

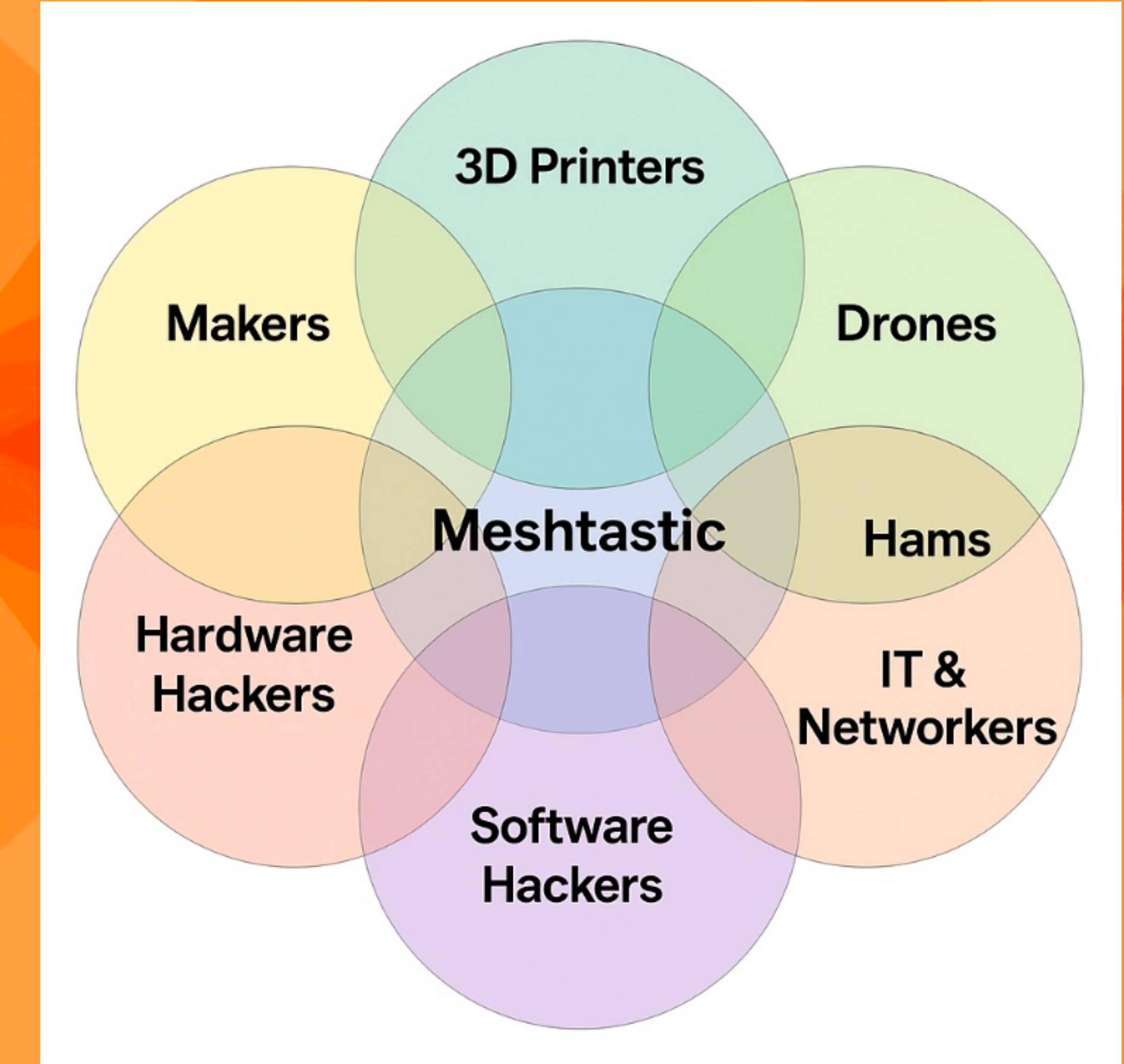
Meshtastic: What's In It For Me?

Bob Van Valzah, ke9yq, May 7, 2025

For Argonne Amateur Radio Club

What's In It For Me?

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

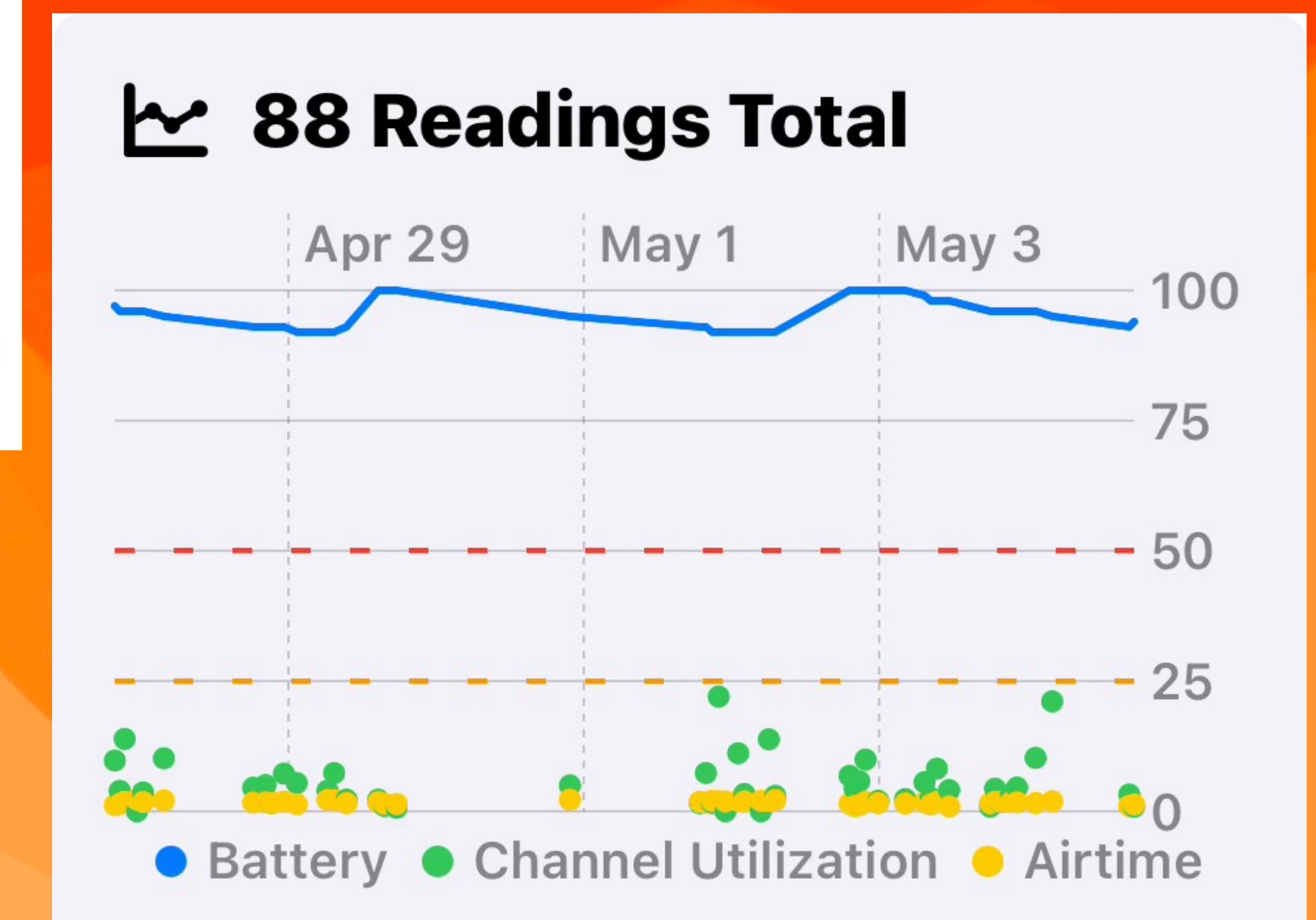
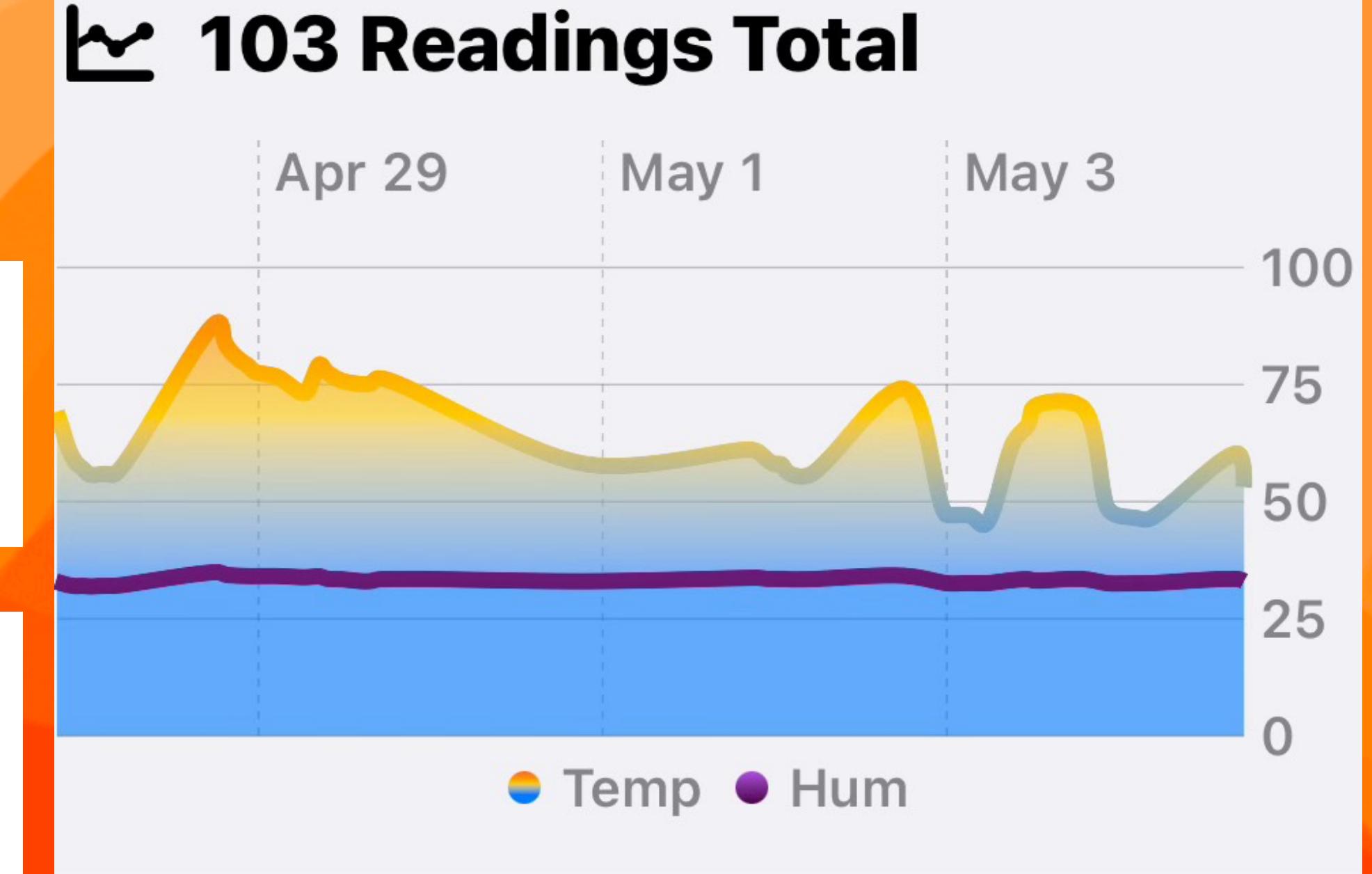
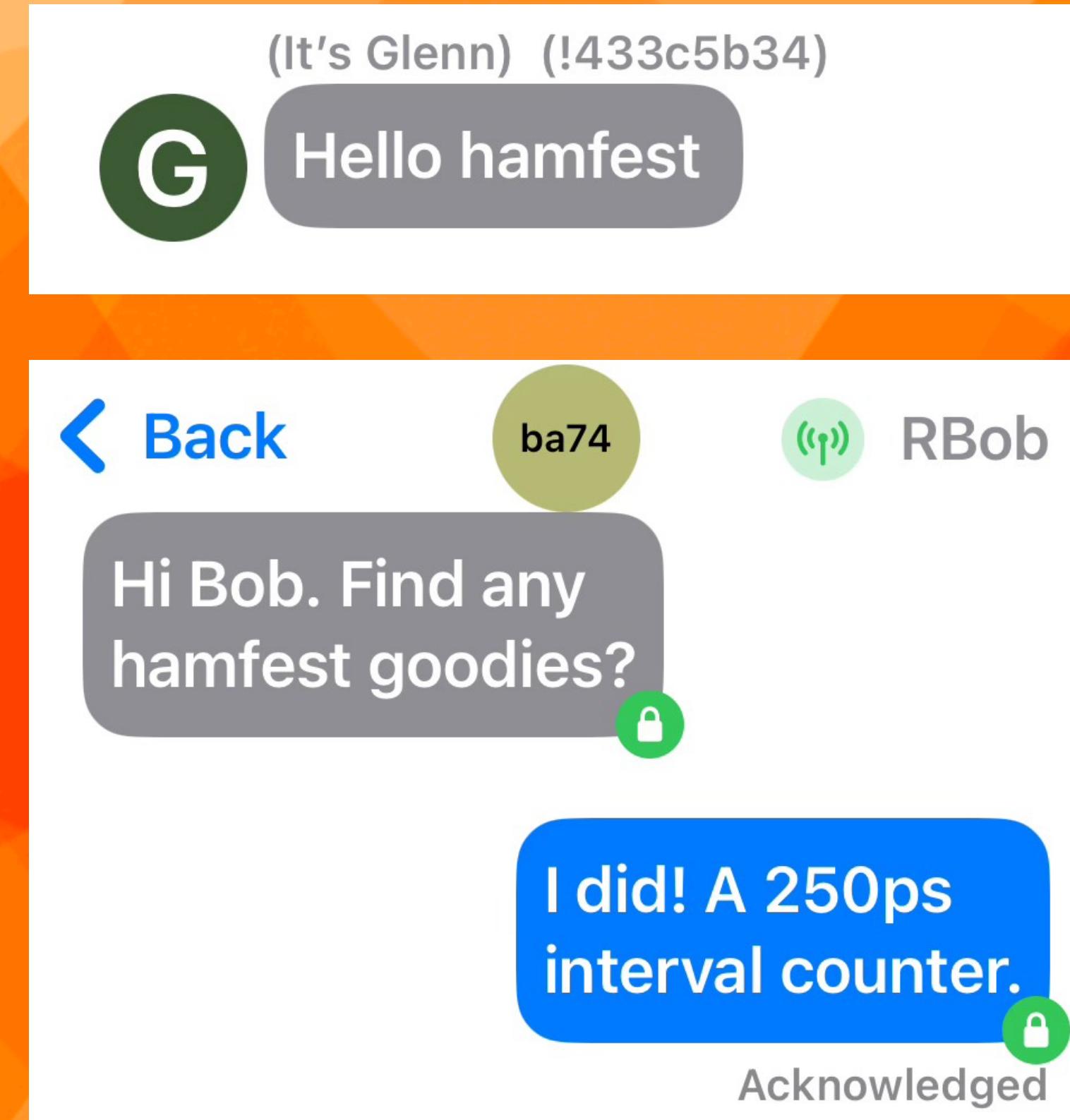
Android Client

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



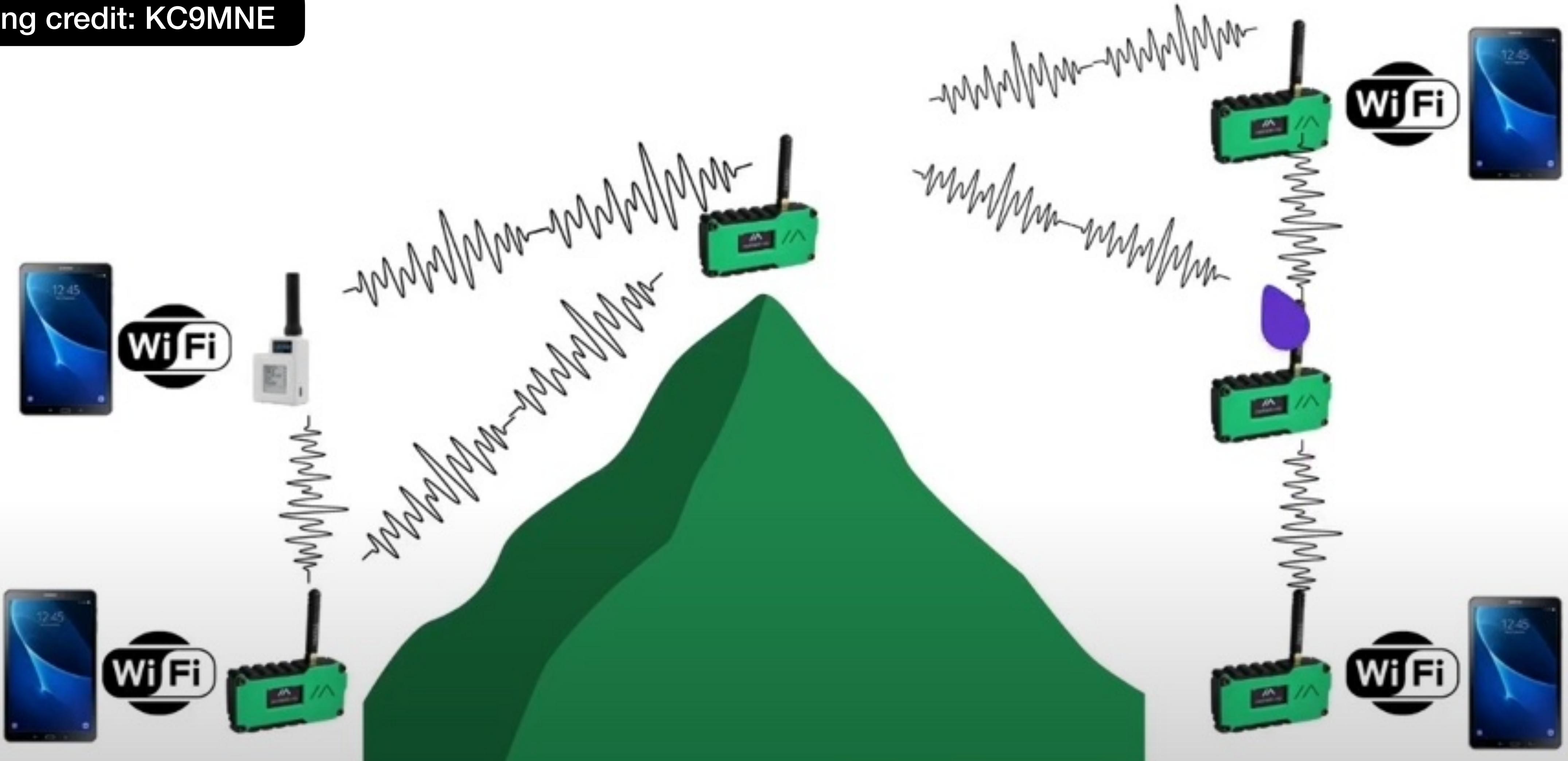
What's In A Node?

- MCU 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?



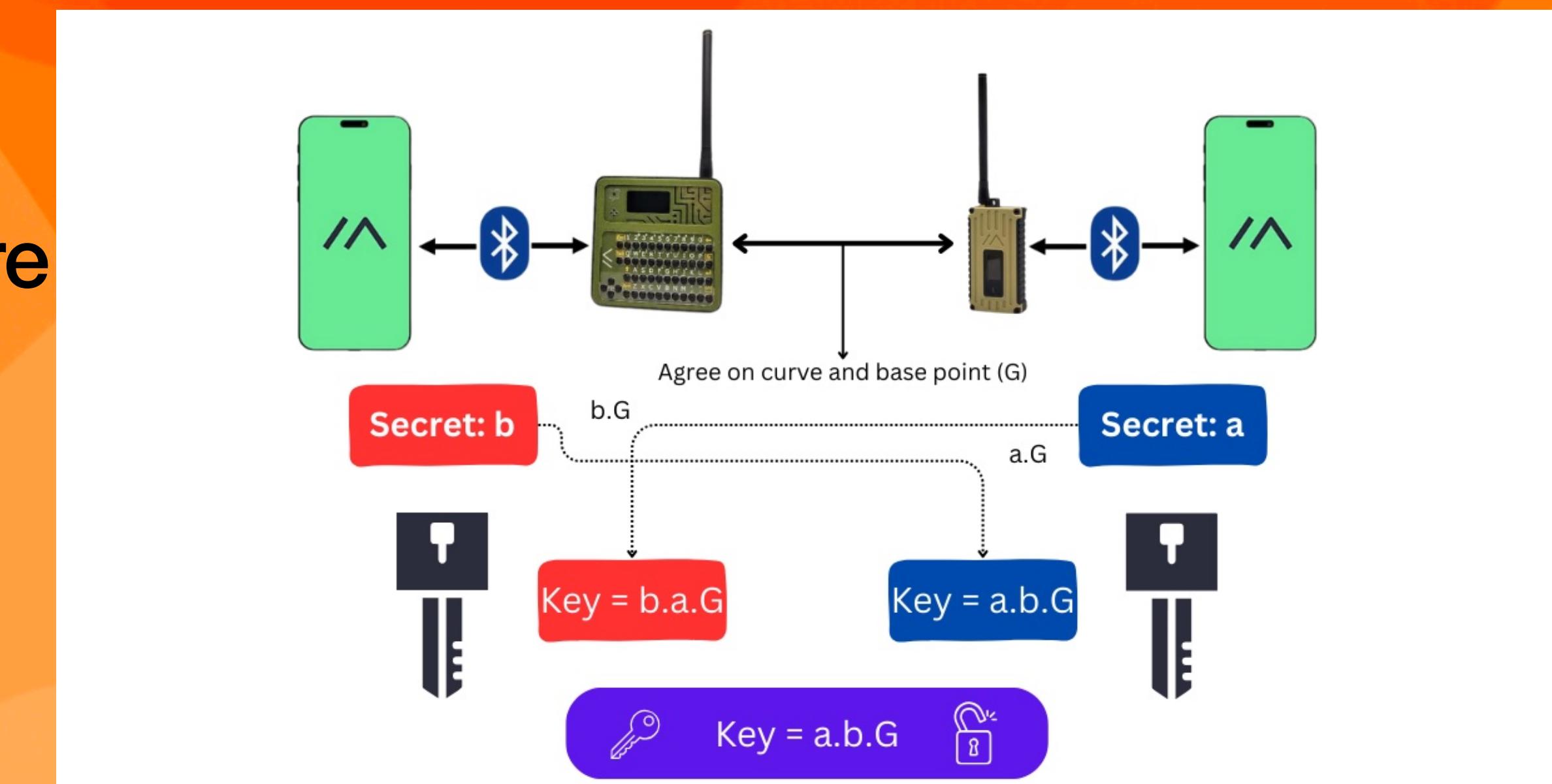
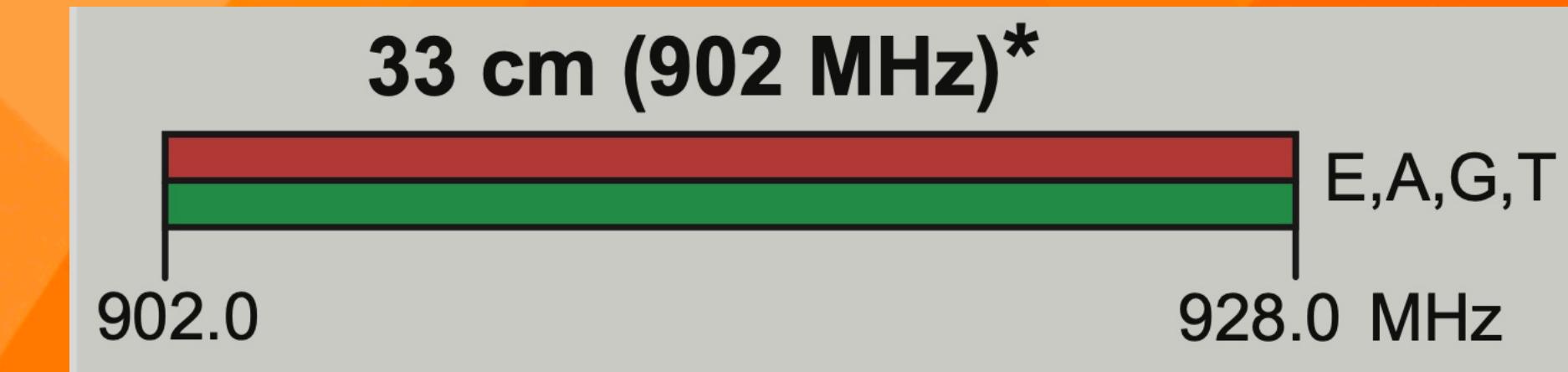
What's A Mesh? What's a Hop?

Drawing credit: KC9MNE



Characteristics

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



Node Roles

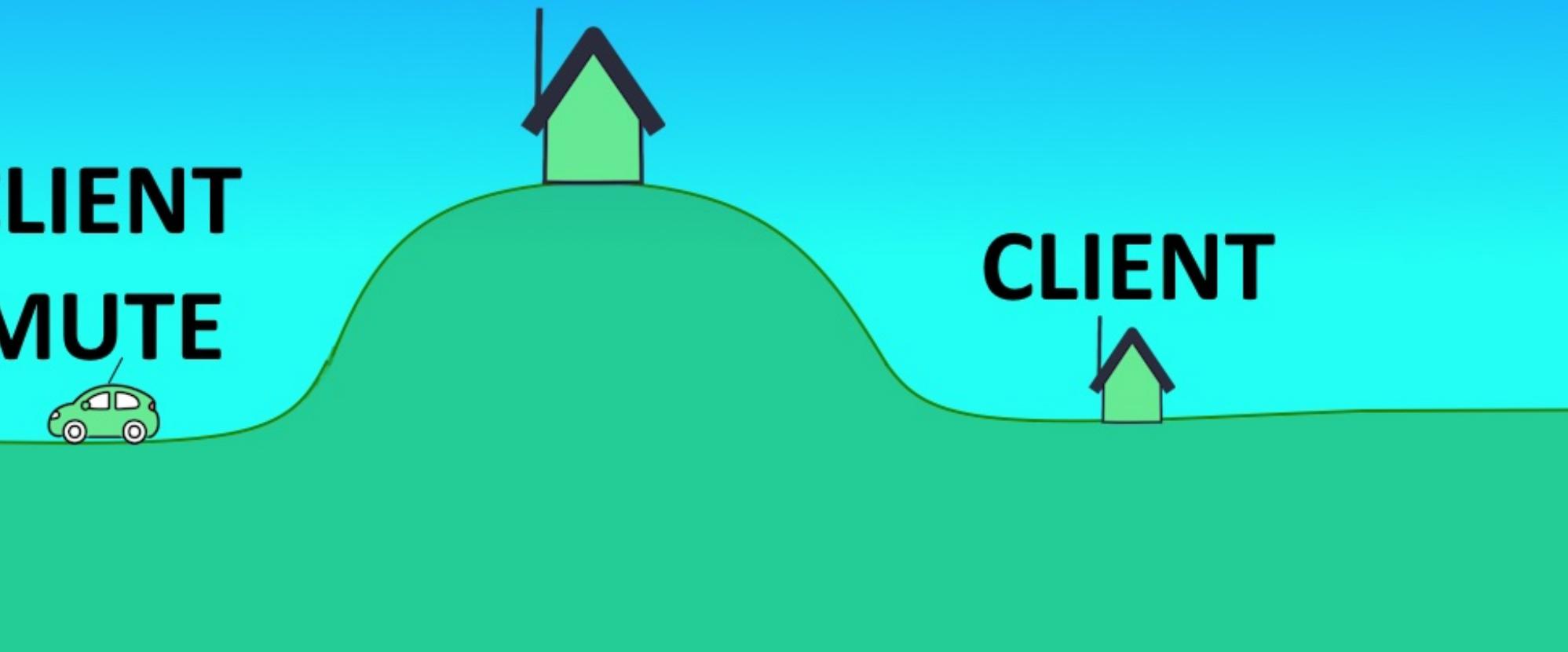
- **Client:** Join mesh, rebroadcasting for others
- **Client Mute:** Join mesh, no rebroadcasting
- **Router:** Prioritizes rebroadcasting, power hungry, discouraged
- **Tracker:** Prioritizes position updates
- **Sensor:** Prioritizes sensor data

RECOMMENDED
MESHTASTIC ROLE SETTINGS

ROUTER

CLIENT
MUTE

CLIENT



When to Transmit?

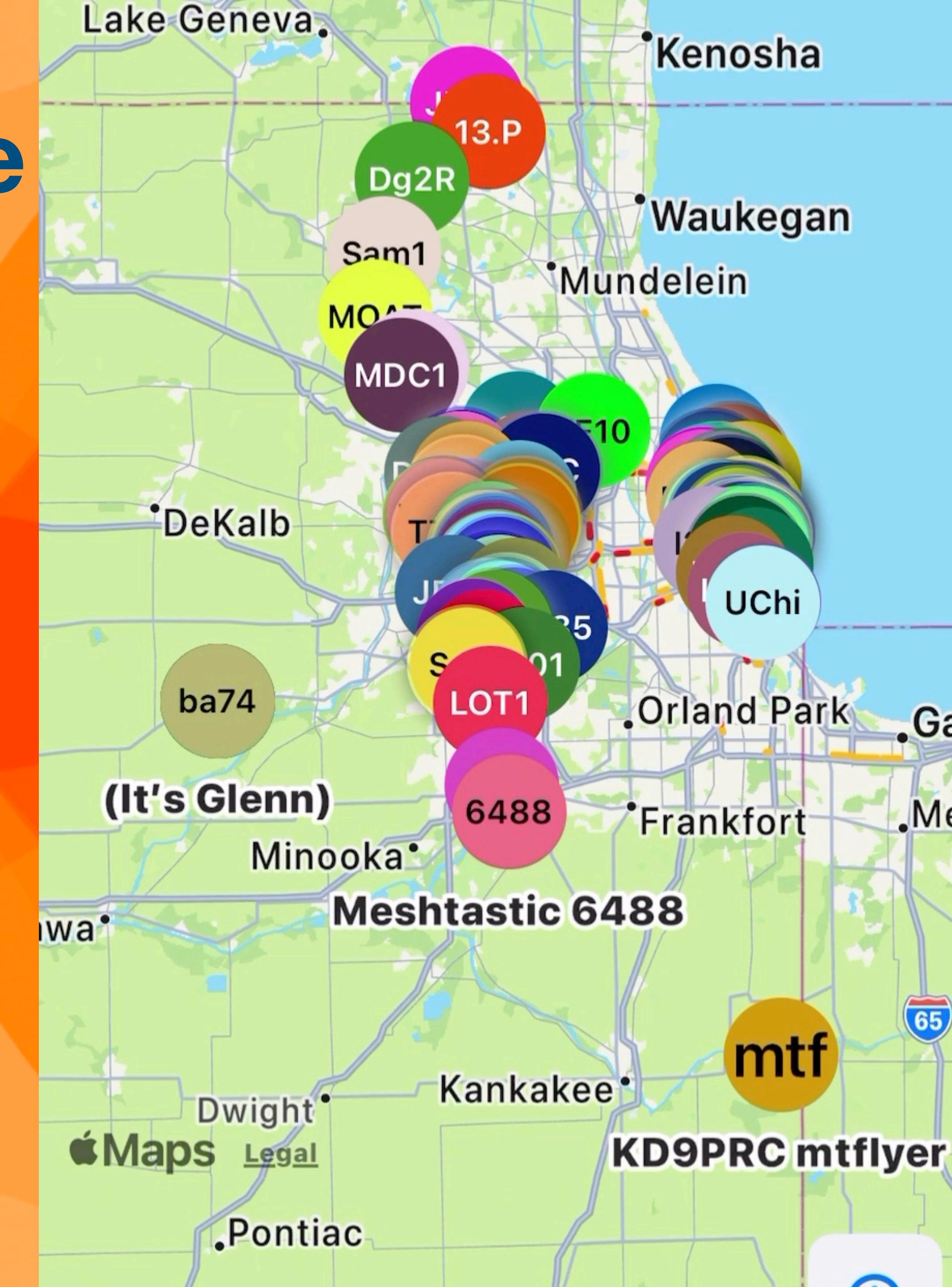
- TX & RX on same frequency, so RX is deaf while TX is on
- Neither node that transmits on top of another can find out
 - That would be CSMA/CD Collision Detection like old coaxial Ethernet
 - Half-duplex radios can only do CSMA/CA: Collision Avoidance
 - Random backoff when your RX hears another node 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)
- Far-away nodes more likely to rebroadcast
- Near nodes hold off if they hear a rebroadcast from others
- Efficient flooding, avoiding unneeded rebroadcasting

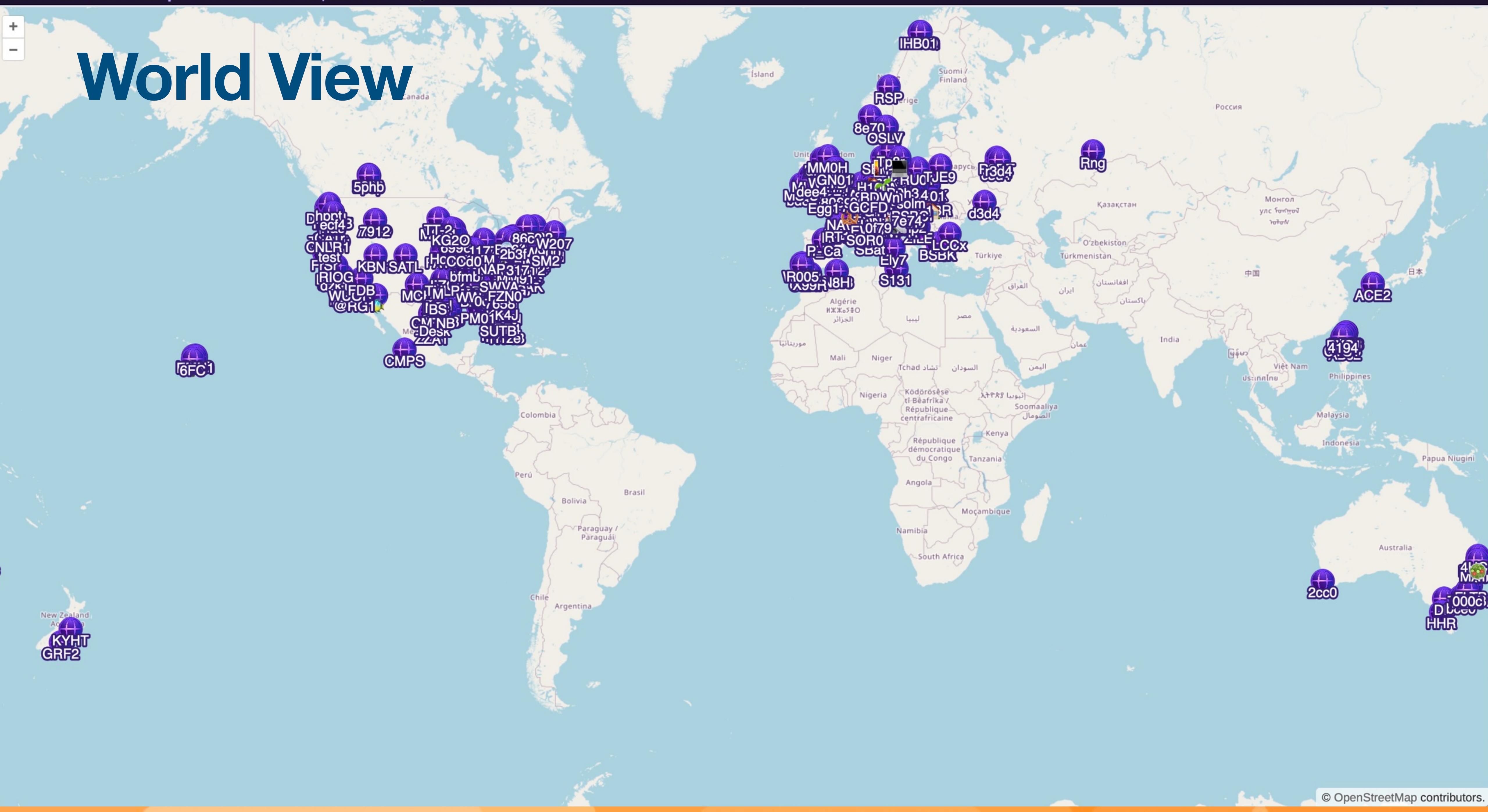
Mesh Map on Bob's Phone

- 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



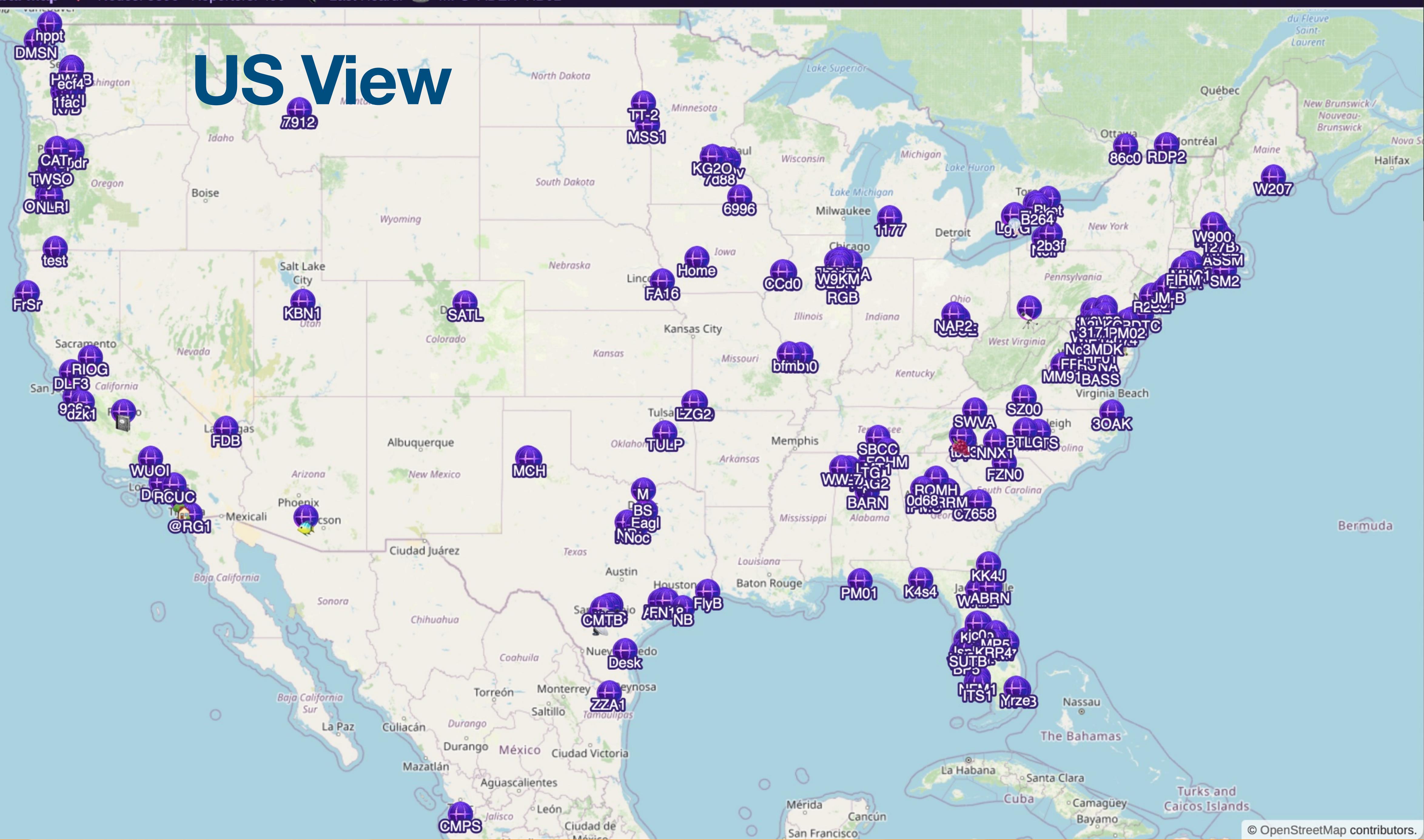


World View

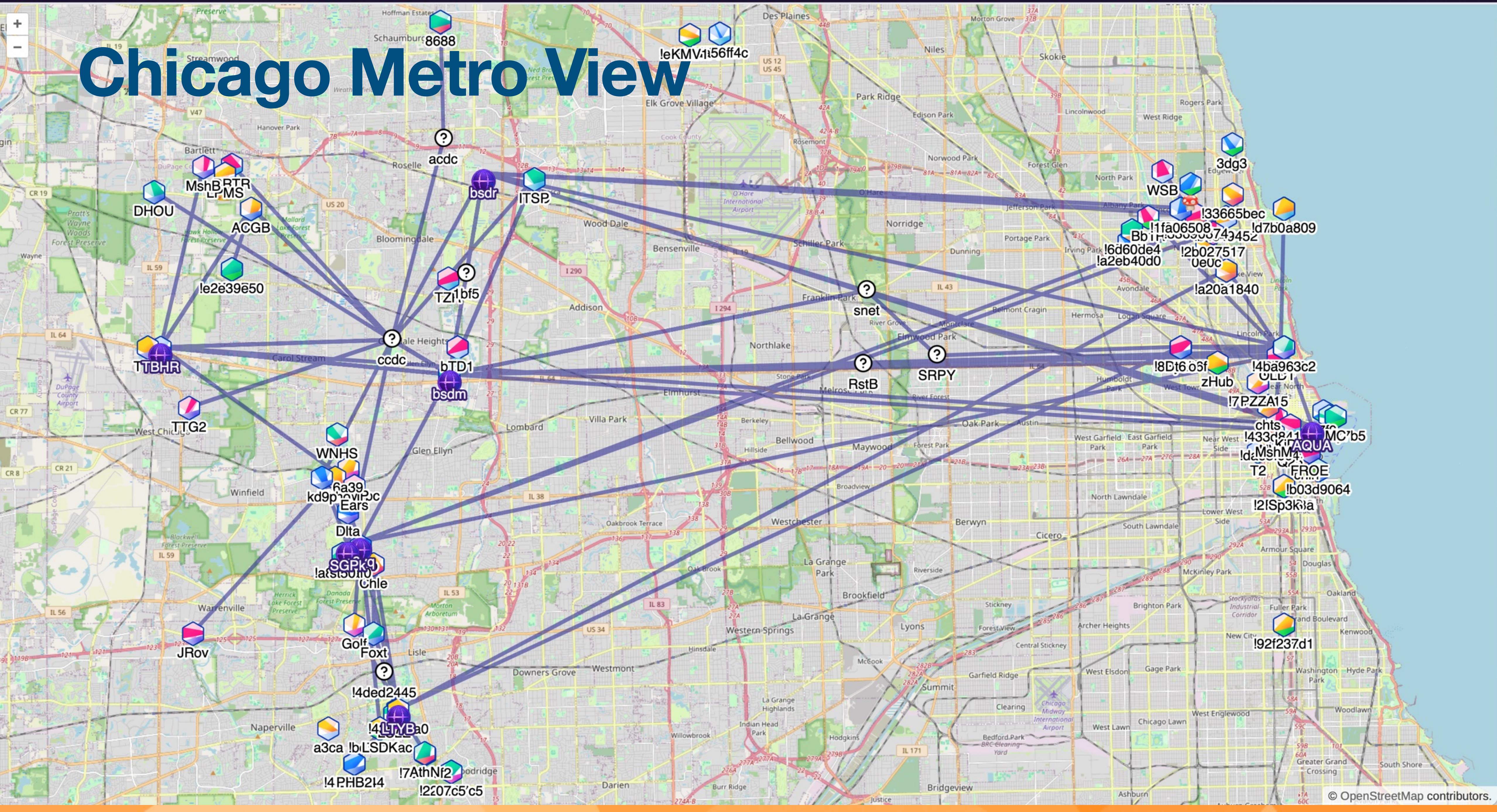




US View

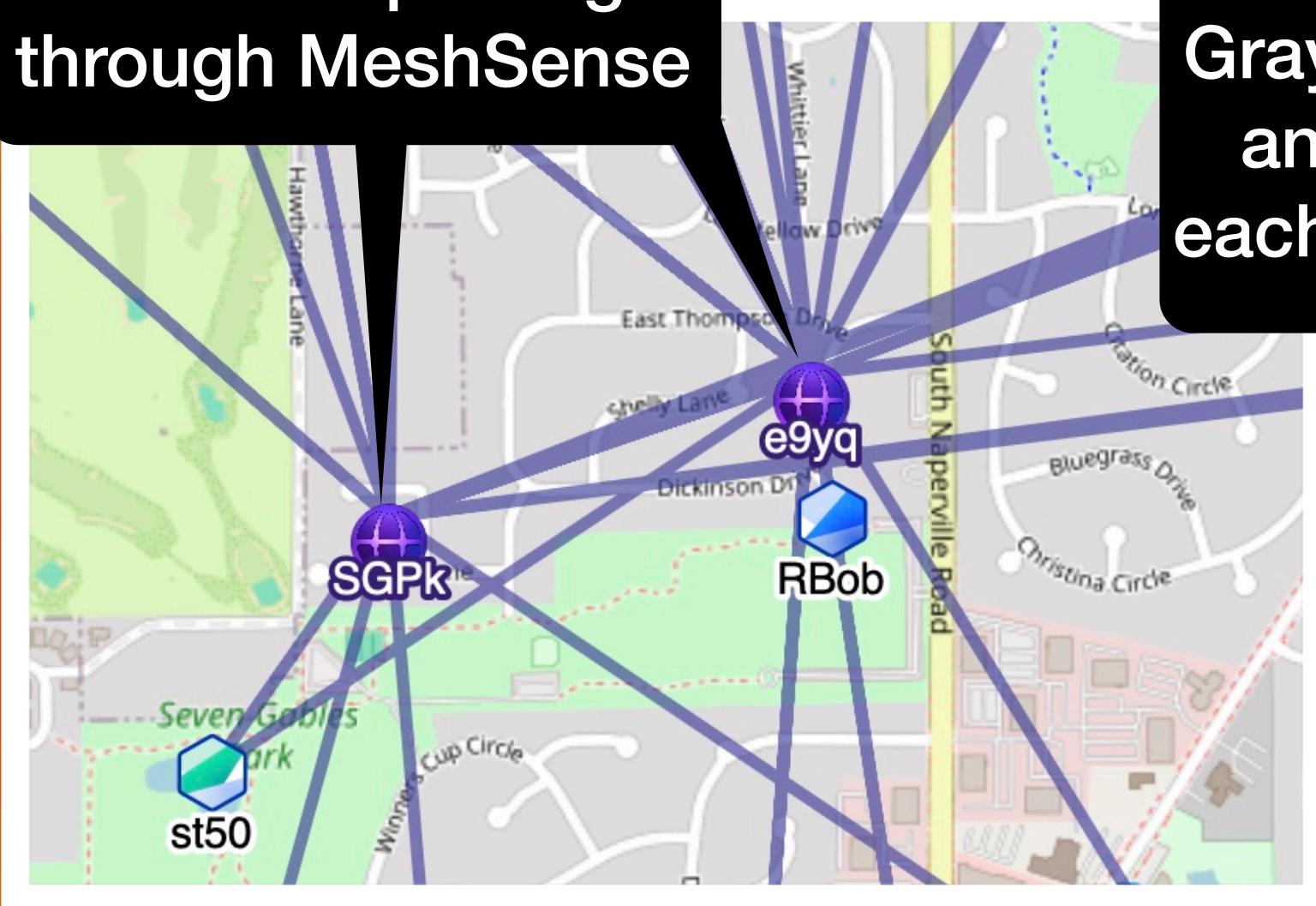


Chicago Metro View

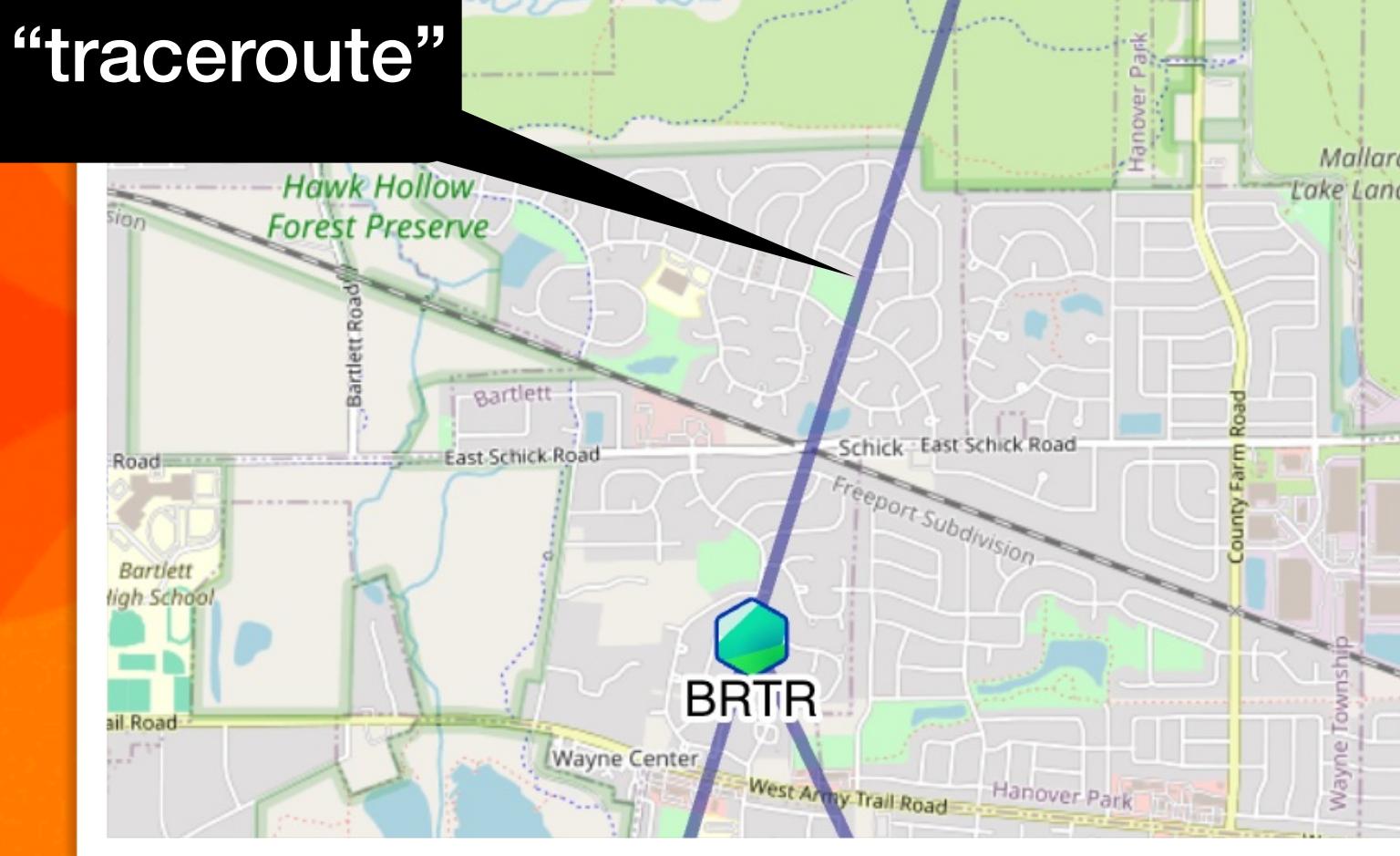


Map Legend

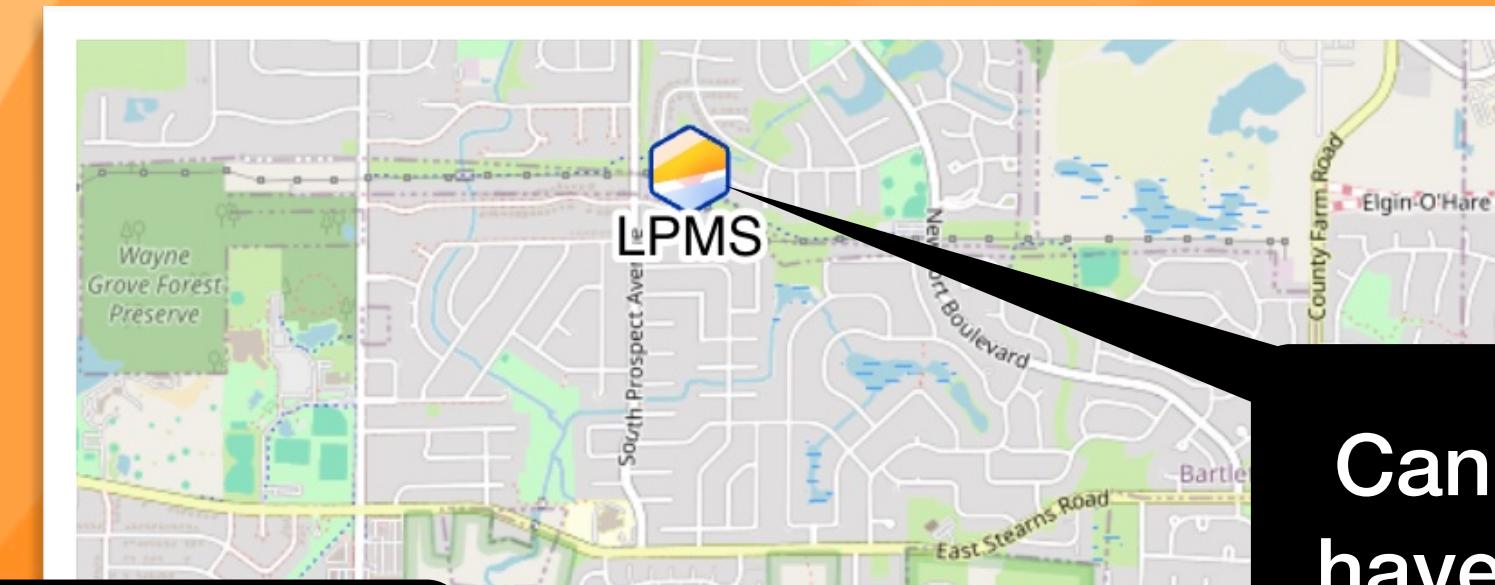
Nodes reporting through MeshSense



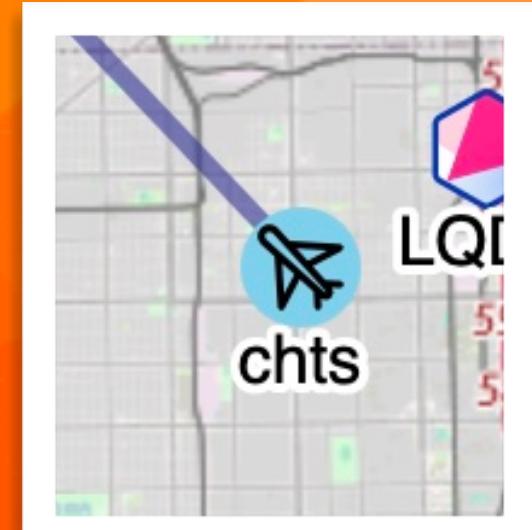
Gray line means ACGB and BRTR can hear each other “traceroute”



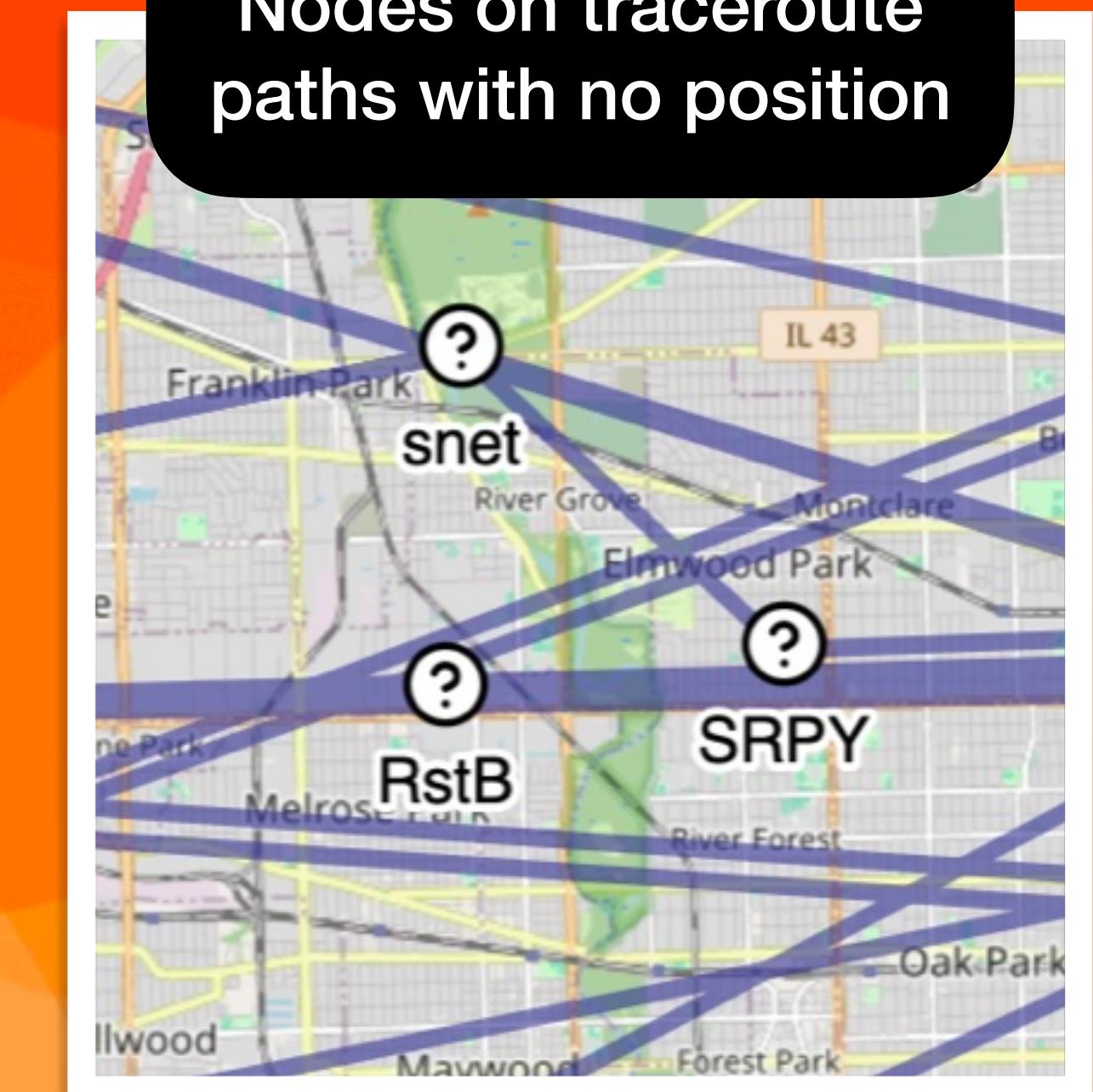
Can hear LPMS and have position, but he can't hear me



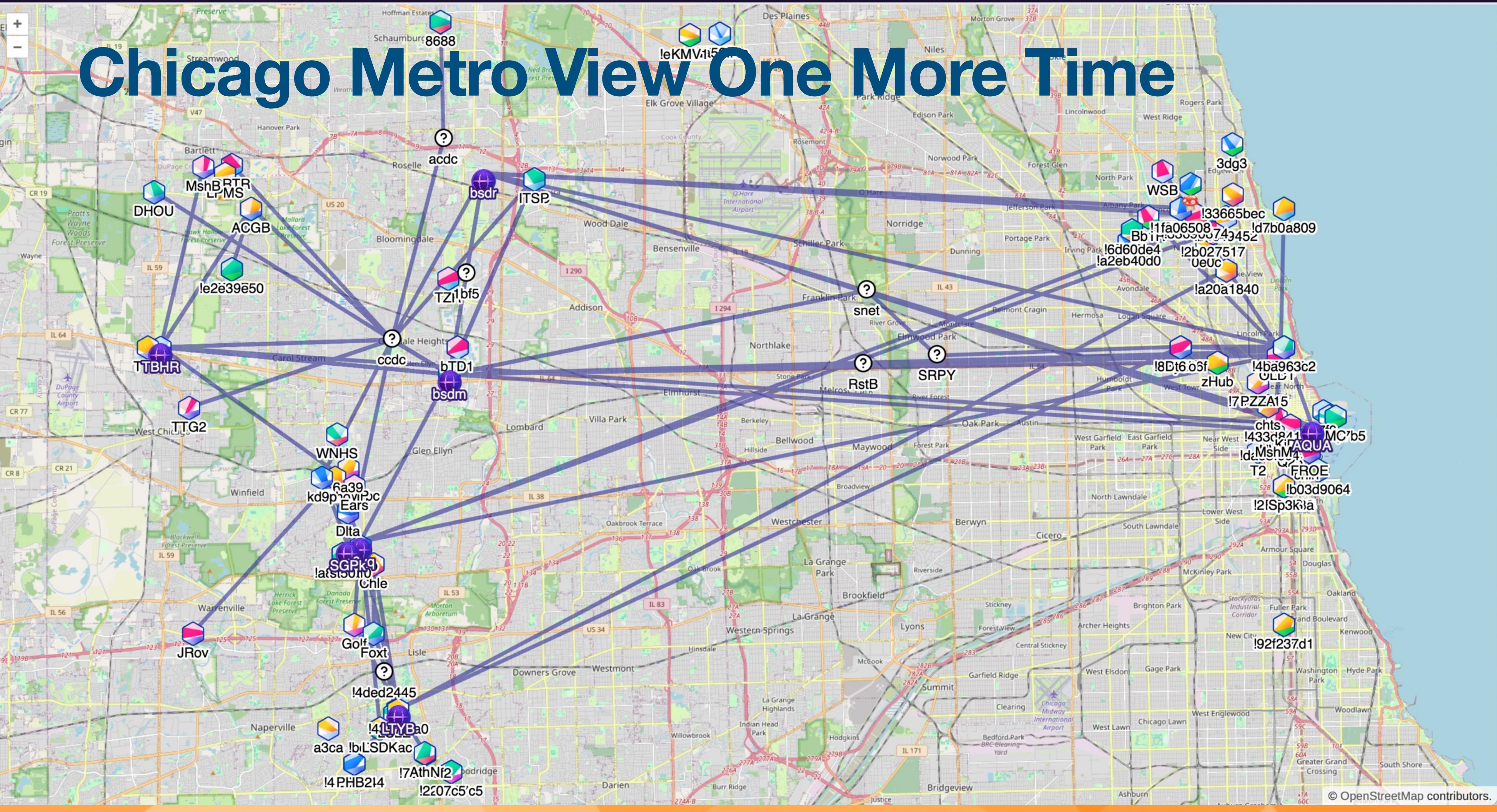
High-altitude node



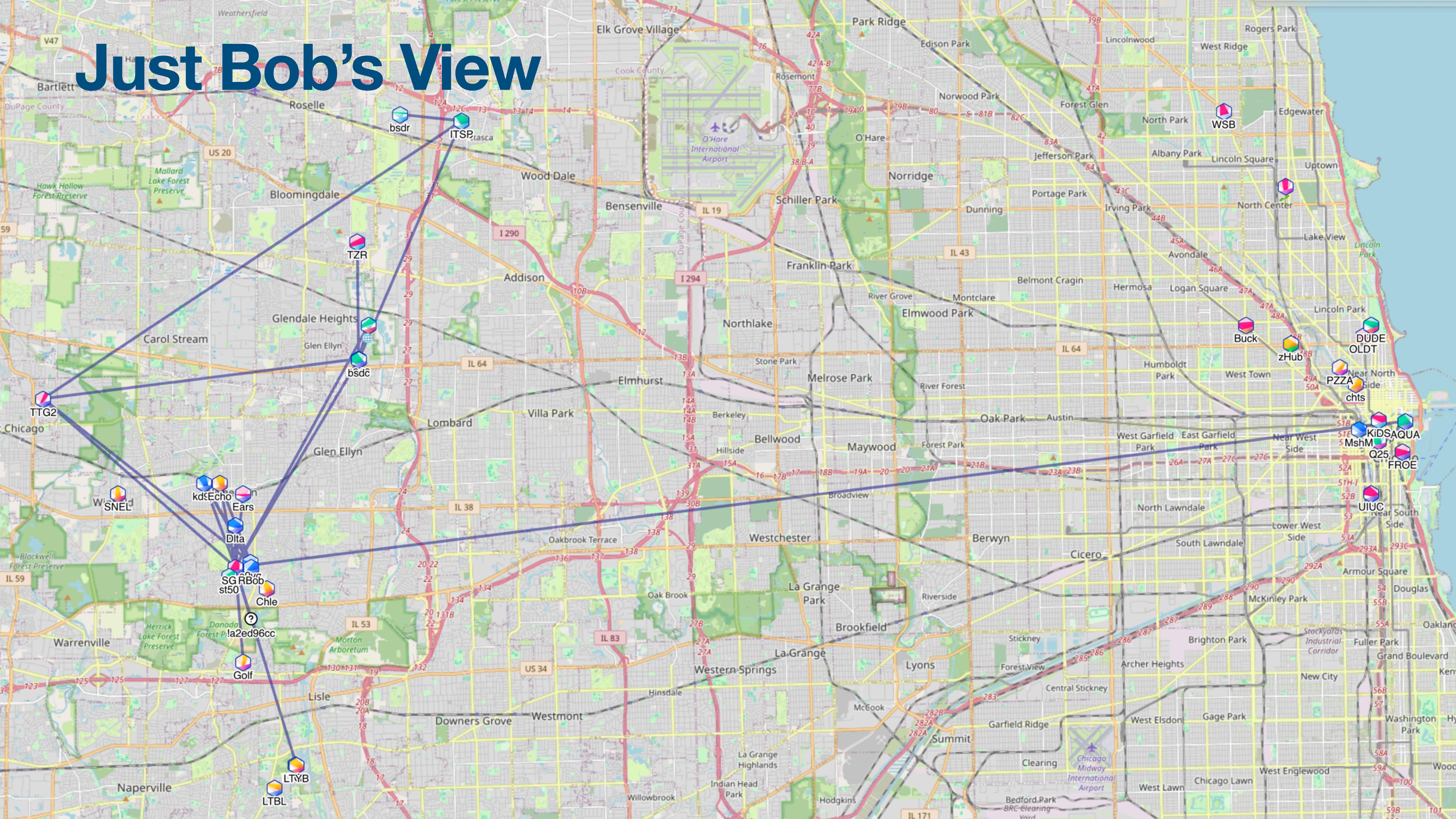
Nodes on traceroute paths with no position



Chicago Metro View One More Time



Just Bob's 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 to 6.25dB

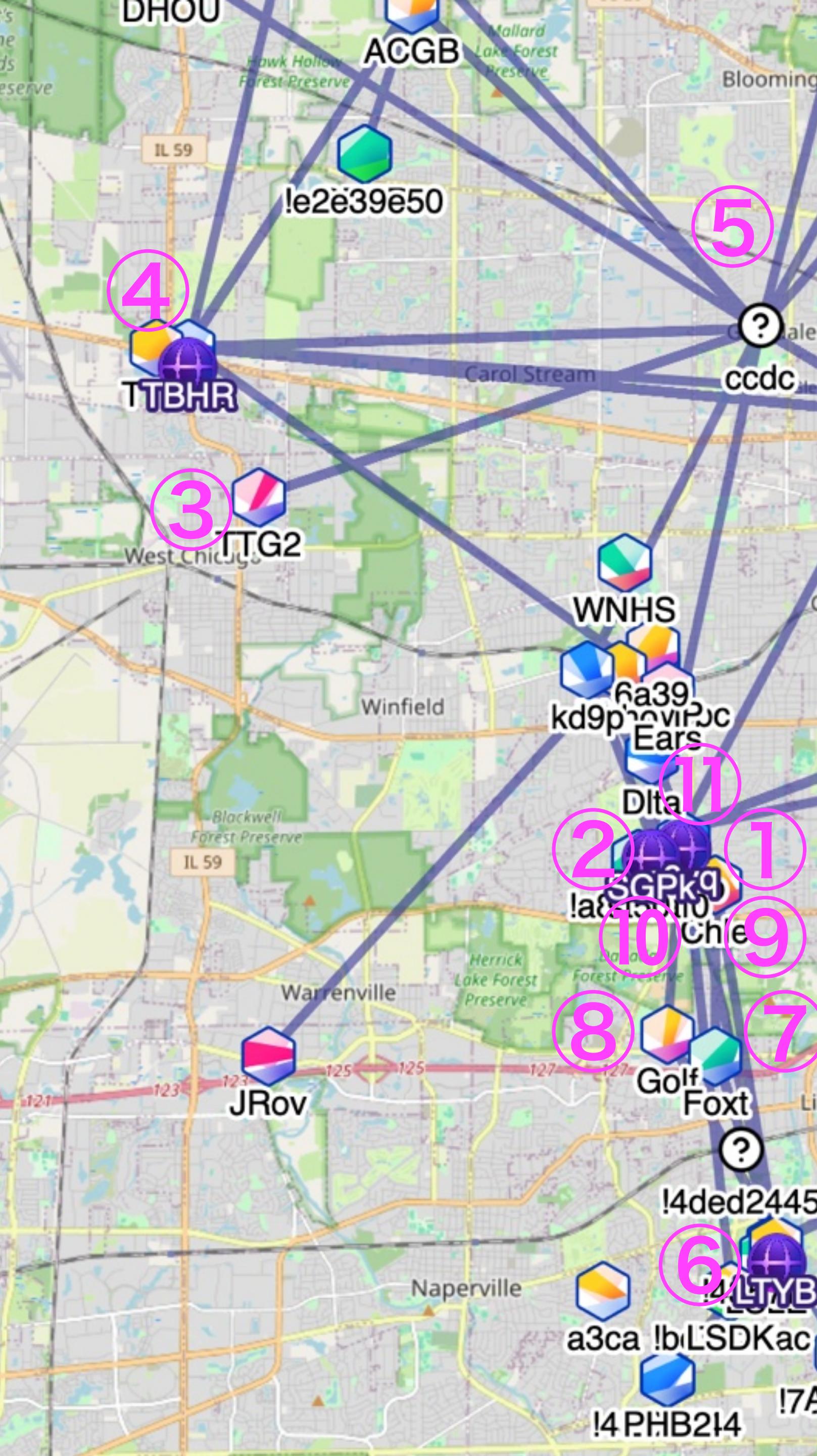
➡ Route: All Ears --> ke9yq (ChiMesh.Org) (6.25dB)

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

⬅ Route Back: Waypoint Echo !8f929380

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

--> All Ears (13.25dB)



➡ Route: All 1 Ears --> ke9yq 2 (ChiMesh.Org) (6.0dB)

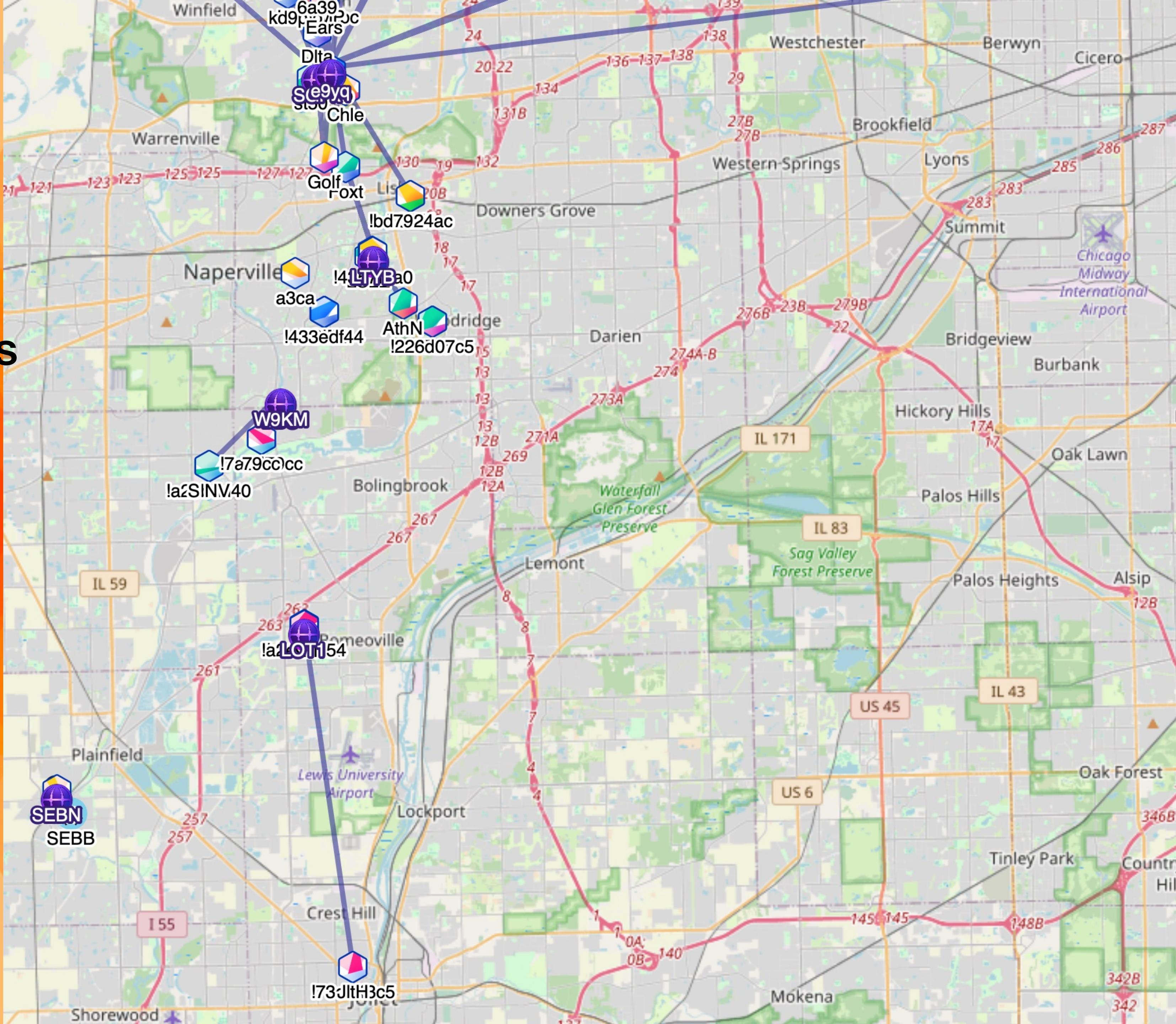
- 3 --> Tegan's Tavern Station G2 (-7.25dB)
- 4 --> TBH Router - West Chicago (no9g.us) (-10.75dB)
- 5 --> Meshtastic ccdc (-8.75dB)
- 6 --> Lisletastic-Yagi-Beam !4357f0a0 (-12.0dB)

➡ Route Back: 6 Lisletastic-Yagi-Beam !4357f0a0 --> 7 Waypoint Foxtrot (-10.0dB)

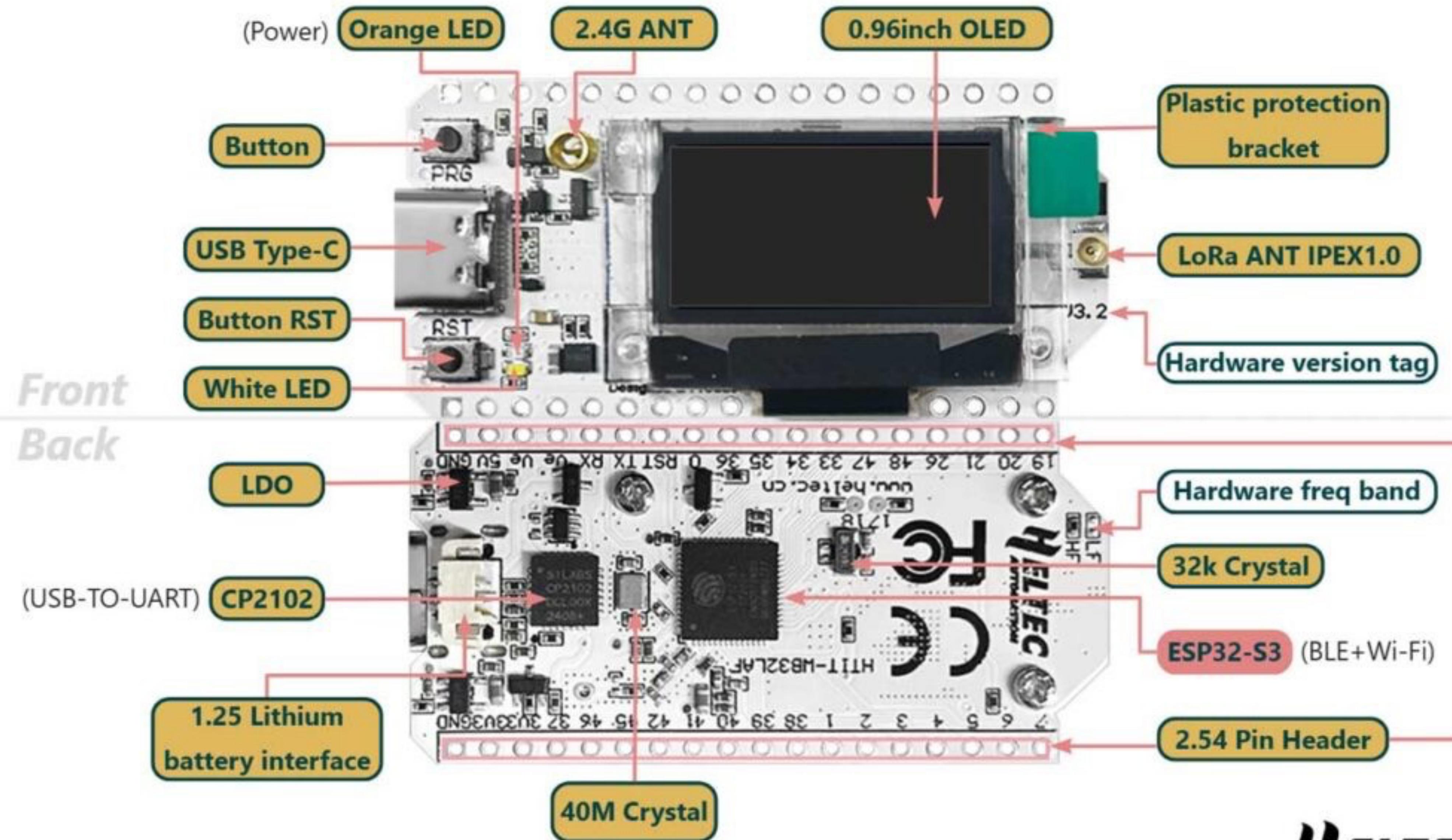
- 7 --> 8 Waypoint Golf (-2.5dB)
- 8 --> 9 Waypoint Charlie (1.5dB)
- 9 --> 10 Roving Bob (-15.75dB)
- 10 --> 11 All Ears (11.75dB)

Argonne Area

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



WiFi LoRa 32 V3



Energy Budgets

- Low energy requirements enable solar nodes
 - Best MCU for job: nRF52840
- Some people home brew Power over Ethernet

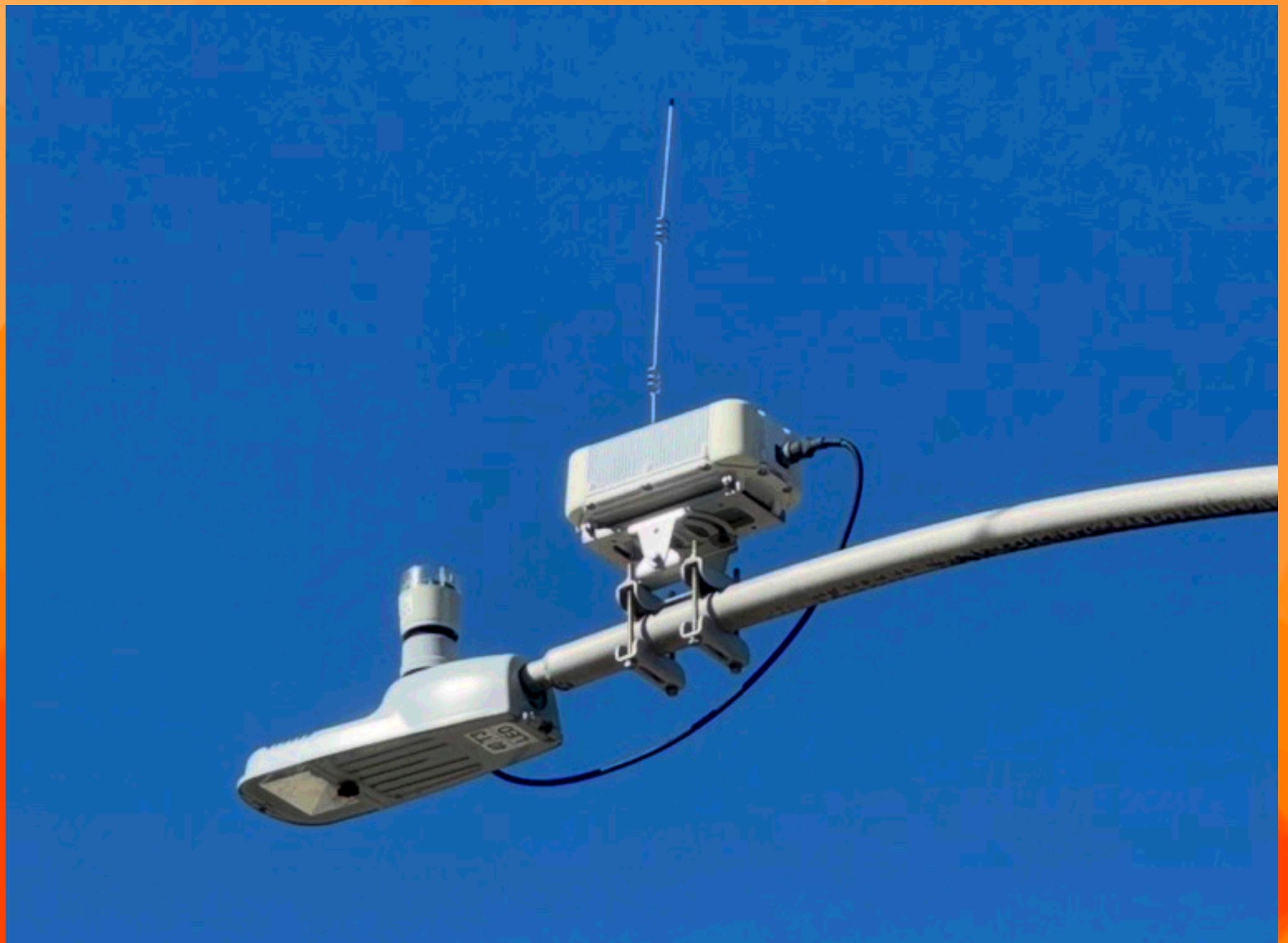
Licensed Amateur Use

IANAL, but . . .

- Privileges
 - Up to 10W TX power
 - Higher gain antennas
- Restrictions
 - No encrypted messages
 - Must ID, effectively giving your location

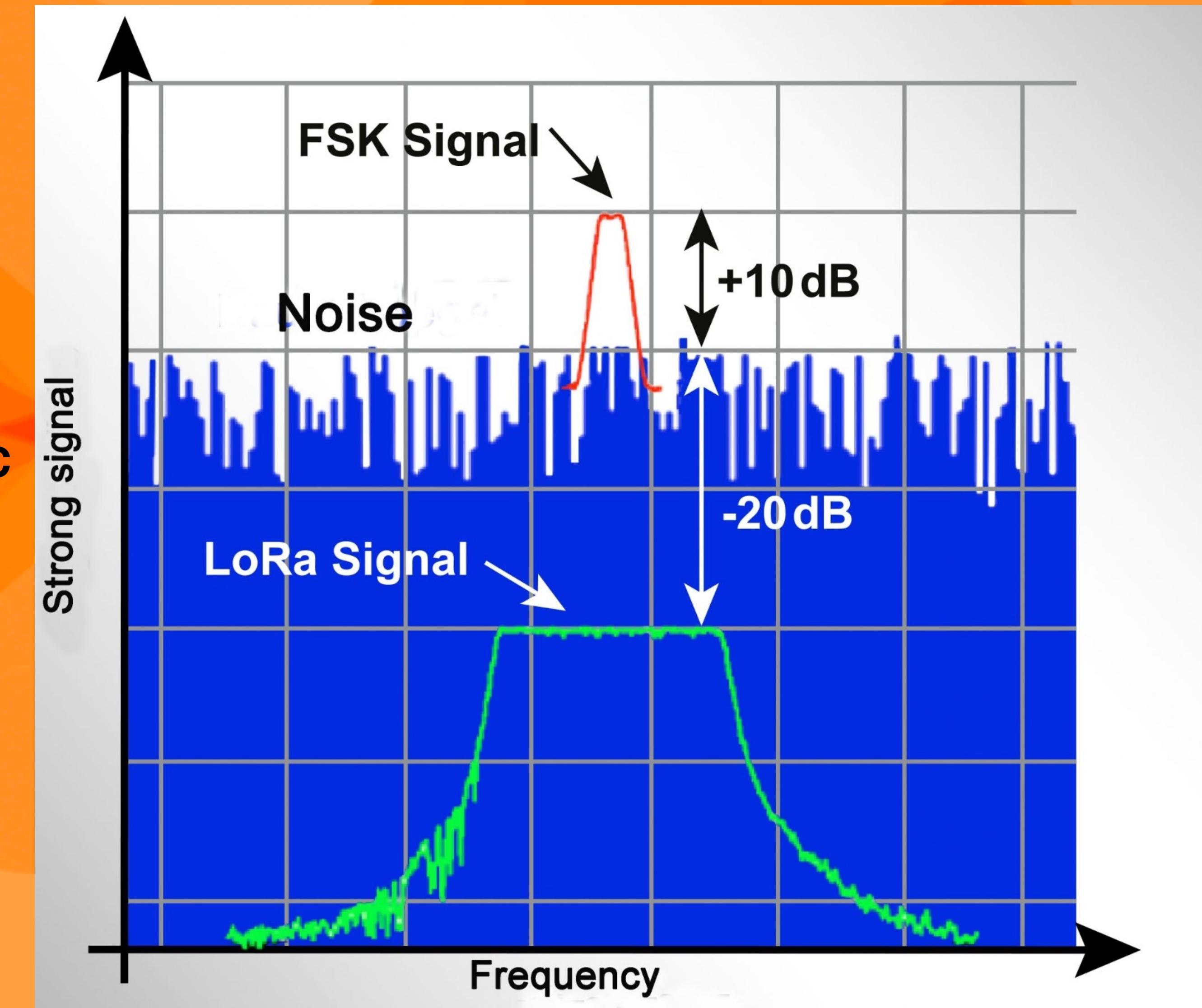
Other 900 MHz Users

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

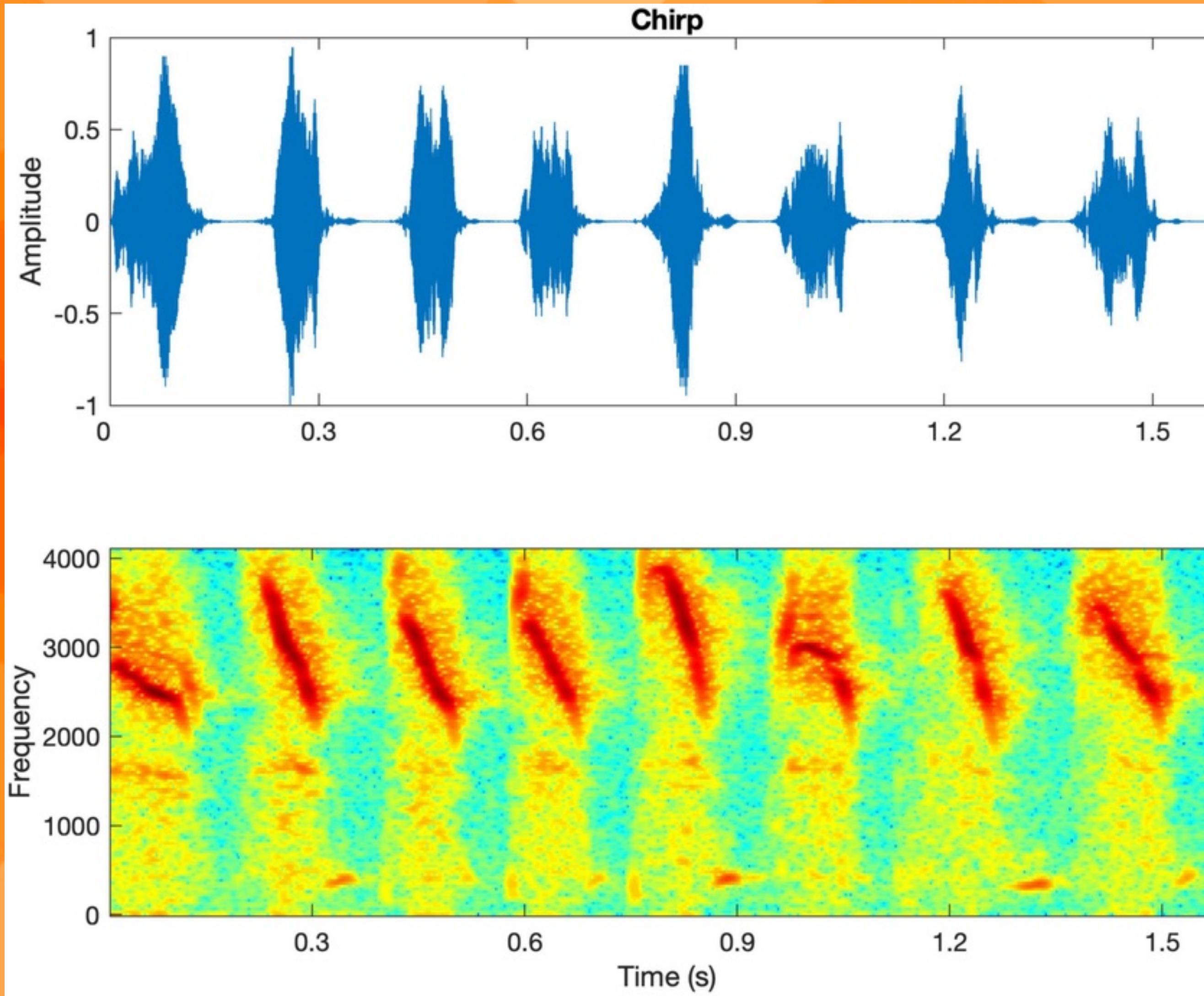


Getting Below the Noise Floor

- ke9yq
- K-E-9-Y-Q
- Kilo Echo Niner Yankee Quebec
- Correlation-based decoding
- _eelo Eck_ _ner Yan_ _bek



Evolution Invents 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

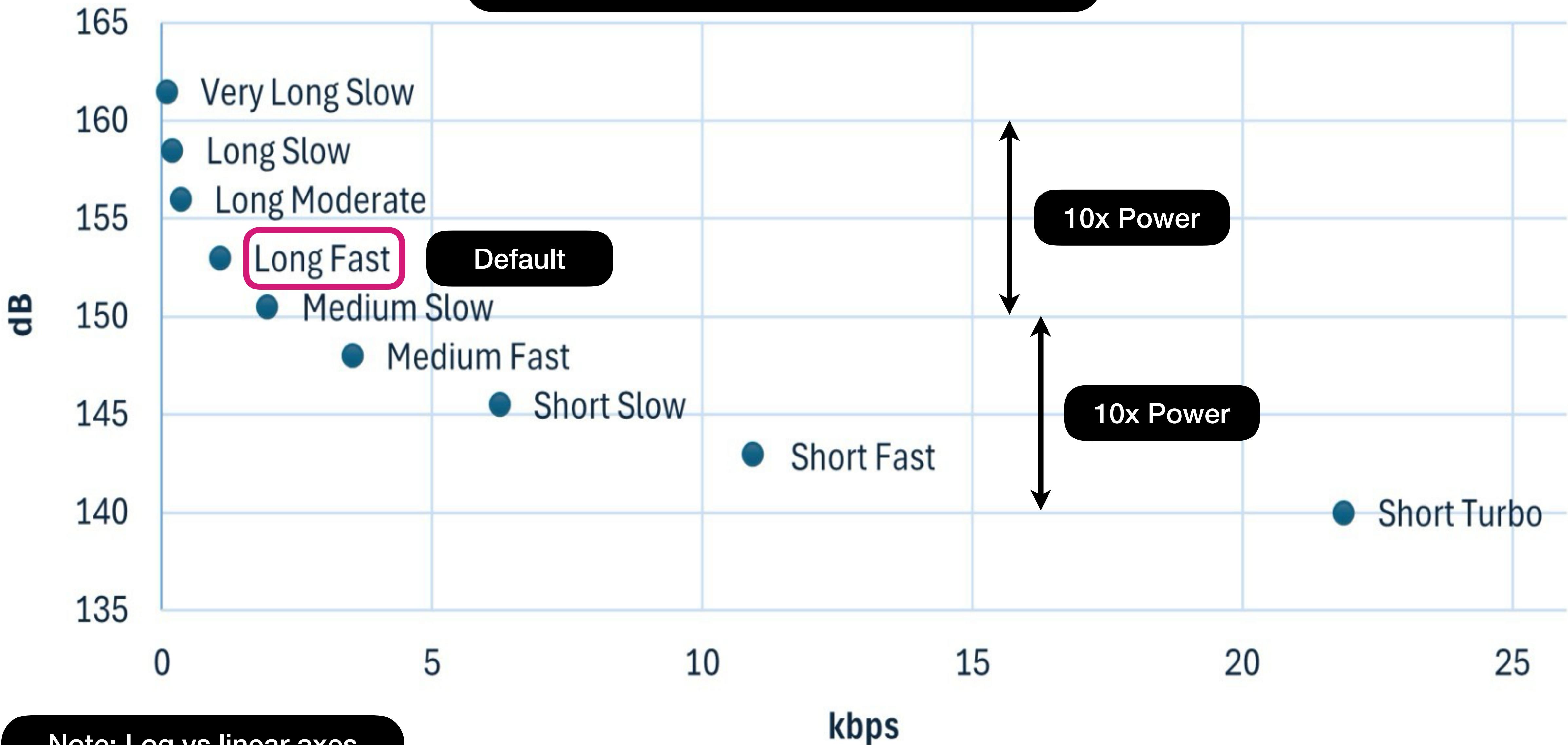
$$\begin{aligned} \mathbb{E}\{x(t; A_0)\} &= \frac{1}{M} e^{j2\pi \frac{B}{2T_s} t^2} \left\{ g_{T_c}(t) \sum_{\ell=0}^{M-1} e^{j2\pi \frac{B}{M} \ell t} + \right. \\ &\quad \left. \sum_{k=1}^{M-1} g_{T_c}(t - k T_c) \left[\sum_{\ell=0}^{M-k-1} e^{j2\pi \frac{B}{M} \ell t} + \sum_{\ell=M-k}^{M-1} e^{j2\pi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

After some manipulation we get

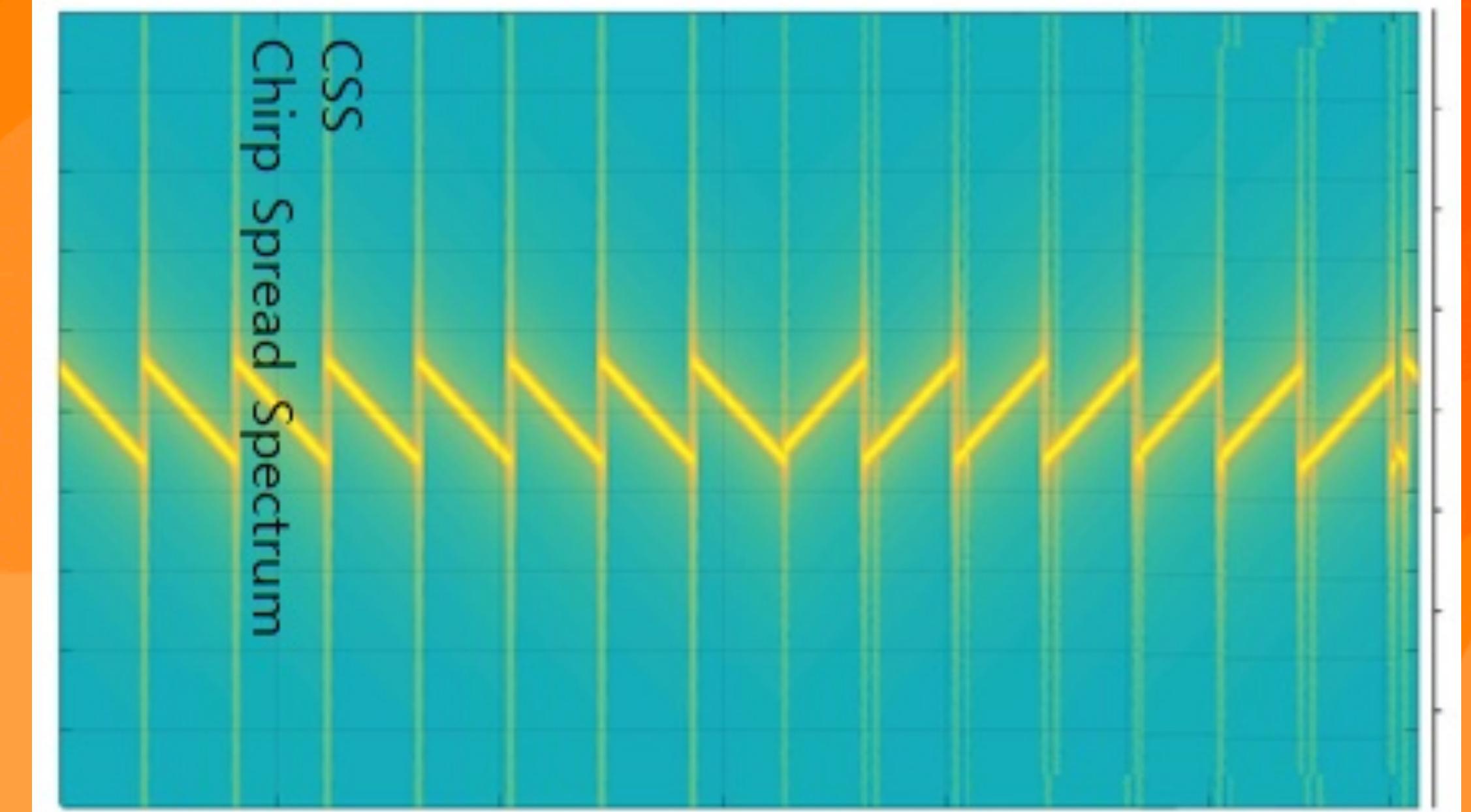
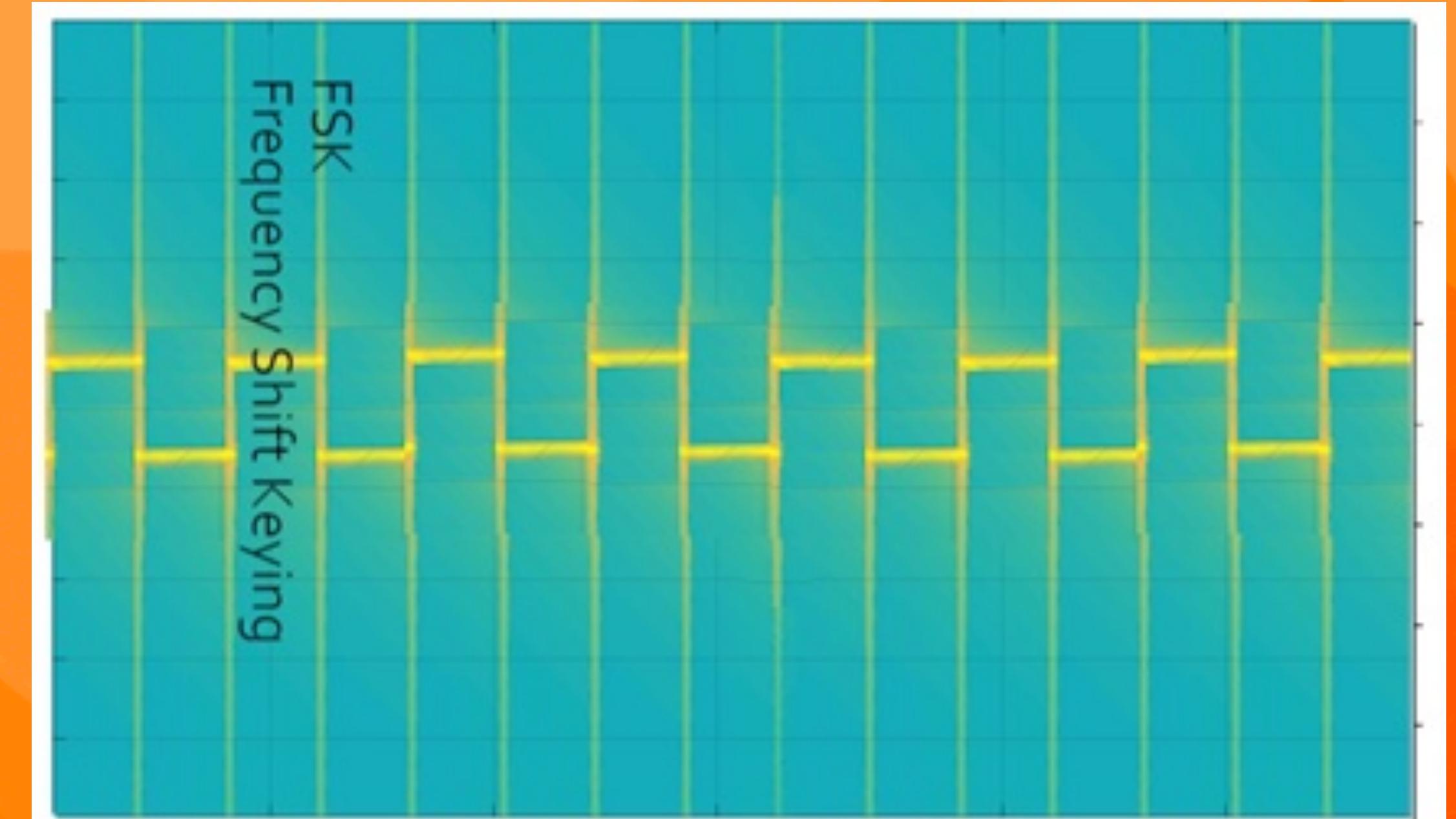
$$\begin{aligned} \mathbb{E}\{x(t; A_0)\} &= \frac{1}{M} e^{j\frac{\pi B t}{M} (B t - 1)} \frac{\sin(\pi B t)}{\sin(\pi B t/M)} \\ &\times \sum_{k=0}^{M-1} g_{T_c}(t - k T_c) e^{-j2\pi B k t / M}. \end{aligned}$$

Link budget VS data rate

Range & Power VS Data Rate

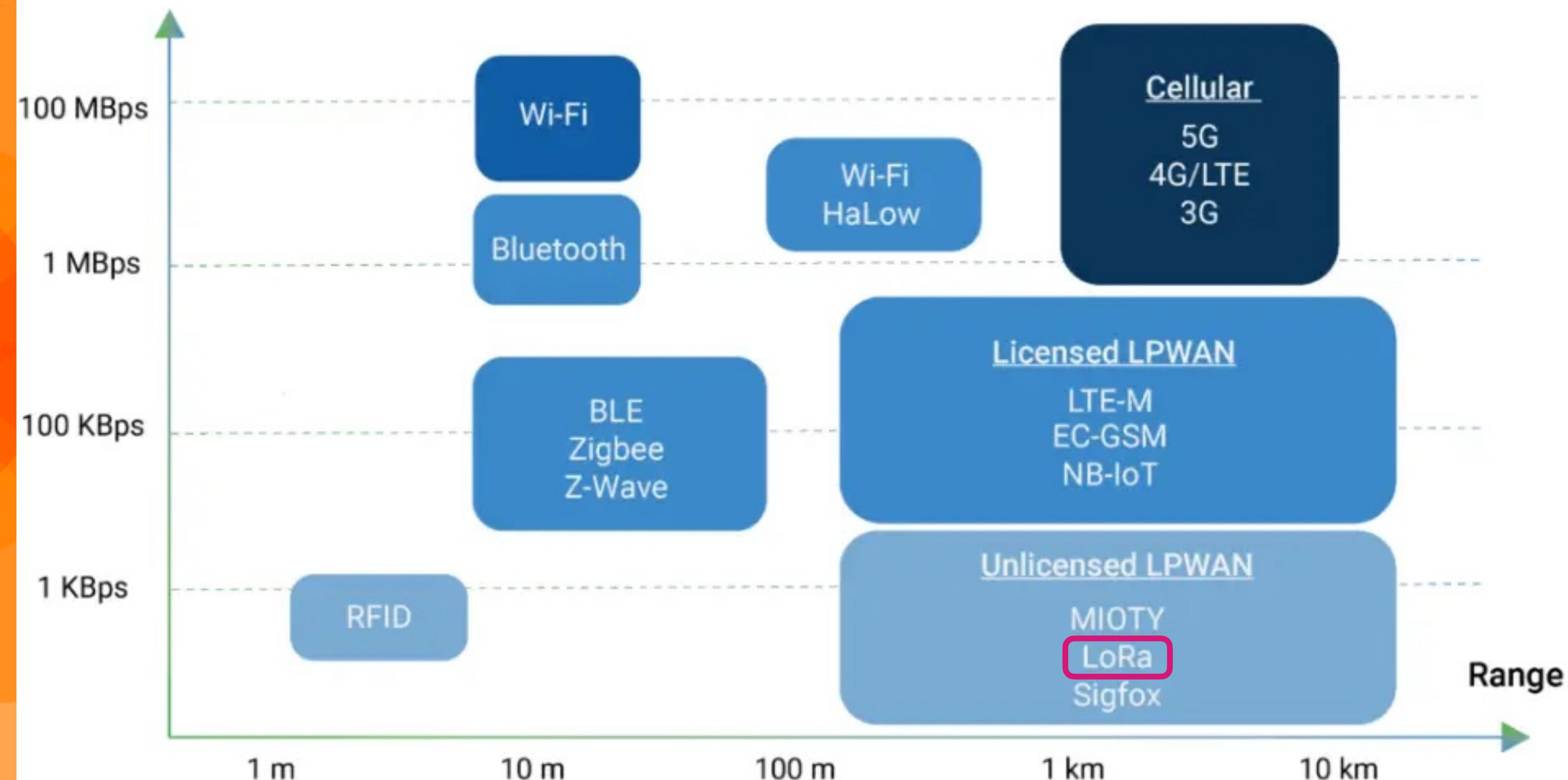


Template Slide

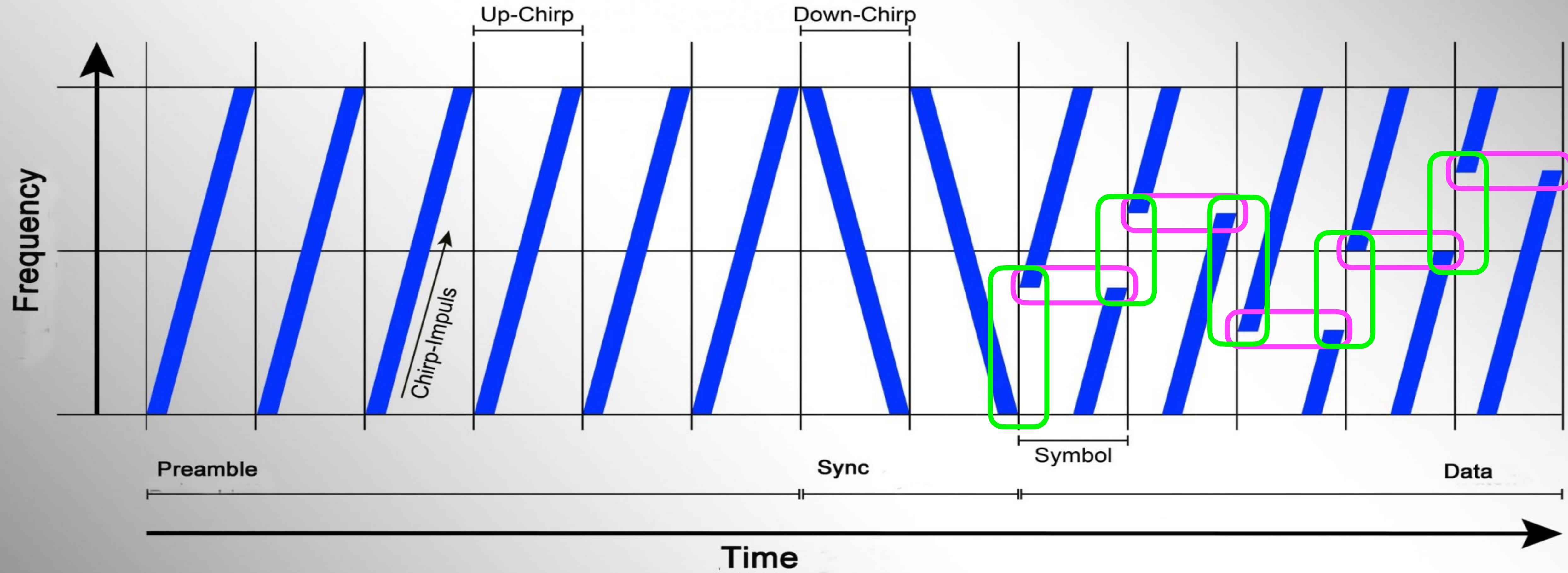


Data rate & Power Consumption

Cost: Low High



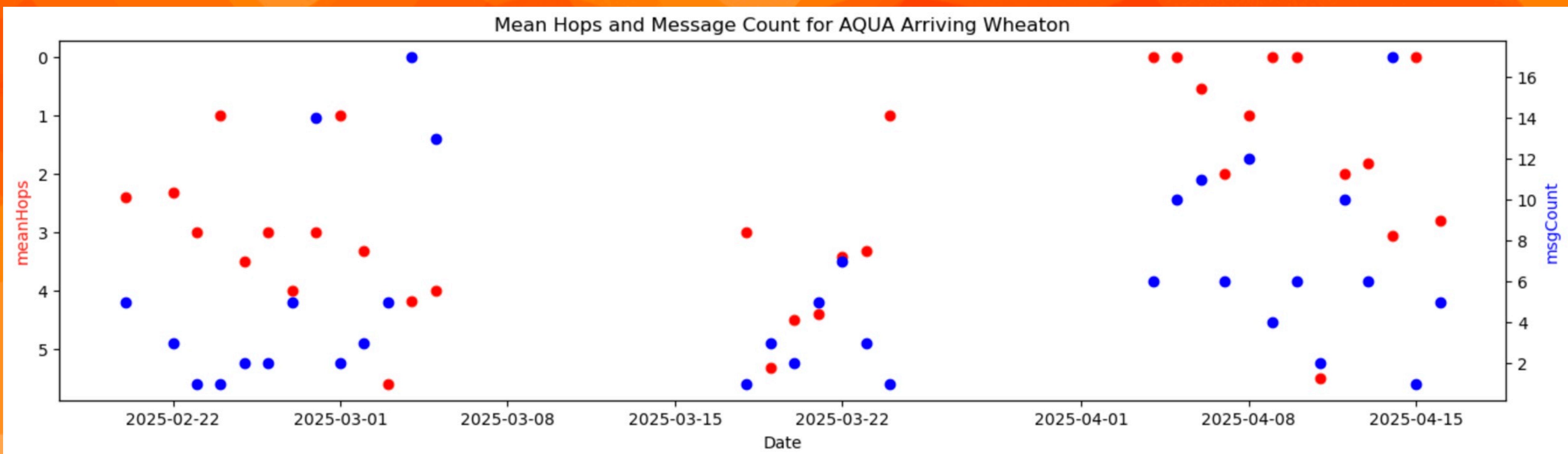
Feedder



Collecting Data

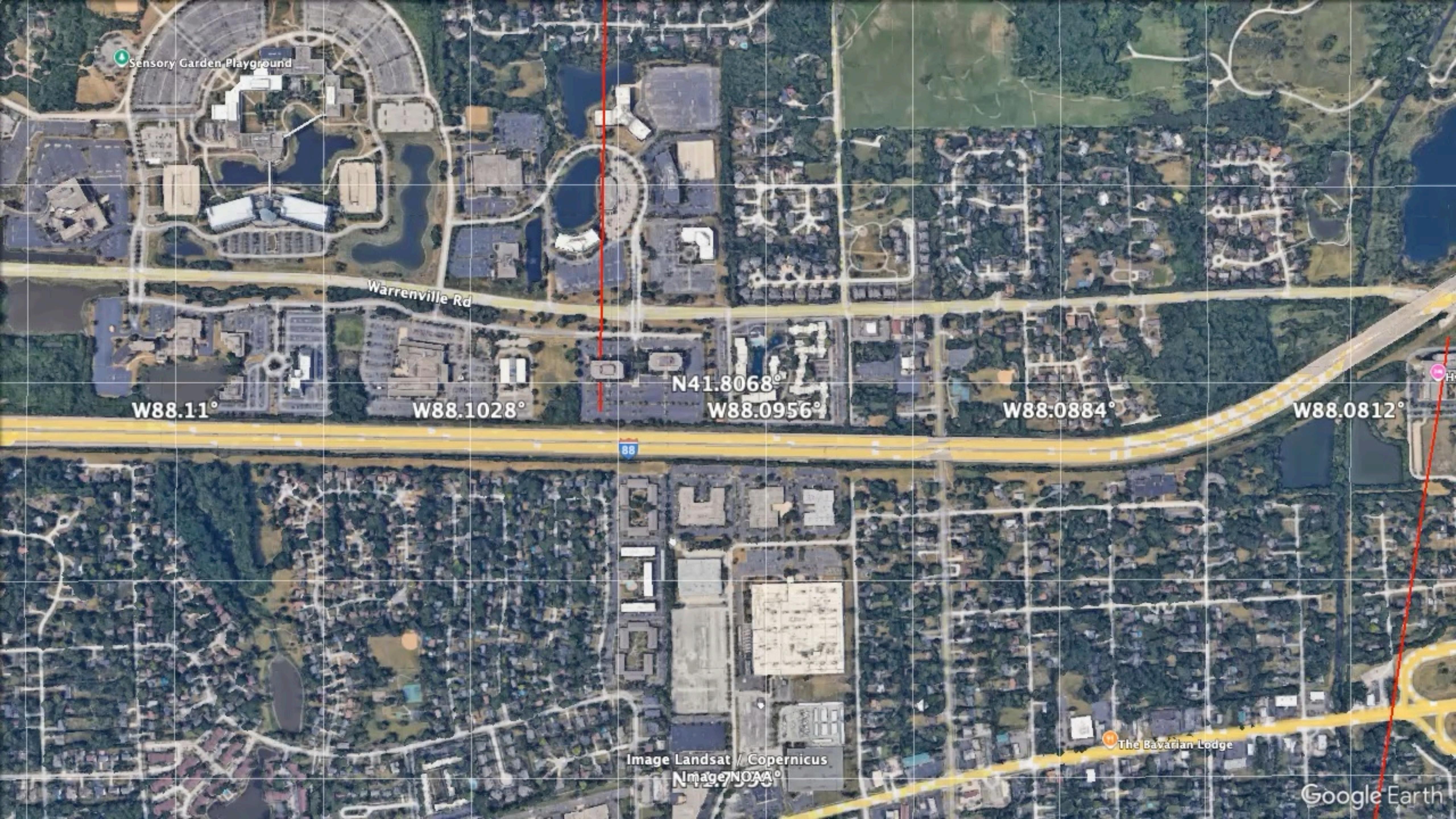
AQUA upgrades his antenna

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



Related Projects

- Meshcore
- Reticulum
- LoRaWAN
- Satellites use LoRa ~440MHz

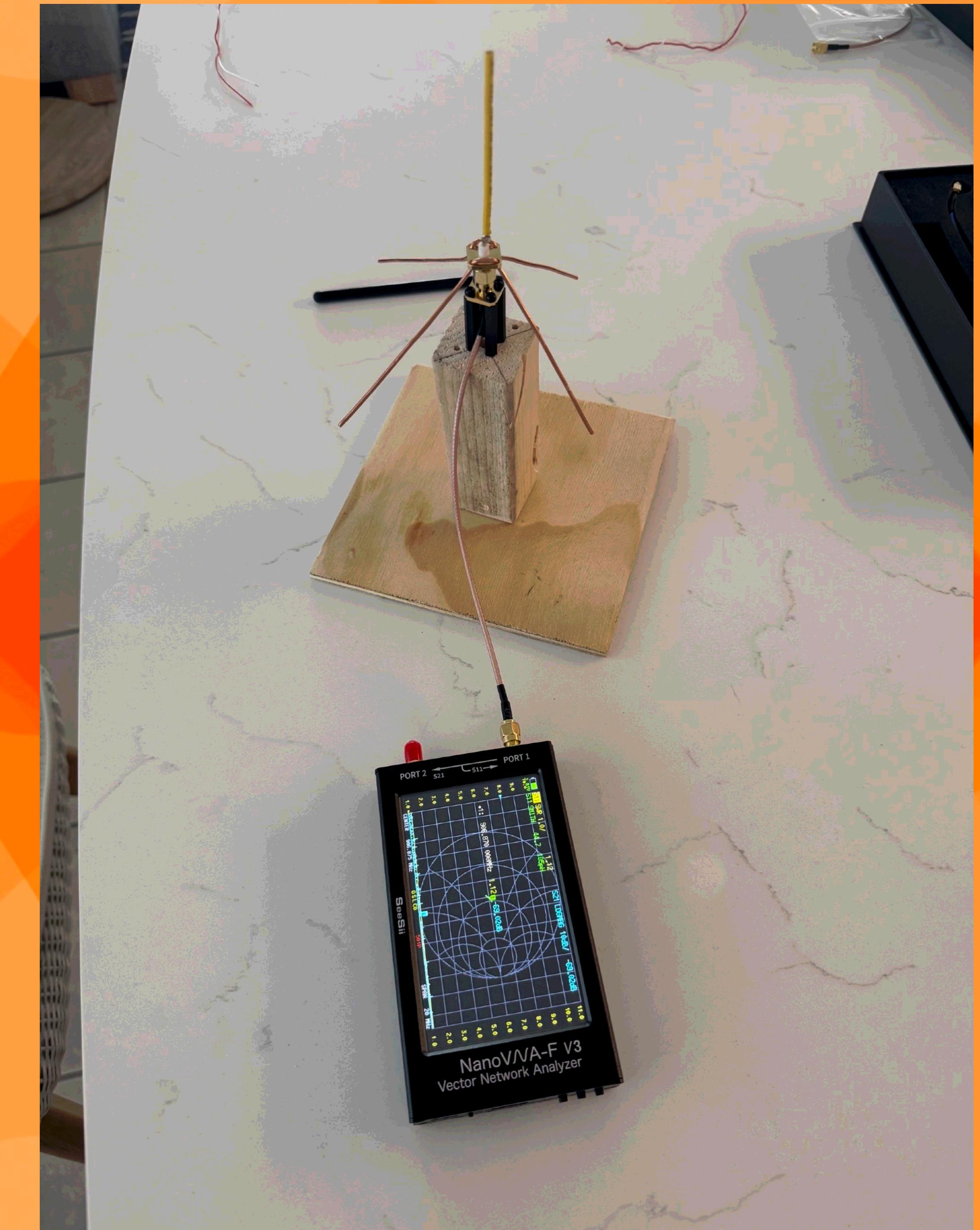


Fun for Bob

- 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

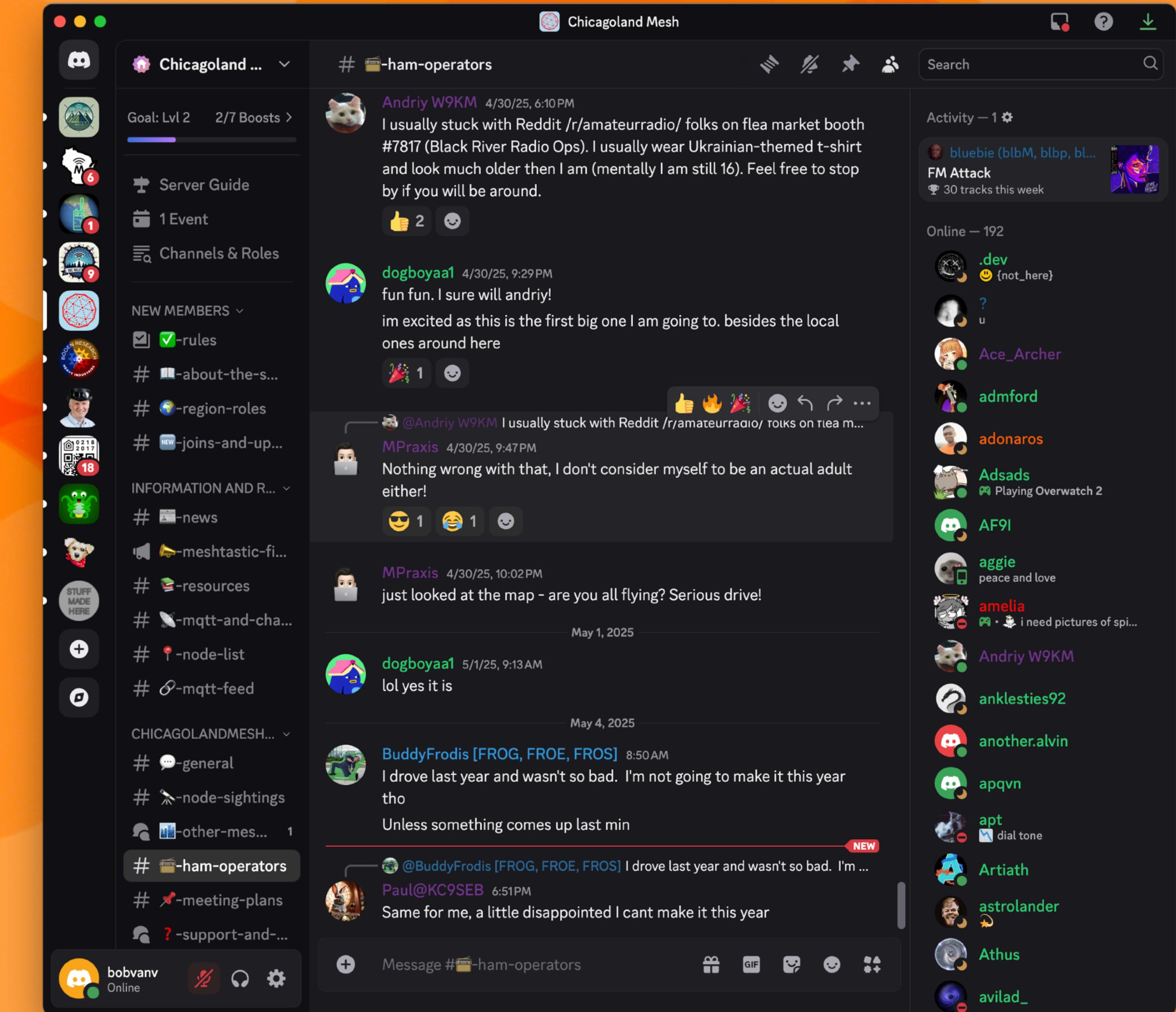
Antenna Build

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



Meshtastic Community

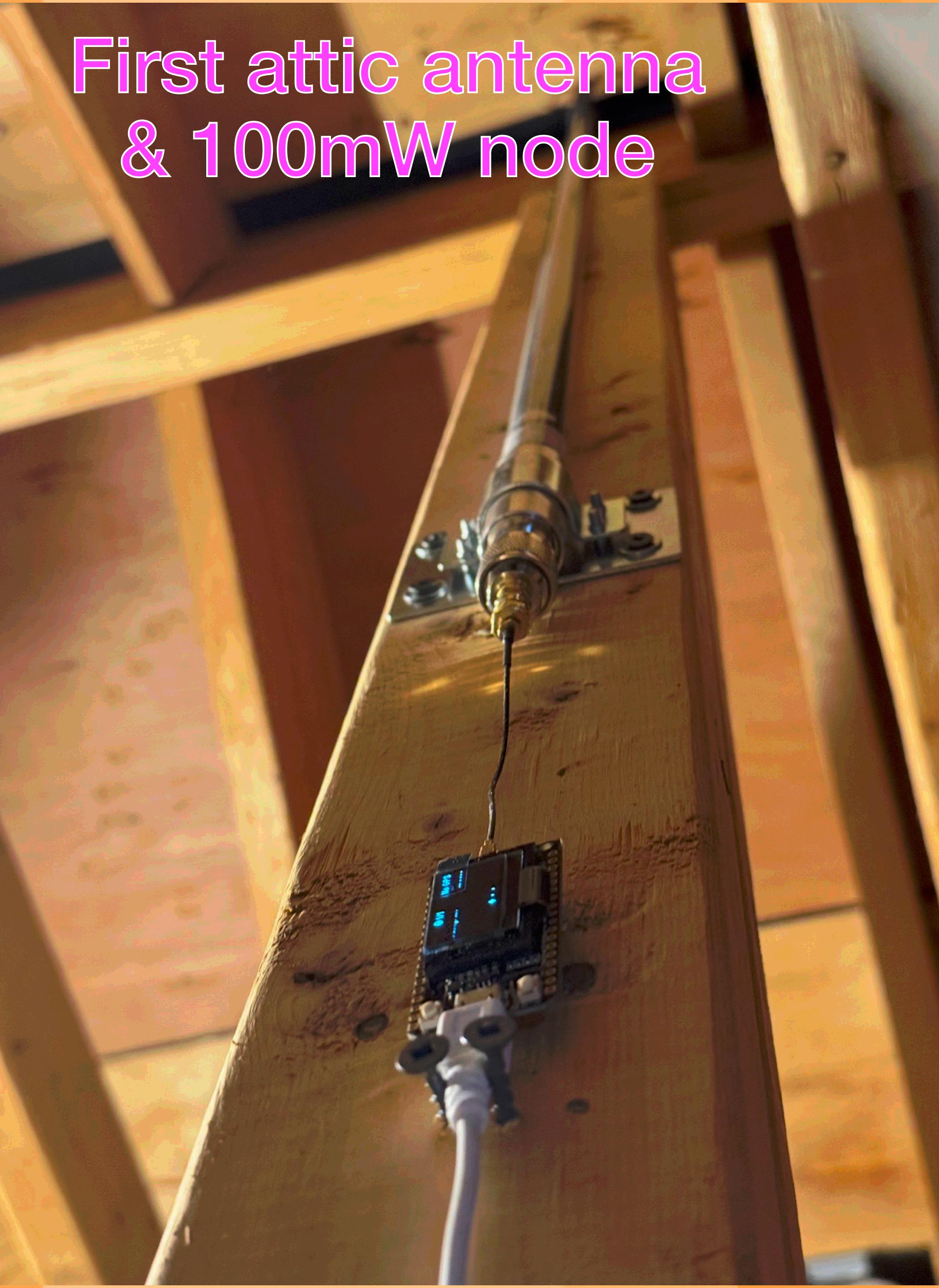
- Join: <http://ChiMesh.Org/discord>



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

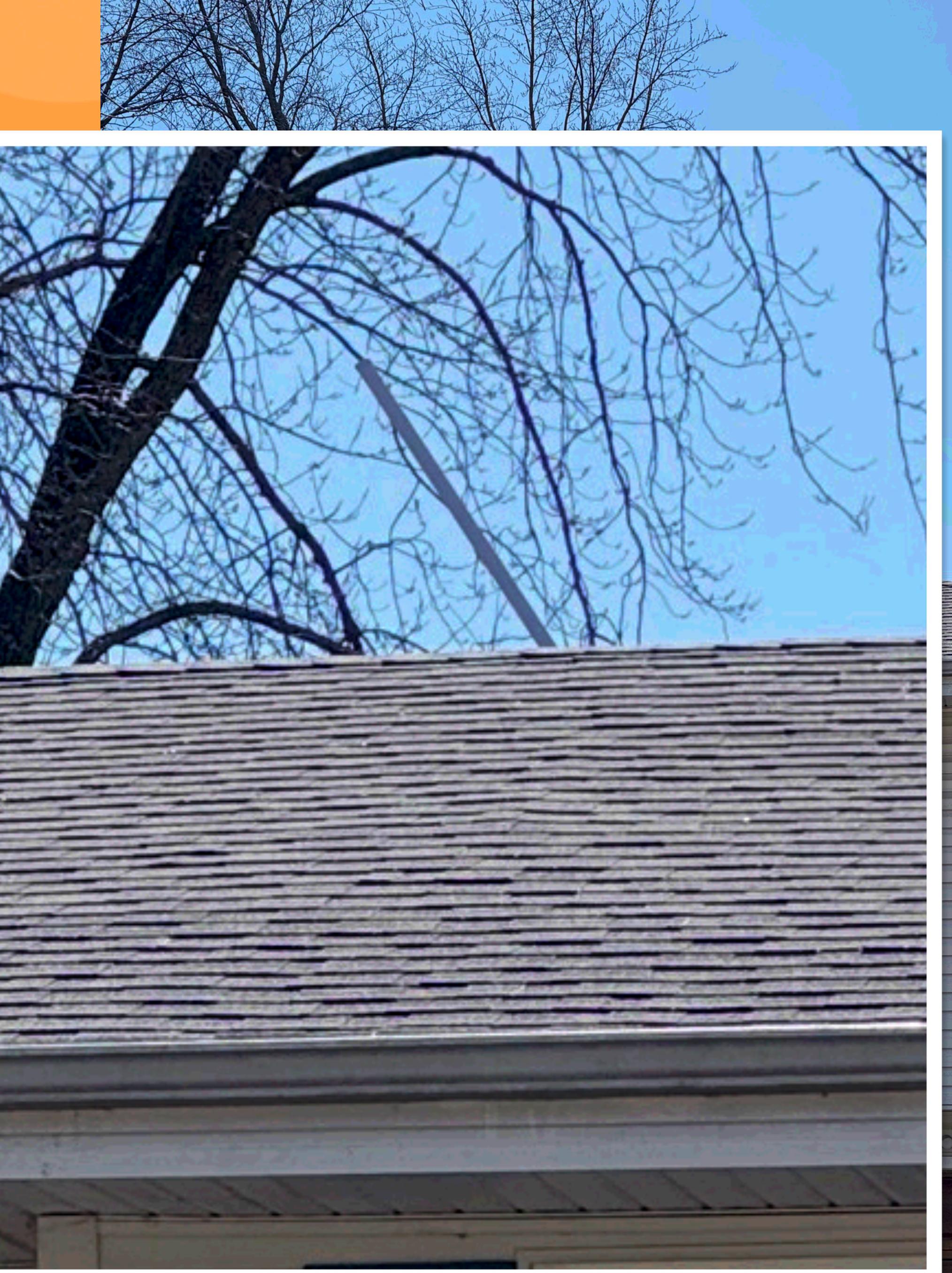




Current Attic Nodes

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)

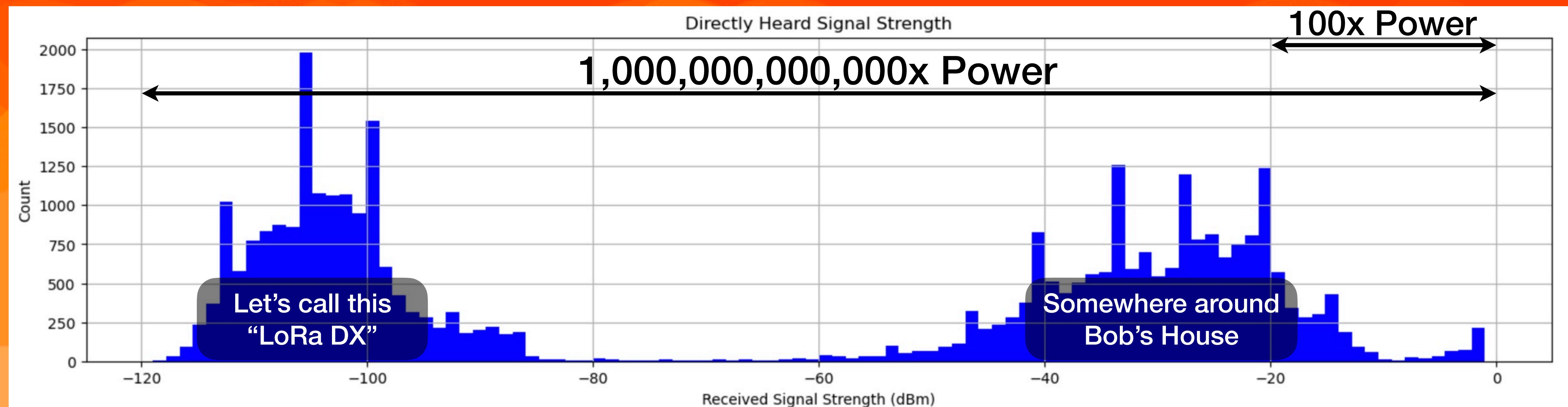


Who took my feed line?

- 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

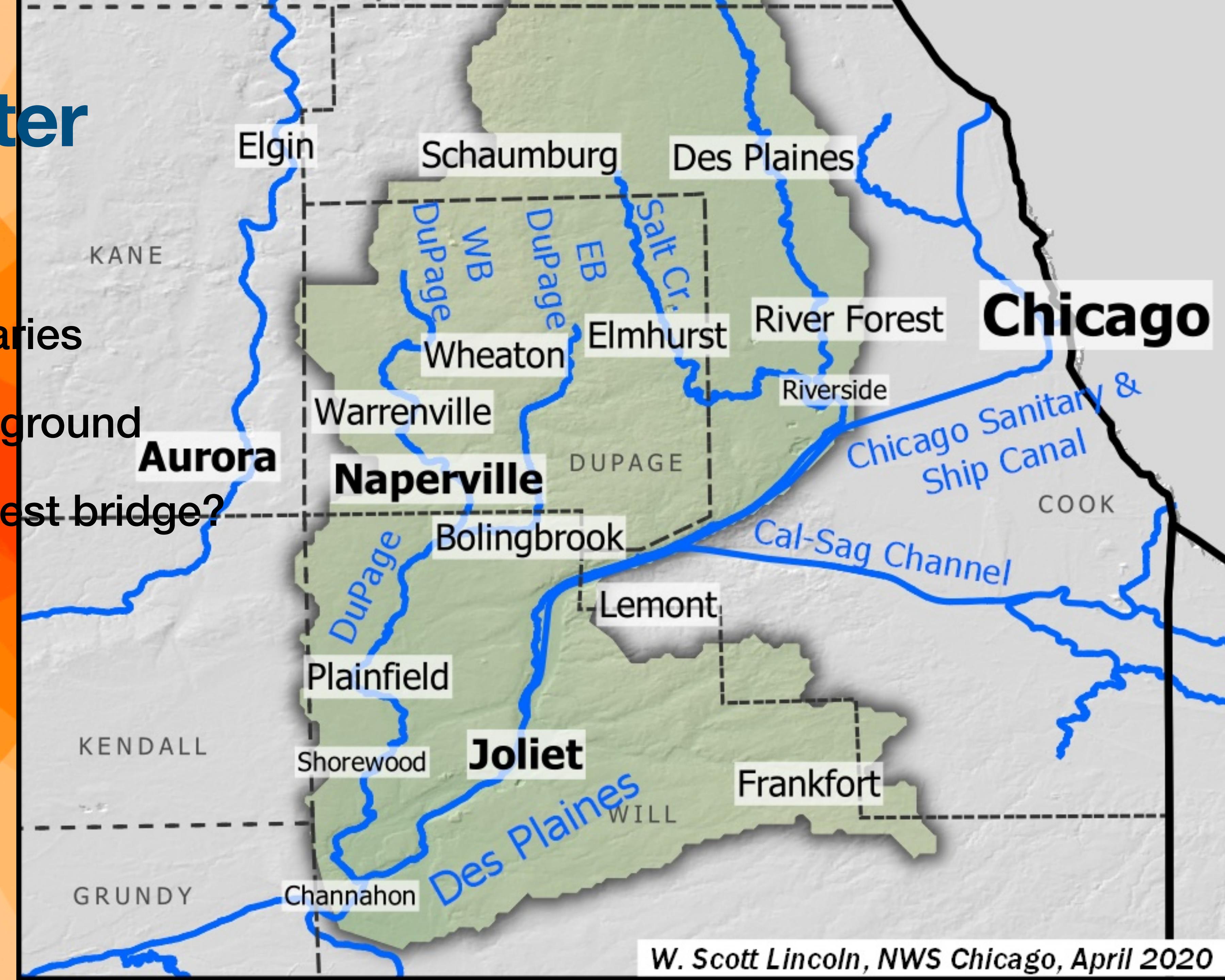
Measured Signal Strength in Wheaton

- Over 35,000 directly-heard messages logged below
- Bimodal distribution
- Not much bellow -115 dBm

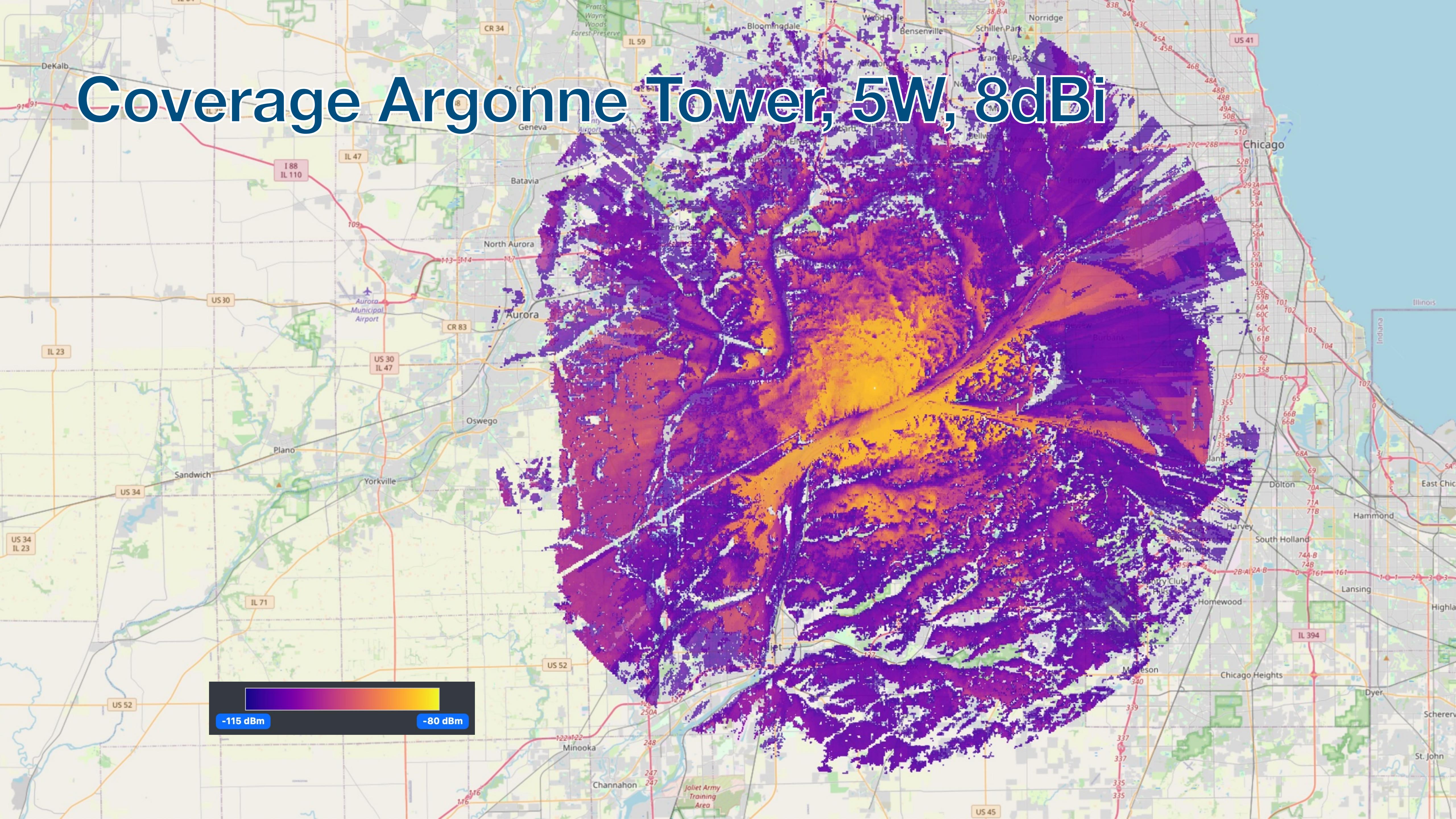


Surface Water

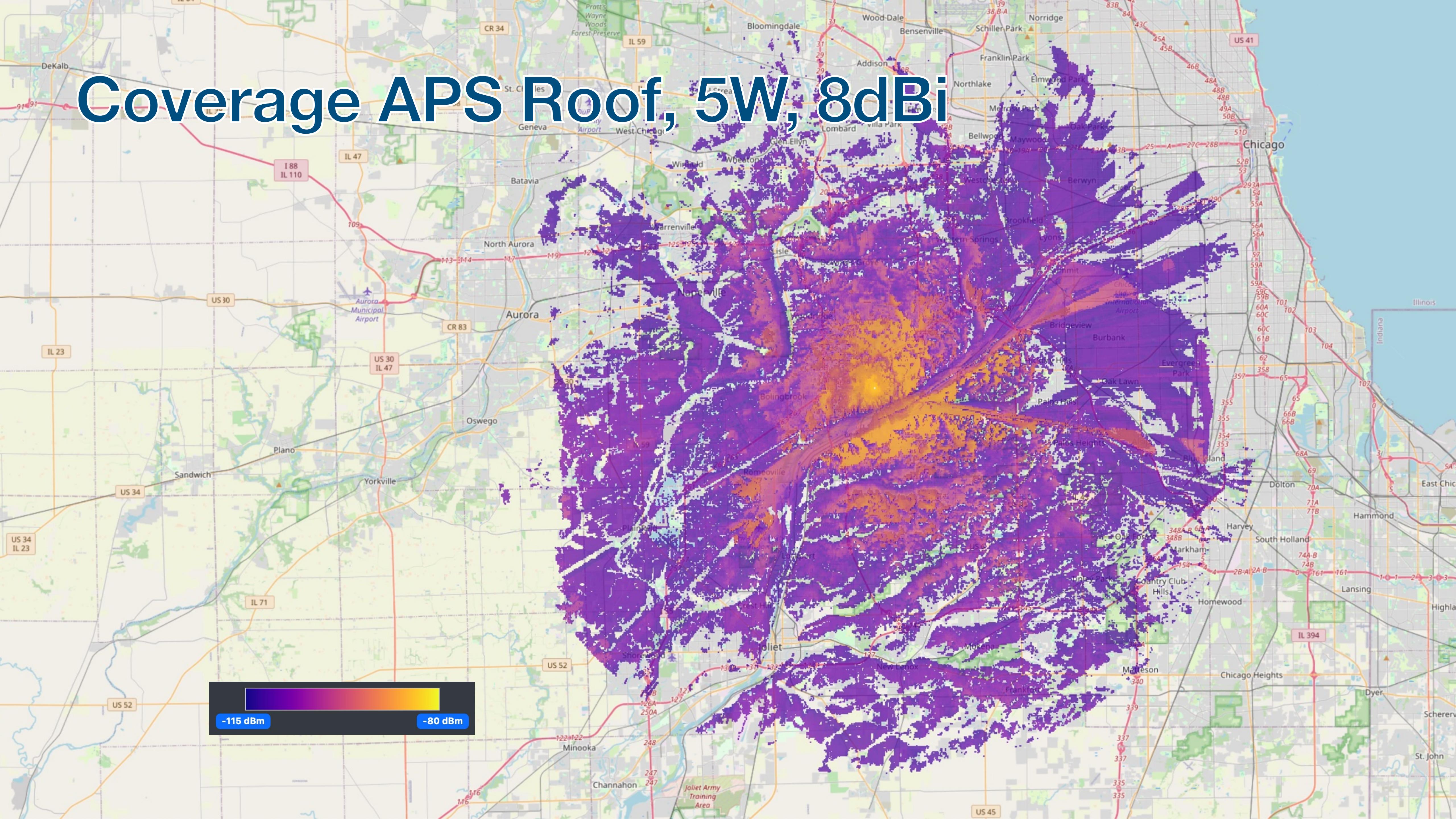
- Watershed boundaries
 - Defined by high ground
- Where is your closest bridge?



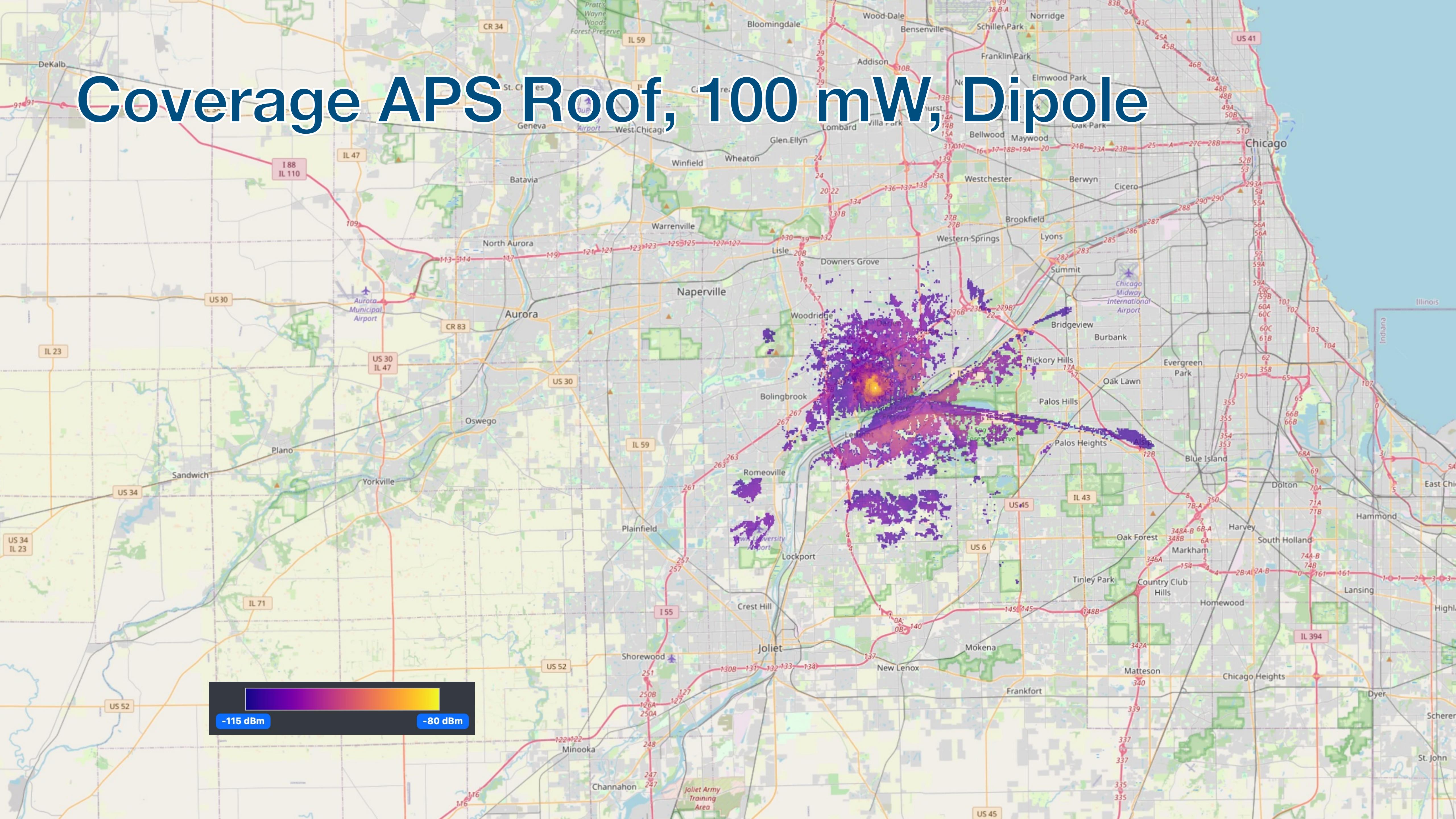
Coverage Argonne Tower, 5W, 8dBi



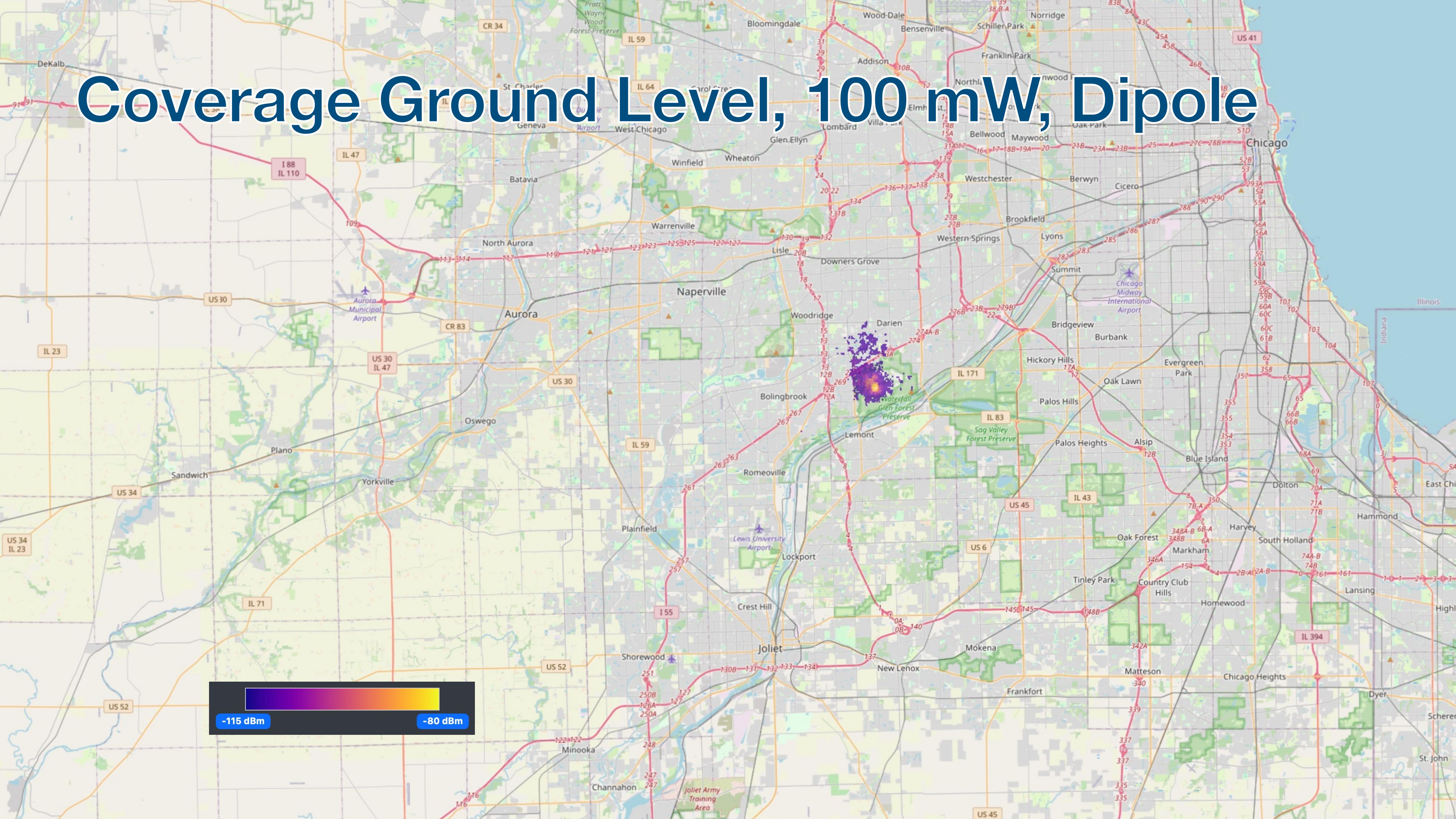
Coverage APS Roof, 5W, 8dBi



Coverage APS Roof, 100 mW, Dipole

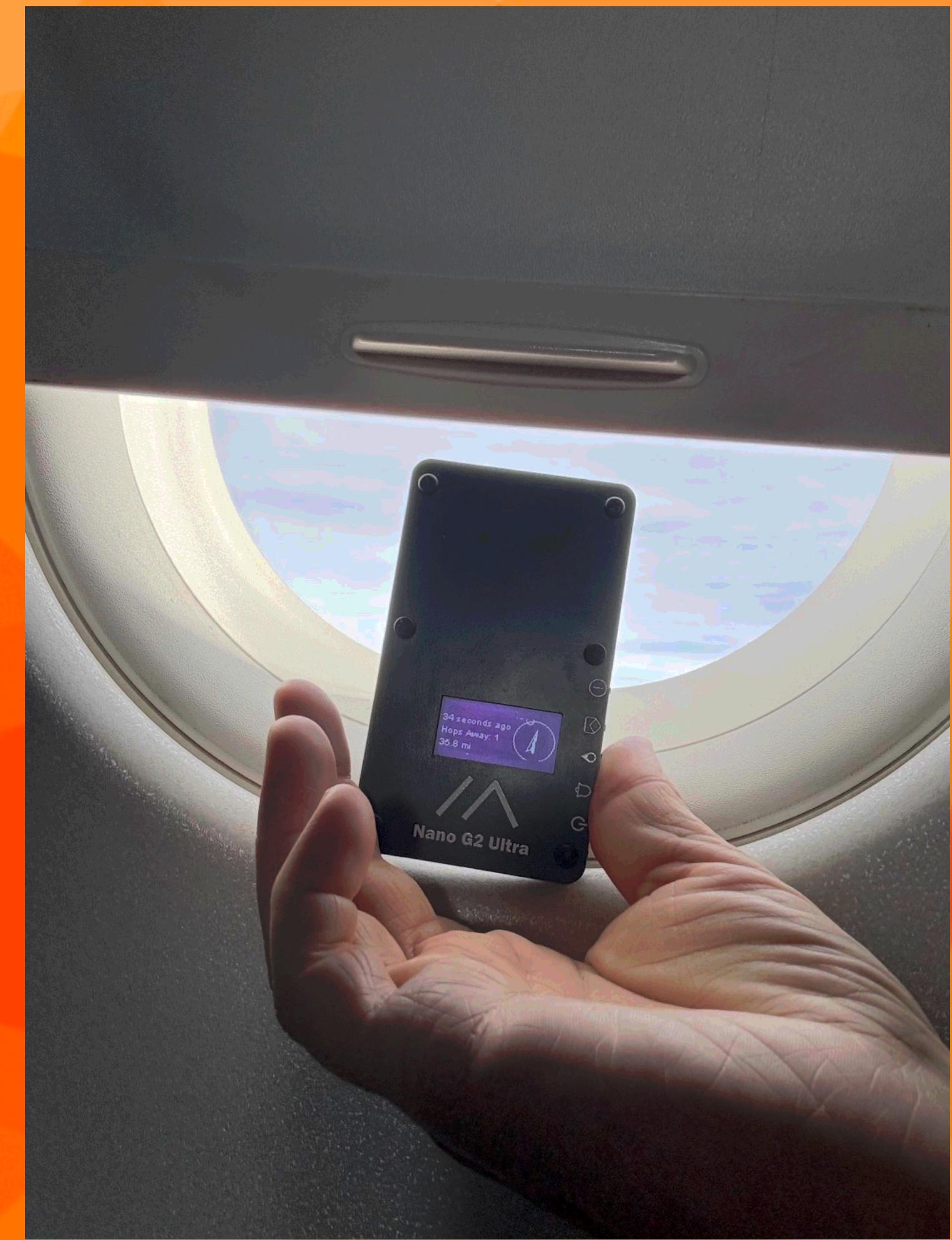


Coverage Ground Level, 100 mW, Dipole



Mobile Node Uses

- Commuting
- Hamfest
- Vacations
- Events/concerts



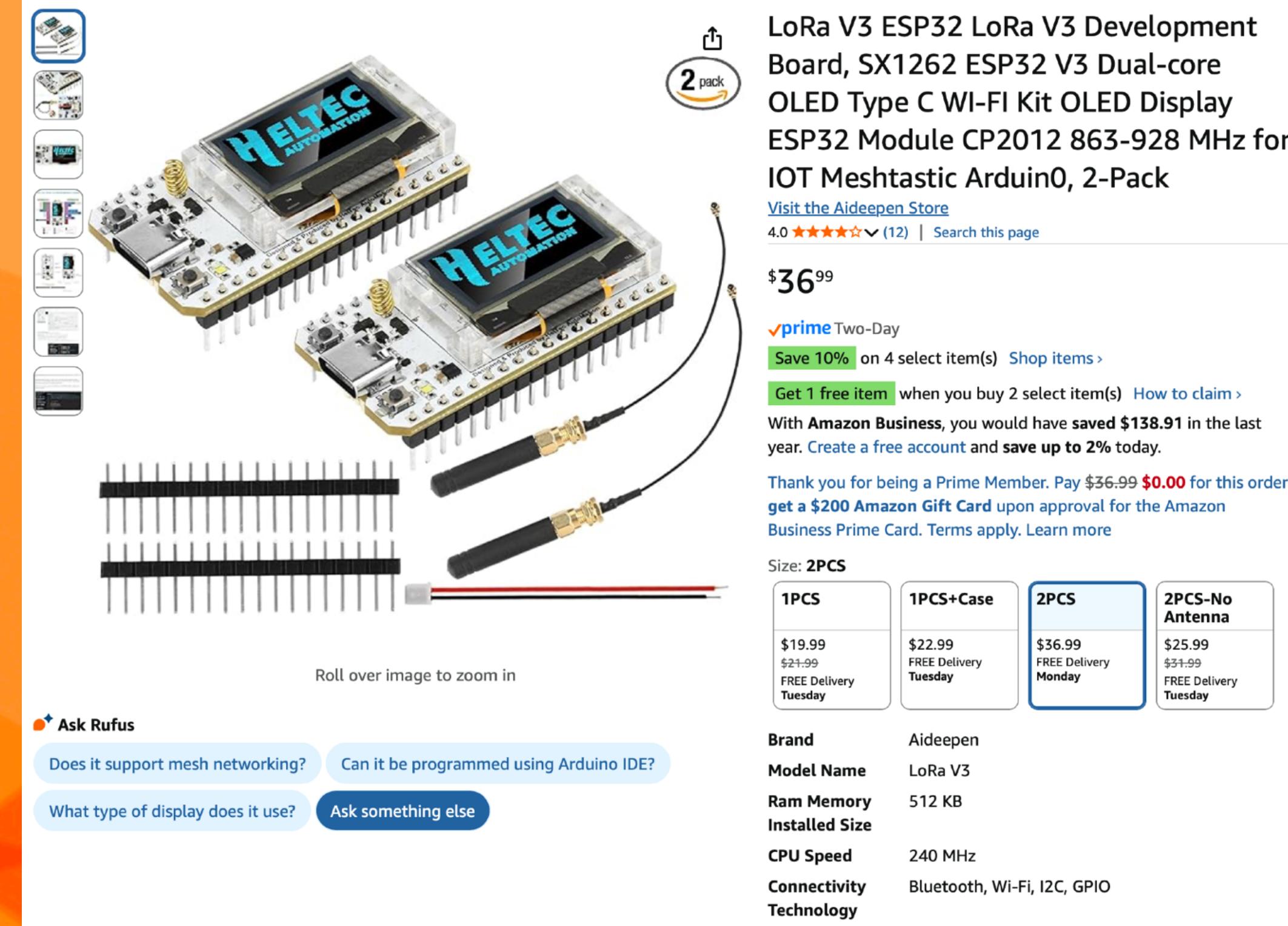
More Mobile Node Uses

- Biking
- Hiking/Skiing
- 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>



\$36⁹⁹
✓prime Two-Day
FREE delivery Monday, May 5.
Order within 2 hrs 48 mins
Shorter shipping distance ▾
Deliver to Robert - Wheaton
60189

In Stock

Quantity: 1

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Buy Now

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See more

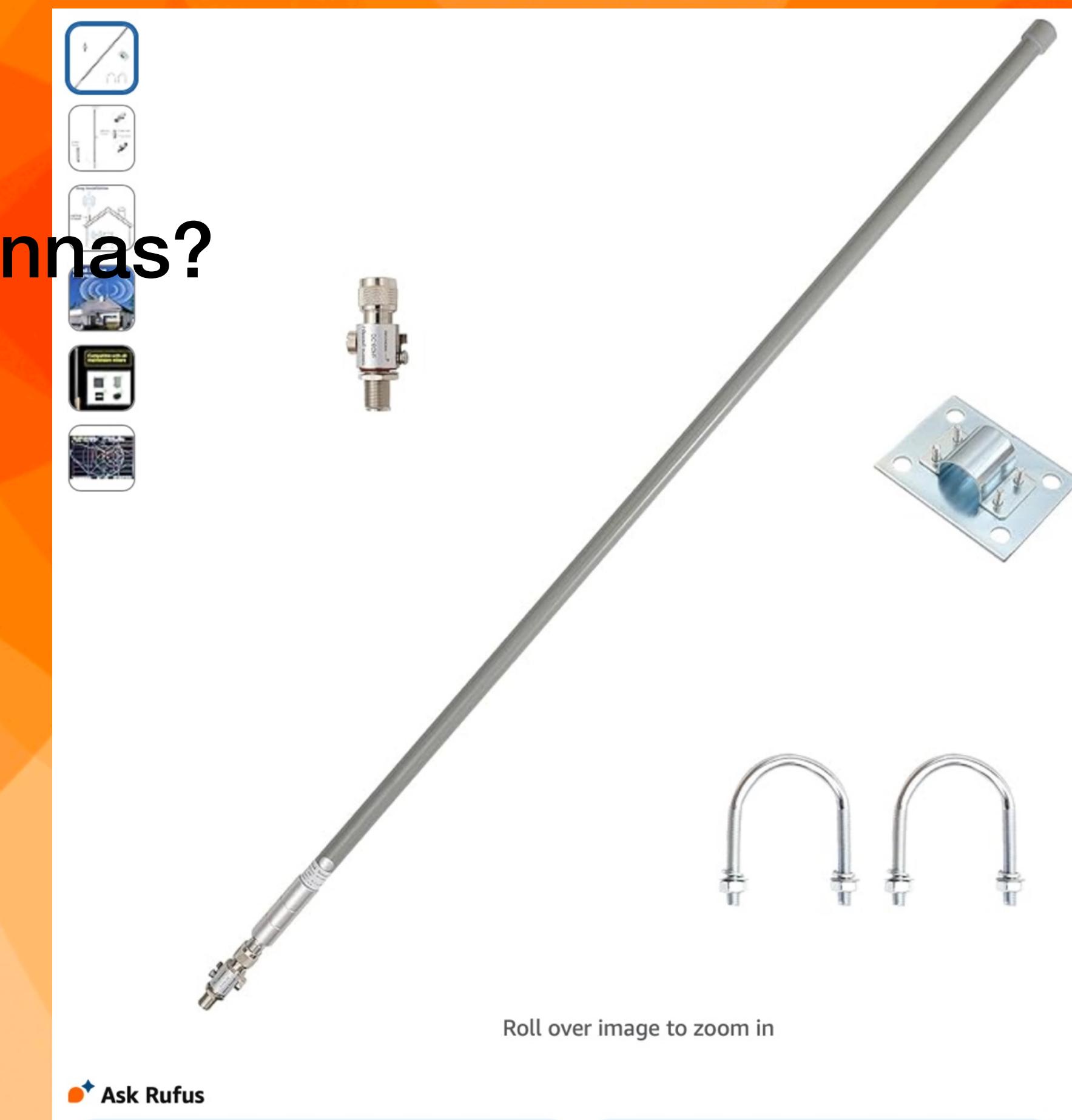
Add a Protection Plan:
 2-Year Protection Plan for \$3.99
 3-Year Protection Plan for \$5.99

Add to List

amazon business

Upgrades

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



Roll over image to zoom in

Ask Rufus

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

[Brand: Hexa Boost](#)

4.4 ★★★★☆ (201) | [Search this page](#)

\$49⁹⁹

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Antenna Radio

Brand Hexa Boost

Color Grey

**Number of
Channels** 1

Impedance 50 Ohm

Maximum 7000 Meters

[See more](#)

About this item

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