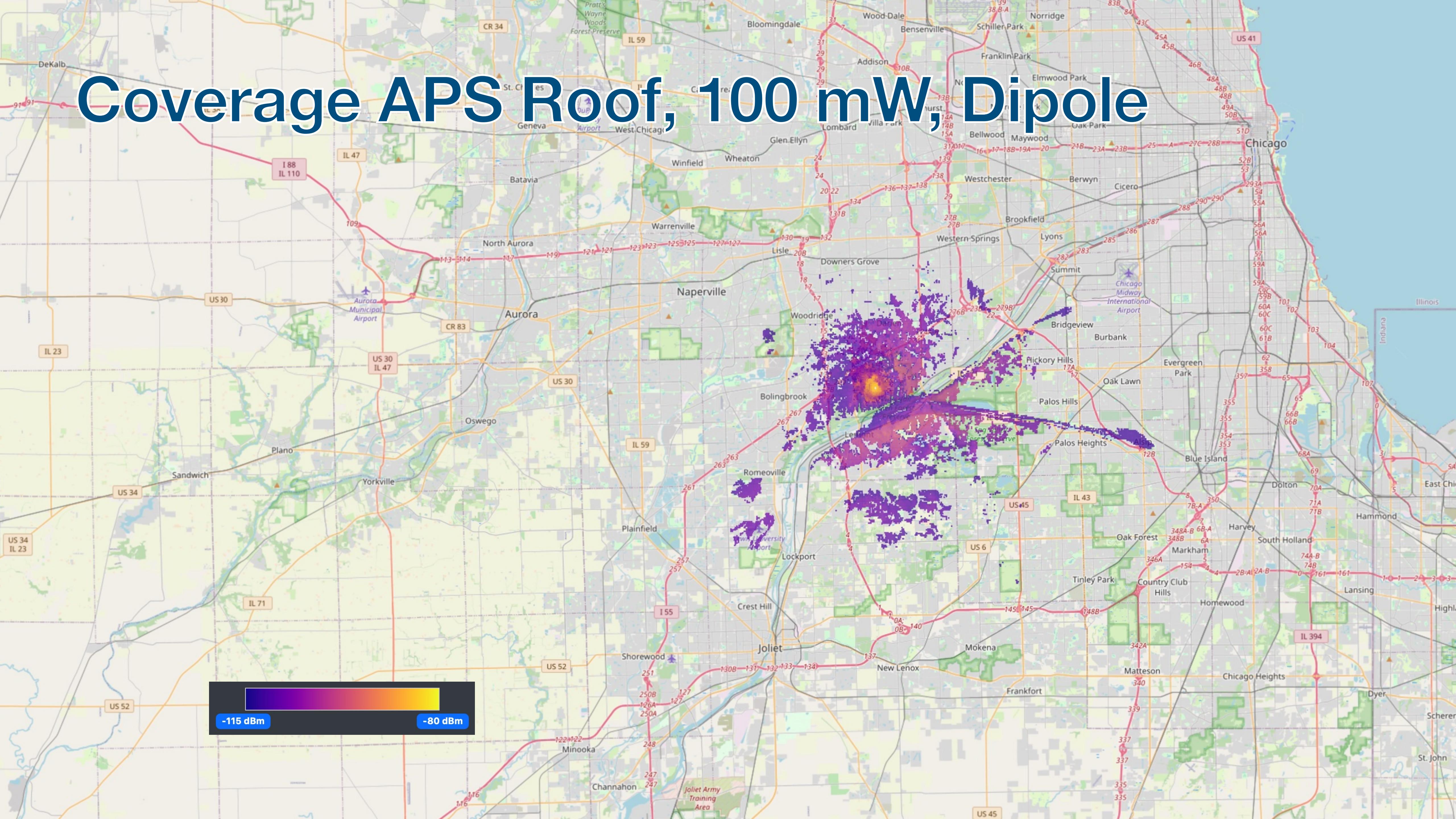
# Coverage Argonne Tower, 5W, 8dBi



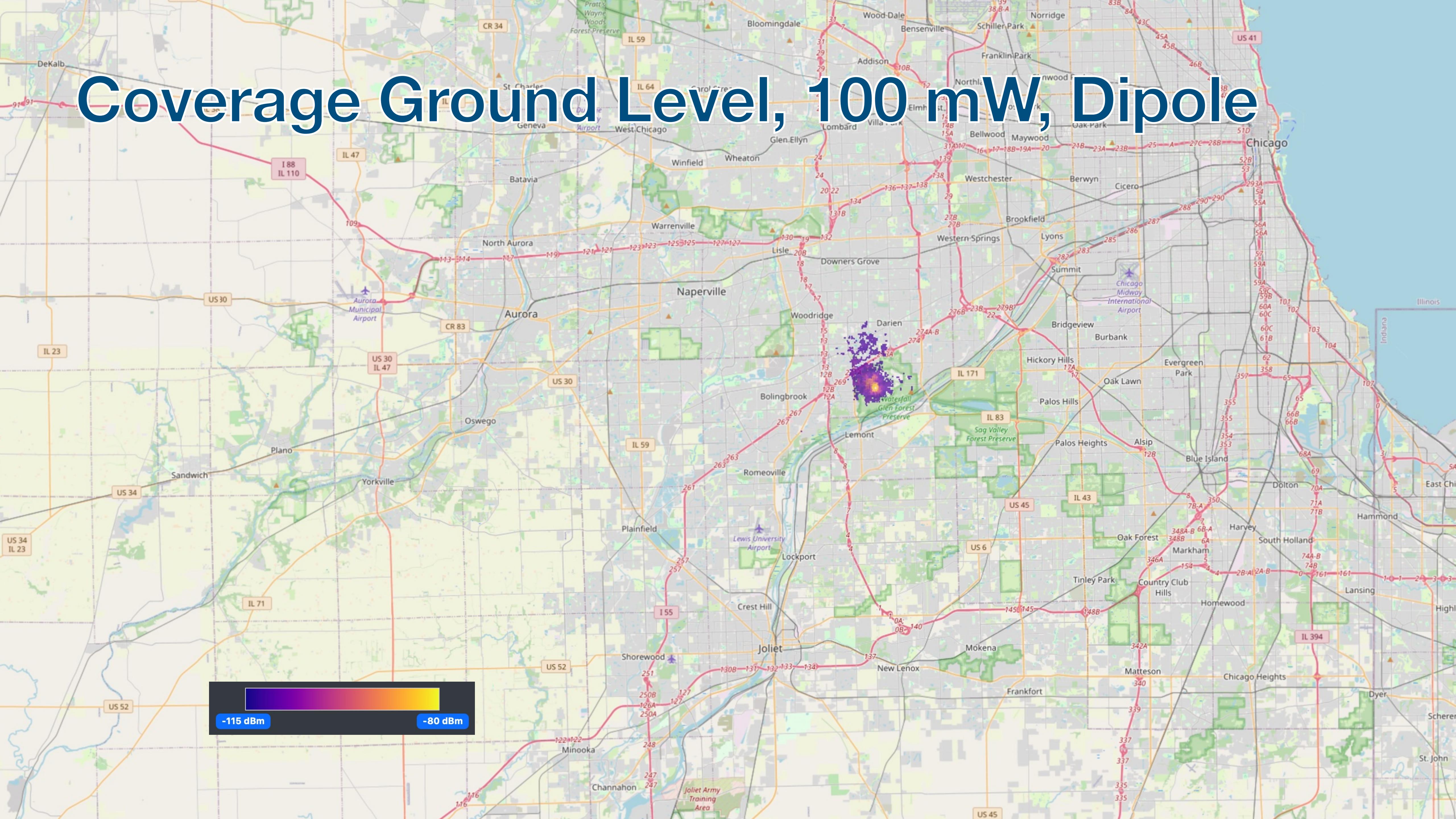
# Coverage APS Roof, 5W, 8dBi



# Coverage APS Roof, 100 mW, Dipole

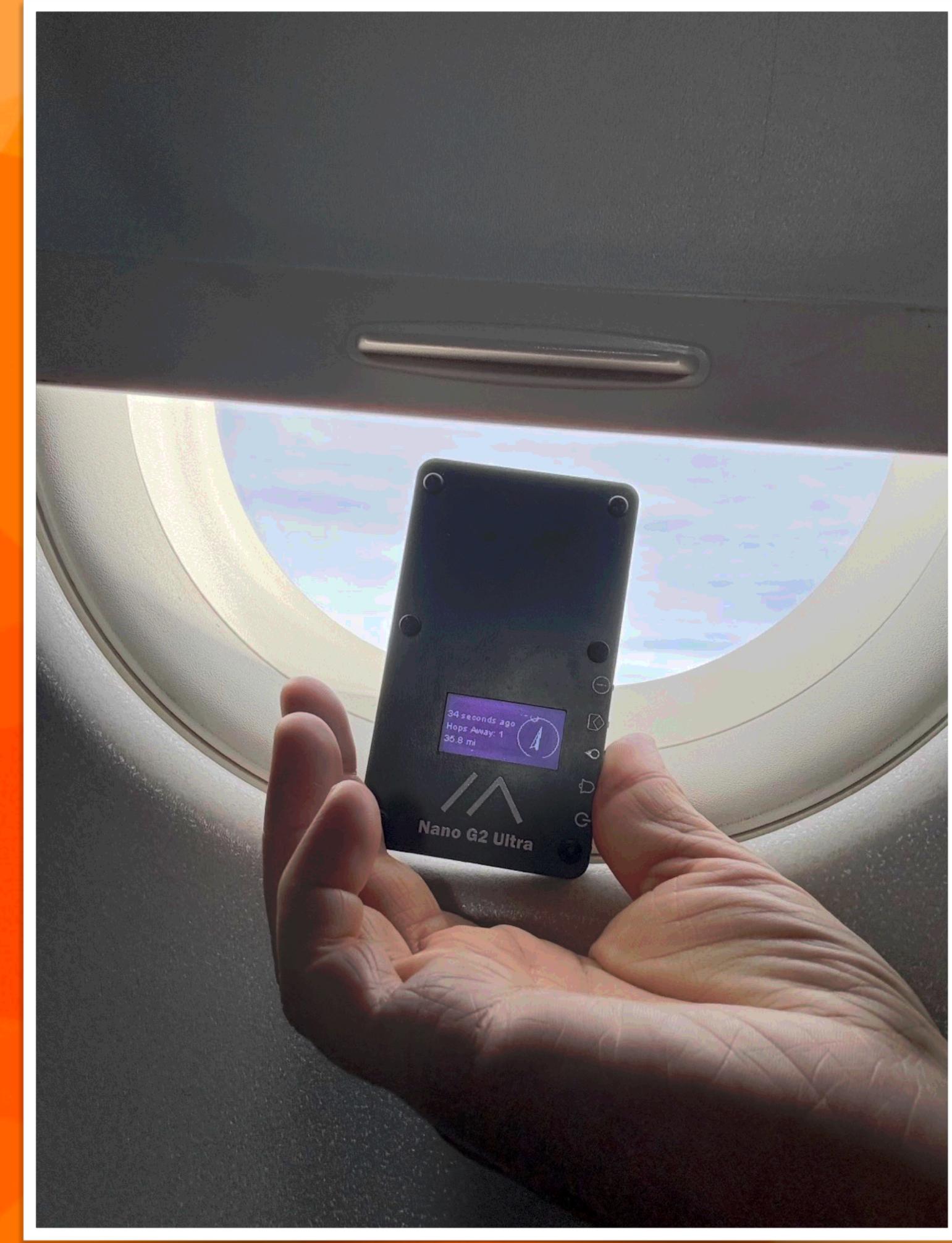


# Coverage Ground Level, 100 mW, Dipole



# Mobile Node Uses

- Commuting
- Hamfest
- Vacations
- Events/concerts



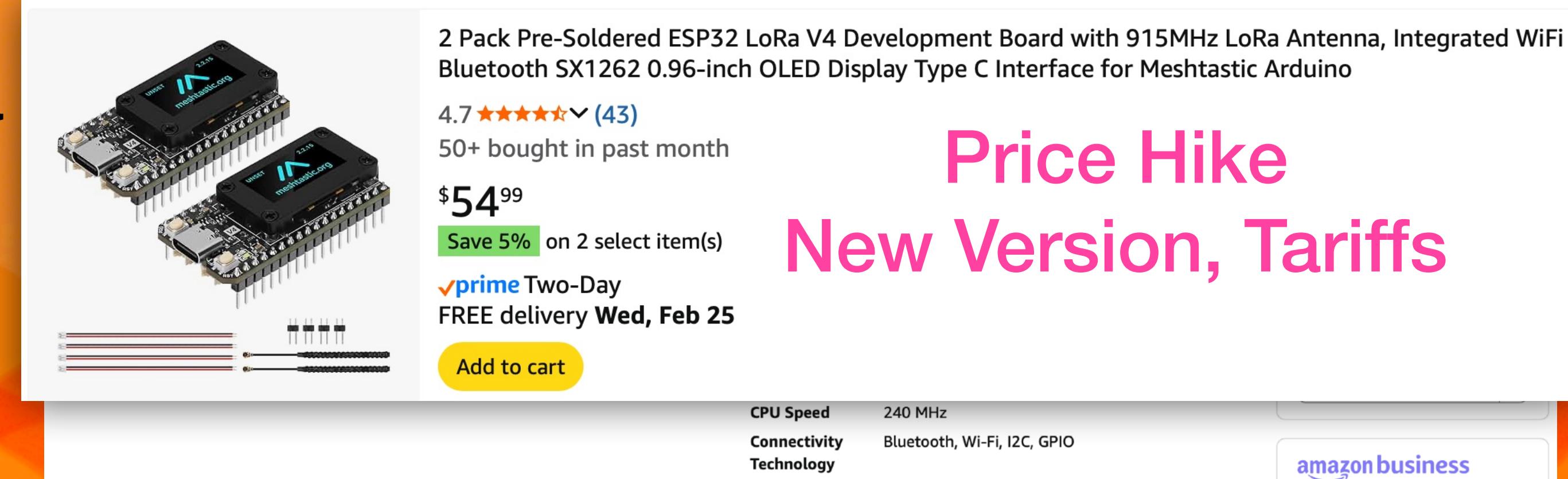
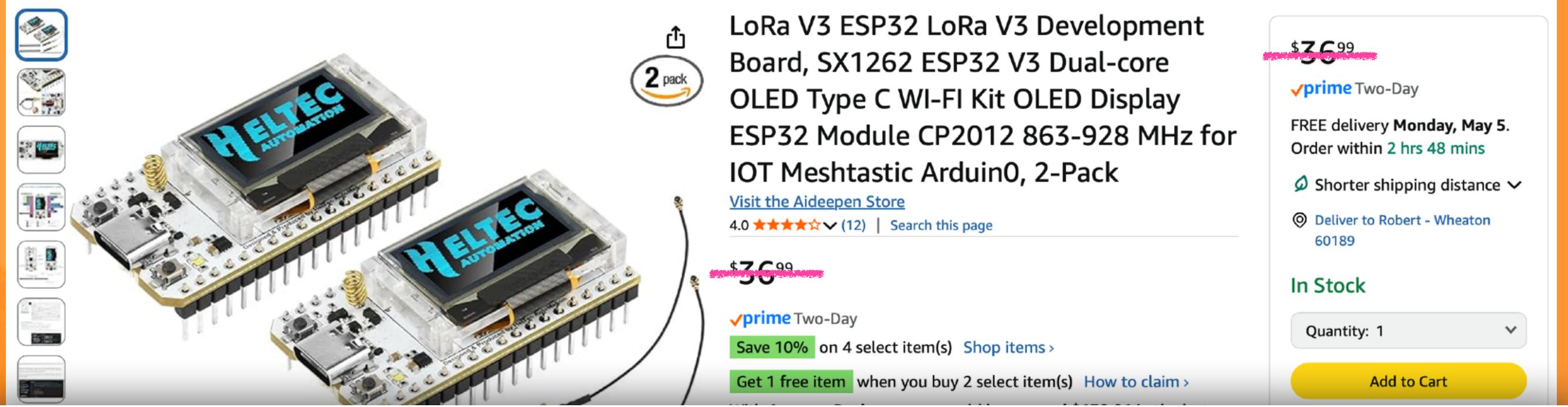
# More Mobile Node Uses

- Biking
- Hiking/Skiing
- GPS gives
  - Heading & distance
- No cellular coverage



# Getting Started

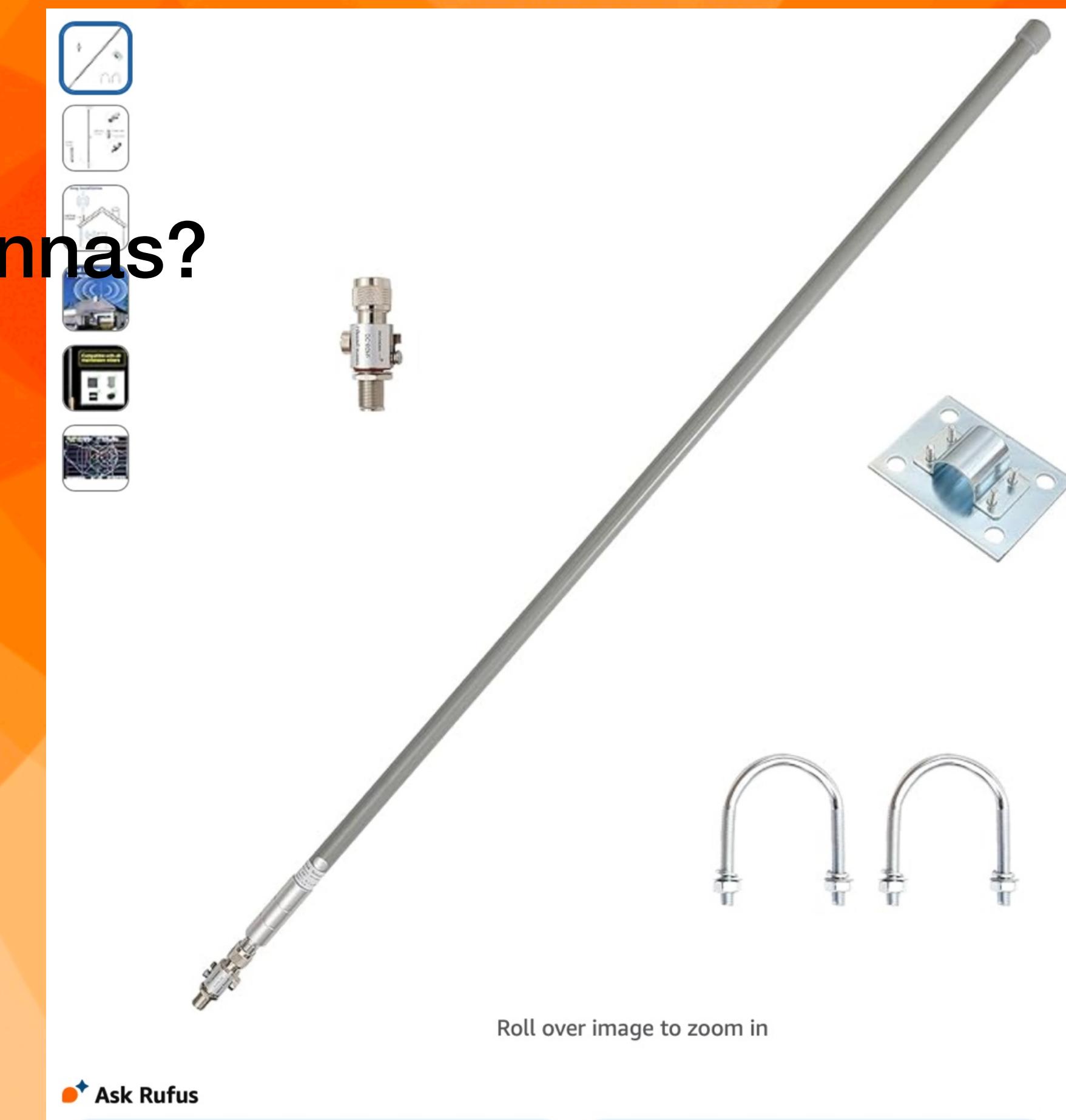
- Amazon Heltec LoRa v3
  - With SMA connector & antenna
  - Cheaper than used Baofeng!
- Run it from USB-C
  - Or add LiPo battery?
  - Maybe 3D print a case?
- Chrome web flasher makes firmware easy: <http://Flasher.Meshtastic.Org>
- Join Discord via <http://ChiMesh.Org/discord>



Price Hike  
New Version, Tariffs

# Upgrades

- Maybe upgrade to better portable antenna
- Maybe upgrade to base collinear antenna
- Buy more nodes?
- eBay Helium antennas?
- Use caution



LoRa Antenna 915MHz Kit 8dBi  
Gain Outdoor Omni-Direction HNT  
Miner Antenna 3.6 ft Helium  
Hotspot Antenna

Brand: Hexa Boost

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Channels

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See more

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Complete Protect: One plan  
covers all eligible past and  
future purchases (Renews  
Monthly Until Cancelled) for

## About this item

- ✓ Optimized for 915MHz (Compatible with 900MHz - 930MHz)

# Acknowledgments

- Jim Lentz, AC9YY, my cousin!
- John, mobile Audio/Visual guru

# Live Demo