Using AREDN Software to Create a Ham Radio IP Network

Updated 11/13/2023 – Vers. 5.5

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Data Rates for Ham Radio Digital Modes

Comparing modulation rates, not throughput:

- Packet radio: 1200 baud (.0012 Mbit/sec <!>)
- PACTOR 3 (HF): ~ 10-20 kbits/sec
- VARA FM: up to 25 kbits/sec (w/specific gear)
- AREDN ham radio network links can run over 100 Mbit/sec

Amateur Radio Emergency Data Network (AREDN) Software as of 11/13/2023

Supports:

- Four brands of equipment, 100+ different models (~20 no longer recommend for new deployment), across four ham bands

- Internet tunneling between nodes, to bridge RF gaps (requires addition of Mikrotik hAP AC (Lite or ac2 or ac3 to shack network)

- Allows operations in Part 97 (ham) channels

- MIMO (Multiple Input / Multiple Output) + 802.11n **(now 802.11ac!)** operation - enhances throughput substantially compared to older devices

- The software provides DNS & DHCP services, route discovery and routing information – makes it relatively easy to get set up and connected.

The Digital Networking Bands

- **902-928 MHz**

  - not used much in urban and suburban areas (very noisy): only one 5 MHz wide channel. We're secondary on that band, the gear is relatively expensive and getting hard to find.

- **2.4 GHz – 2300-2450 MHz**

  - Only one usable 10 MHz wide Part 97 channel (Channel -2); Channel -1 may work OK away from cities.

  - Noisy due to splatter from poorly designed Part 15 wireless gear

- **3 GHz – 3300-3500 MHz**

  - The good news: it's all ours! No U.S. Part 15 in this band

  - The bad news: we have to buy export equipment and it's almost ~~double~~ quadruple the price of 2 or 5 GHz equipment

  - The worse news: in April 2022, the FCC gave half of it to the 5G carriers; we'll find out the fate of the other part of the band in the future.

- **5 GHz Band – 5650-5925 MHz**

  - Lots of channels.

  - The Part 97 band overlaps a lot of Part 15 channels, which can be useful for spreading traffic out.

  - We're secondary in this band. In October of 2020 the FCC took away primary occupancy of this band from the DOT (Department of Transportation). They're allowing Part 15 users to spread into the entire band now.

Wireless Access Points running AREDN software

They're like handie-talkies:

- They're low power (typically 600 milliwatts)
- They're limited to line of sight
- So they usually communicate through hilltop sites
- If your node hears multiple hilltops, it will always choose the best signal for its default route. So there's no point in using an omni antenna. A dish pointed at the strongest node is recommended.

Networking is a modern ham radio activity

But it's just infrastructure. It doesn't do anything…

It's all about the "Services"

•Services = things you can actually use
Some examples:

- Messaging/Email

- Keyboard to keyboard (text)

- Voice

- Video

- Document editing/management

- File Sharing Services

- Web servers

- Repeater linking

- *Anything else you can think of subject to the Part 97 regulations*

Messaging

The future of EmComm is not voice, but rather data

Messaging

- Email servers & clients:

    - Standard email servers (configured for mesh network)
    - Thunderbird client, etc.
    - Web clients are available (e.g., Roundcube)
    - Can send & receive to/from Internet mail (if server is configured for it)

Thunderbird configured for both gmail and mesh mail

Roundcube web email reading mesh email account

Winlink
(Winlink Global Radio Email)

A worldwide messaging system, originally for boaters. Can use:

- **On HF**
- ALE (Automatic Link Establishment)
- AX.25 Packet Radio
- PACTOR, PACTOR 2, PACTOR 3, PACTOR 4*
- VARA/HF (software modem)
- ARDOP   (older generation software modem; falling out of use)

  *Only legal in the U.S. during emergencies, when authorized by FCC

Winlink

On VHF
- AX.25 Packet Radio
- APRS
- VARA/FM
- AREDN network
  - much faster, no digipeating required

- Has a large set of standardized messaging templates. (e.g. ICS, USGS, FEMA)

Winlink Architecture (Conventional Mode)

- CMS

- RMS (gateway)

- Client (you)

Amazon 1

Amazon 2

Common Message Servers (CMS)

Internet

Remote Message Servers (RMS)

Telnet

HF: Pactor, WINMOR, Robust Packet, VARA, ARDOP
VHF/UHF: Packet, VARA
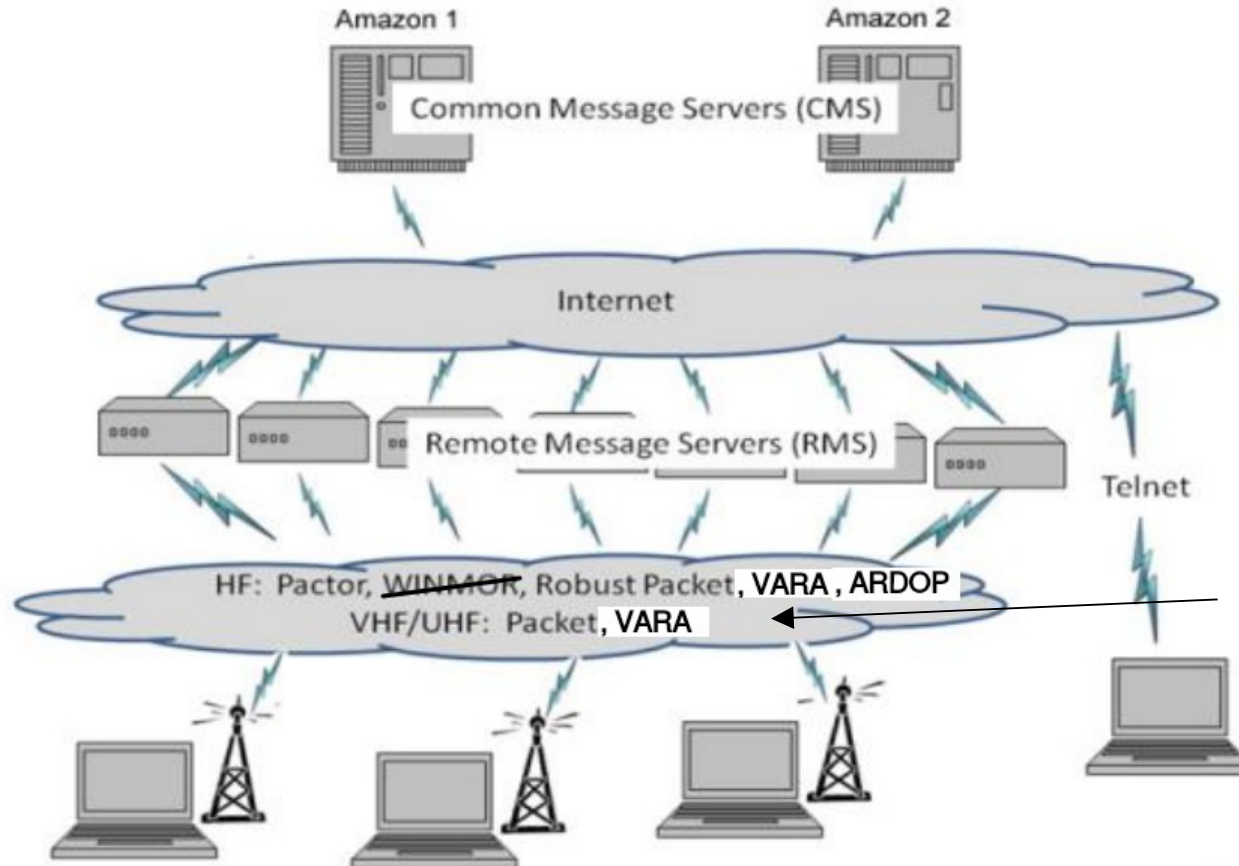
Ham networking goes here

Winlink Express Client

Setup can be complex, depending on how many modes your station is set up for: Pactor, VARA, AX.25 packet, AREDN network, etc.

Keyboard to Keyboard

- **MeshChat**

  - Runs on a Raspberry PI

  - Multiple channels can be created

  - Automatically finds other MeshChat servers

  - Web-based interface

  - Built-in "dropbox"

MeshChat example

Communication "Hubs"

- Mattermost & RocketChat - like Slack

- Text & pictures

- Multiple channels available

- Web access + Windows, IOS, MacOS,

  and Android apps available

Mattermost
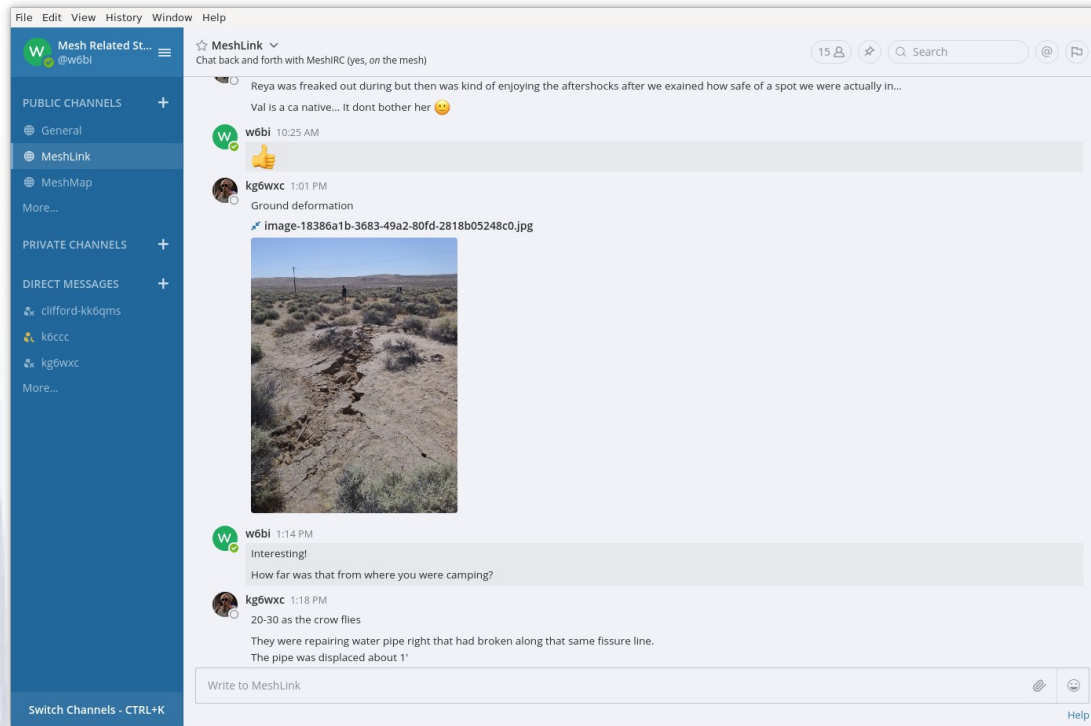
- Screenshot of ham network Mattermost server in Ventura County

- Also linked to another Mattermost server in San Bernardino County (100 air miles, 150 network miles away)

- Also linked to a Mattermost server on the Internet

VOIP (Voice Over IP w/Phones)

- Phone calls over the ham radio network
- Old photo, pre-deployment:
  - Old Cisco VOIP phone $25
  - Grandstream VOIP phone switch ~$275

- VOIP PBX installed in mountaintop repeater building (K6PVR – Sulphur Mountain, Ojai, California)
- Voice mail, conference calls, etc
- About 30 extensions: ham and served agencies (PD EOCs, hospitals, etc.)

VOIP (Voice Over IP Phones)

- Grandstream GXP 1625 VOIP phone (about $35) Two lines, POE-capable

- Other brands and models will work (Be careful buying old phones – make sure they can work with the SIP protocol; some are proprietary).

- Showing a missed phone call

- Showing one or more voice messages waiting

Another VOIP PBX

W6BI-SFV-PBX

- Raspberry Pi 3 running FreePBX
- Deployed to the adjacent valley; trunked to first PBX
- Offers extensions, voice mail, conference bridges, etc.

Collaboration Servers!

- Like the gamers use to coordinate their teams

- Voice and/or video chat. Very useful – and fun!

- TeamSpeak, Mumble, TeamTalk, etc.

- Teamtalk provides these features:

  - One to one chats

  - Many to many (chat rooms)

  - Can set up as many channels as necessary

  - Multiple, **simultaneous** conversations possible – all **full duplex** (you can interrupt whomever's speaking   :-D)

  - Speaker/microphone or headset (**HIGH quality audio**; not limited to 300-3,000 Hz like regular ham radio)

Collaboration Servers! (cont.)

- PTT, VOX or open mic (each audio stream uses 50-100 kbps (up & down) – minimal load on a healthy network)

- File sharing and desktop sharing are also available

- The Teamtalk server runs nicely on a Raspberry Pi (RPI 3: typically < 10-15% CPU utilization)

- Clients available for Windows, Debian Linux, MacOS, IOS, and Android

Teamtalk Weekly Net – Call of person talking has green background; when they unkey it turns yellow

Teamtalk Net
Video can be bandwidth-heavy. It's optional

Aux channels; switch to
one by double-clicking
Green – who's talking
Yellow – who talked last
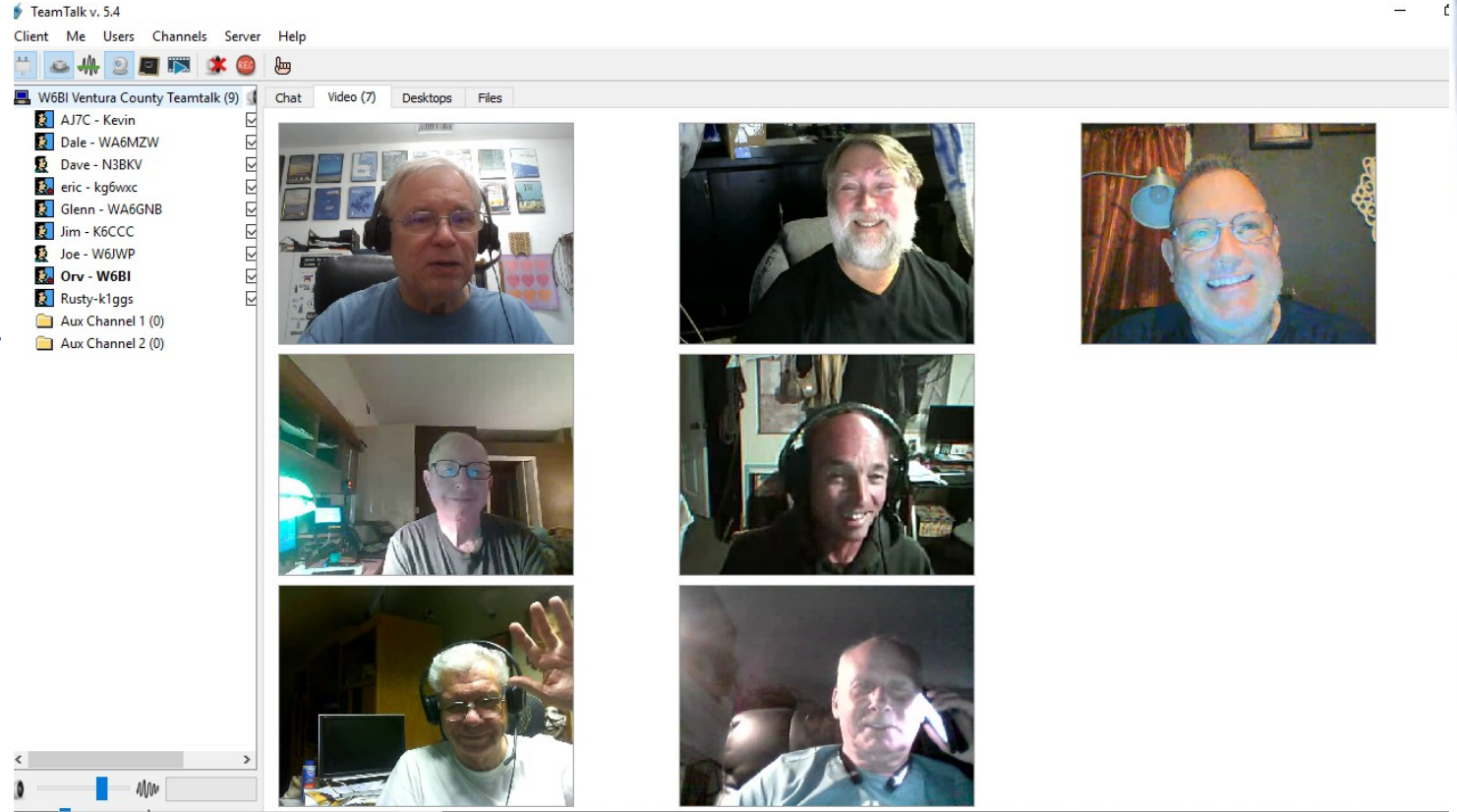
Video – Webcam Examples

Field day setup, 2016
As the crow flies, about seven miles. But two ranges of hills were in the way.
Via network - 3 hops on 2.4 & 5.8 GHz, about 40 miles total path length.

Typical PTZ camera view

Reeves Road Ojai Valley
05-29-2018 Tue 10:11:52 AM

The Thomas Fire – Ventura, CA Dec 2017.
Streamed to YouTube for wide viewing

The Woolsey Fire – Thousand Oaks, CA 11/2018
Also streamed to YouTube

The Woolsey Fire – Thousand Oaks, CA 11/2018
Also streamed to YouTube

Brush fire in Santa Susana Pass – right below radio site. Also streamed to YouTube

Document Sharing

- Etherpad - like Google Docs (but no spreadsheets)

- NextCloud cloud storage

- Several others

Etherpad example (not ham)

NextCloud – a drop box

RoIP (Repeater Over IP) repeater linking via equipment from JPS Communications, SkyMira, Orion Systems, etc.
Allstar, Dstar & DMR repeaters can be linked via the hamnet, too
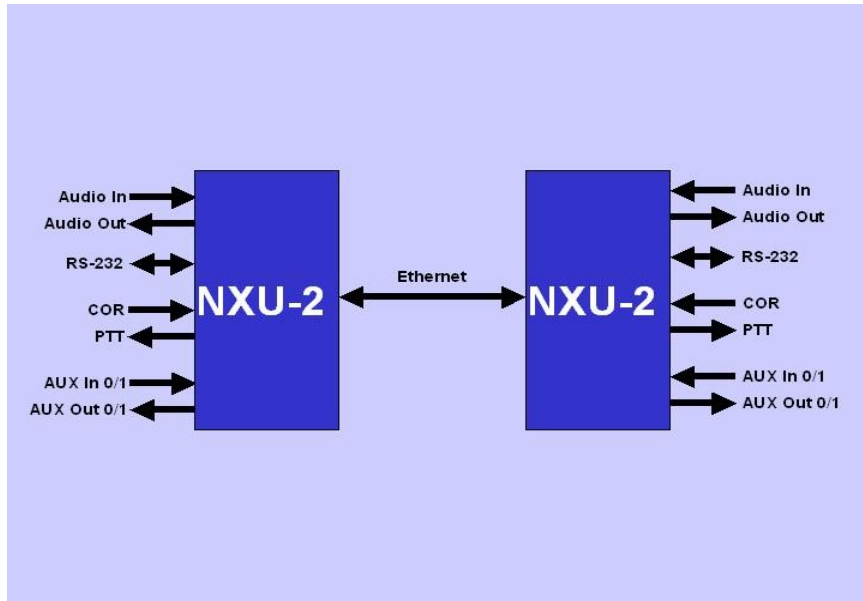
Put your Weather Station on the hamnet!
Example uses Weewx software (weewx.com) on an RPI
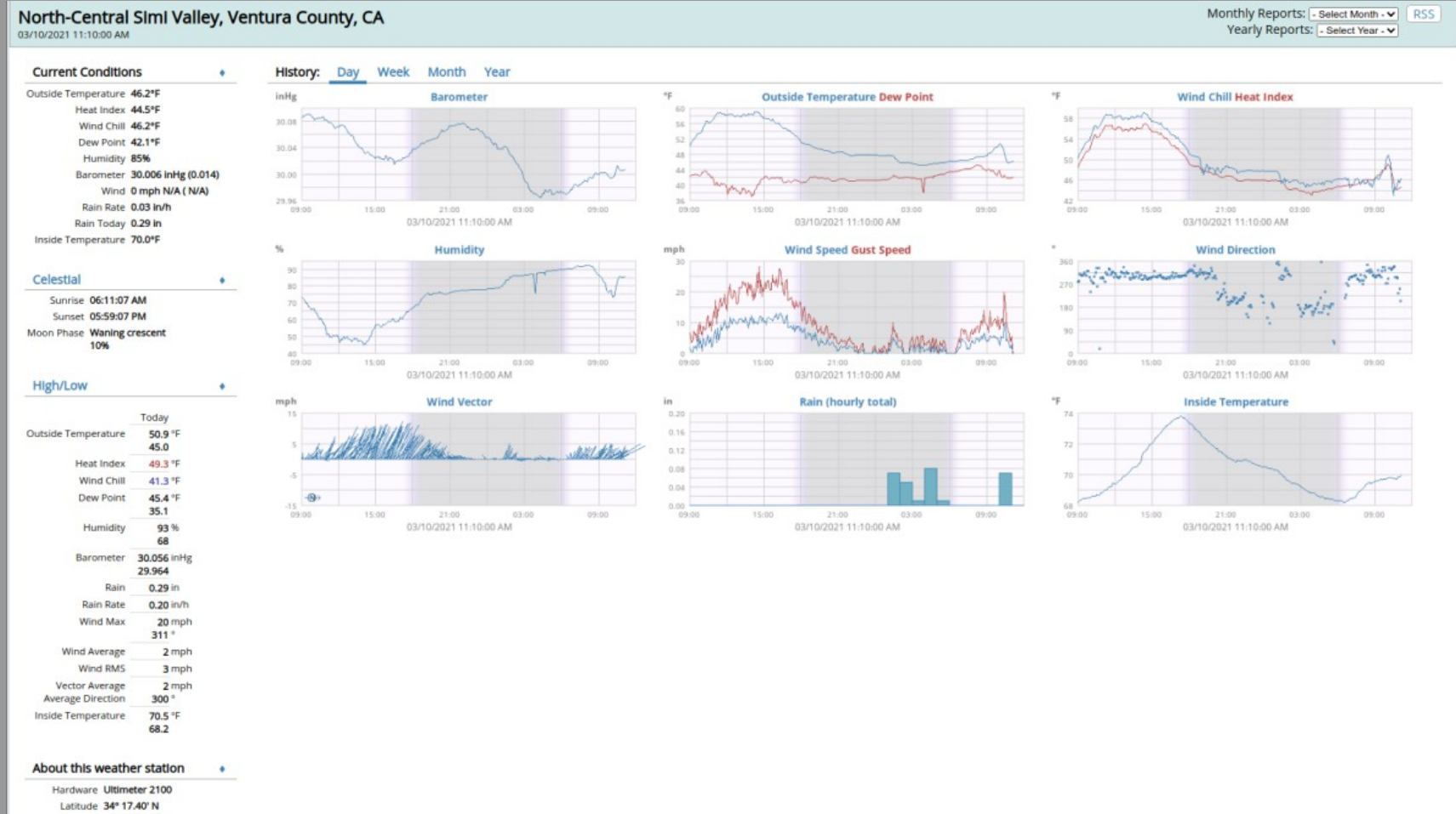
Weewx gone wild - highly-customized

Gotta have some fun!
Scrabble server, running on hamnet!

bzflag ("tank") game!

Texas Hold 'Em server :-)

Cameras!

Cameras!

05/06/2023 15:37:46

SimiWest-West PTZ

Cameras!
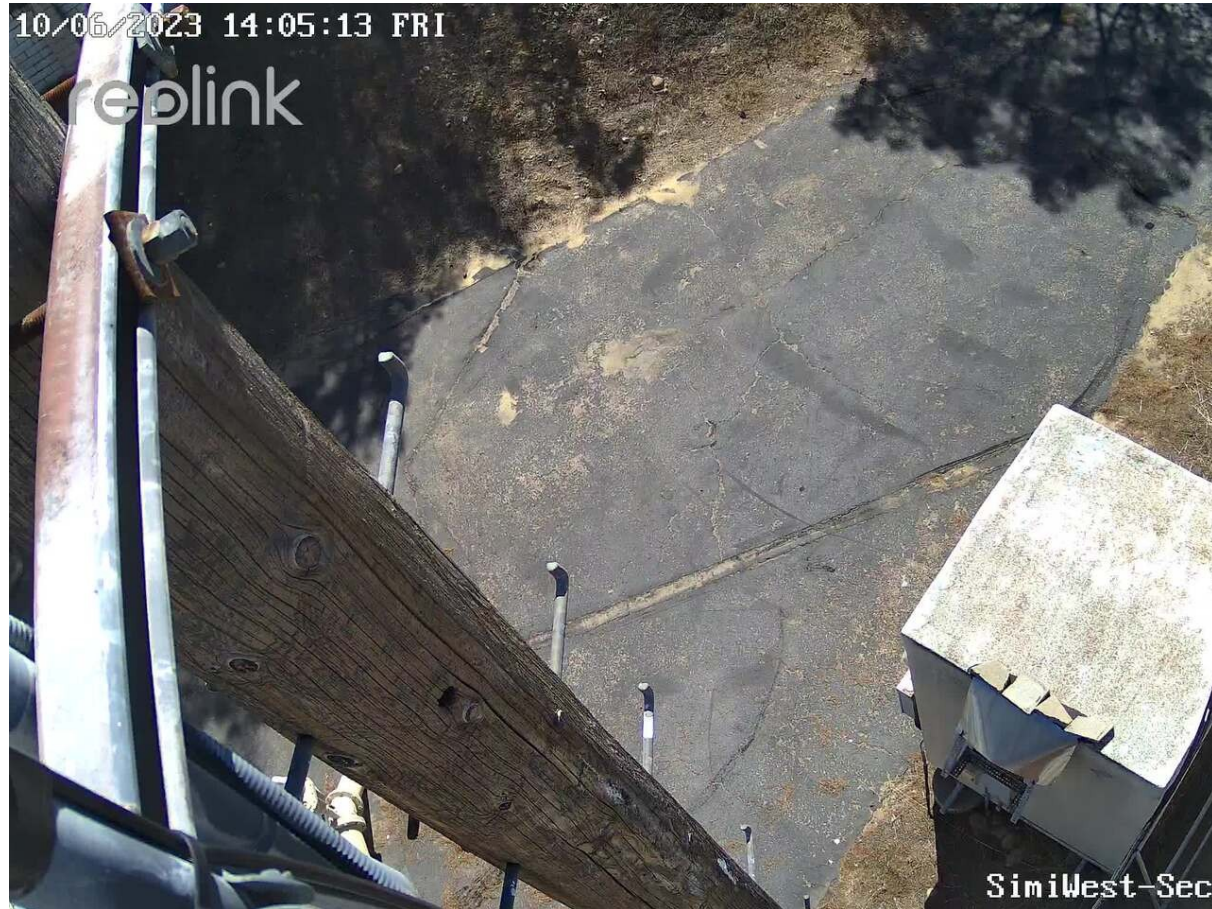
Cameras!

06/20/2023 14:45:13 TUE   KB6BF Pismo Cam

Network map – (supernode network)
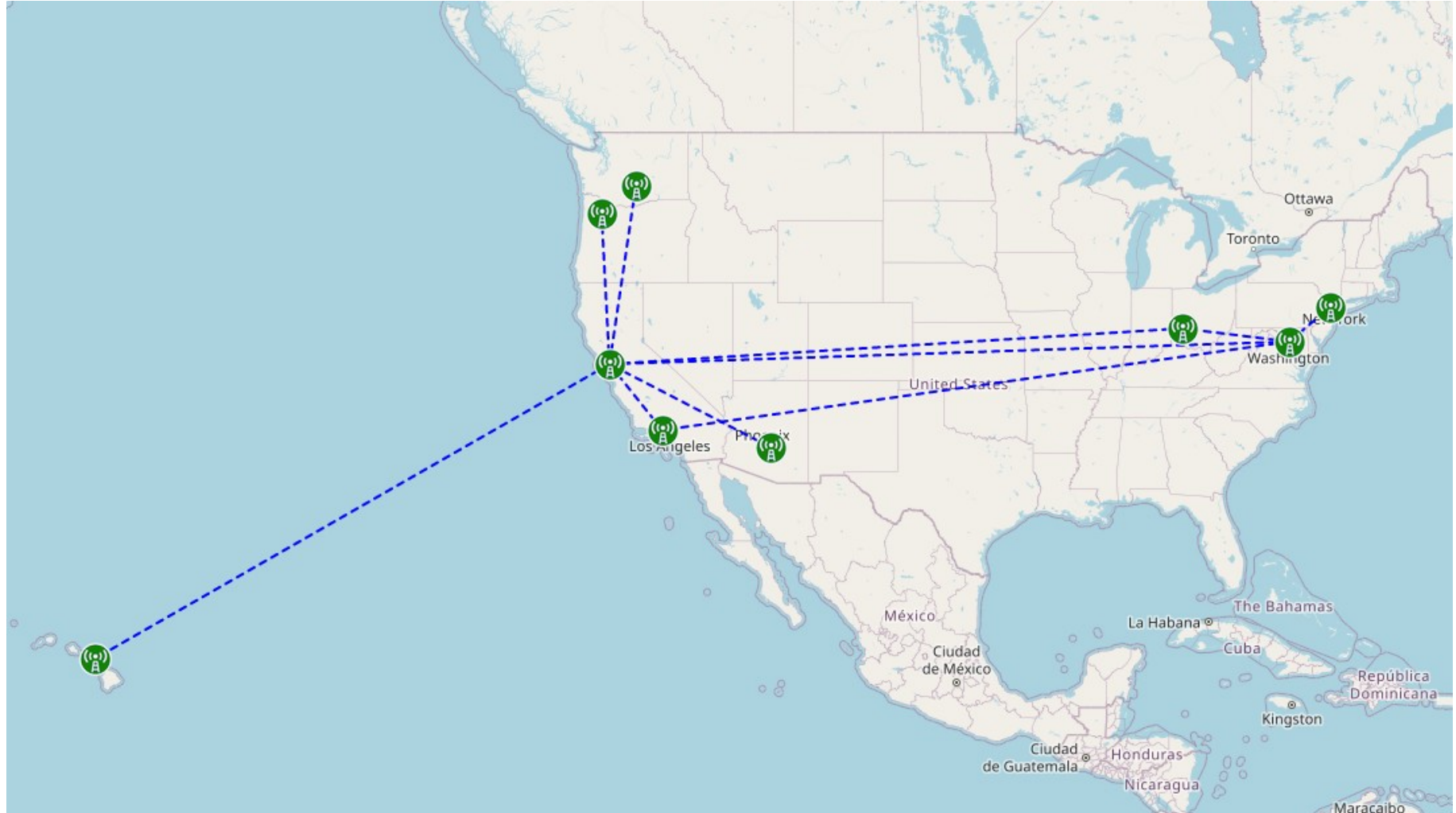
Network map – (supernode view)
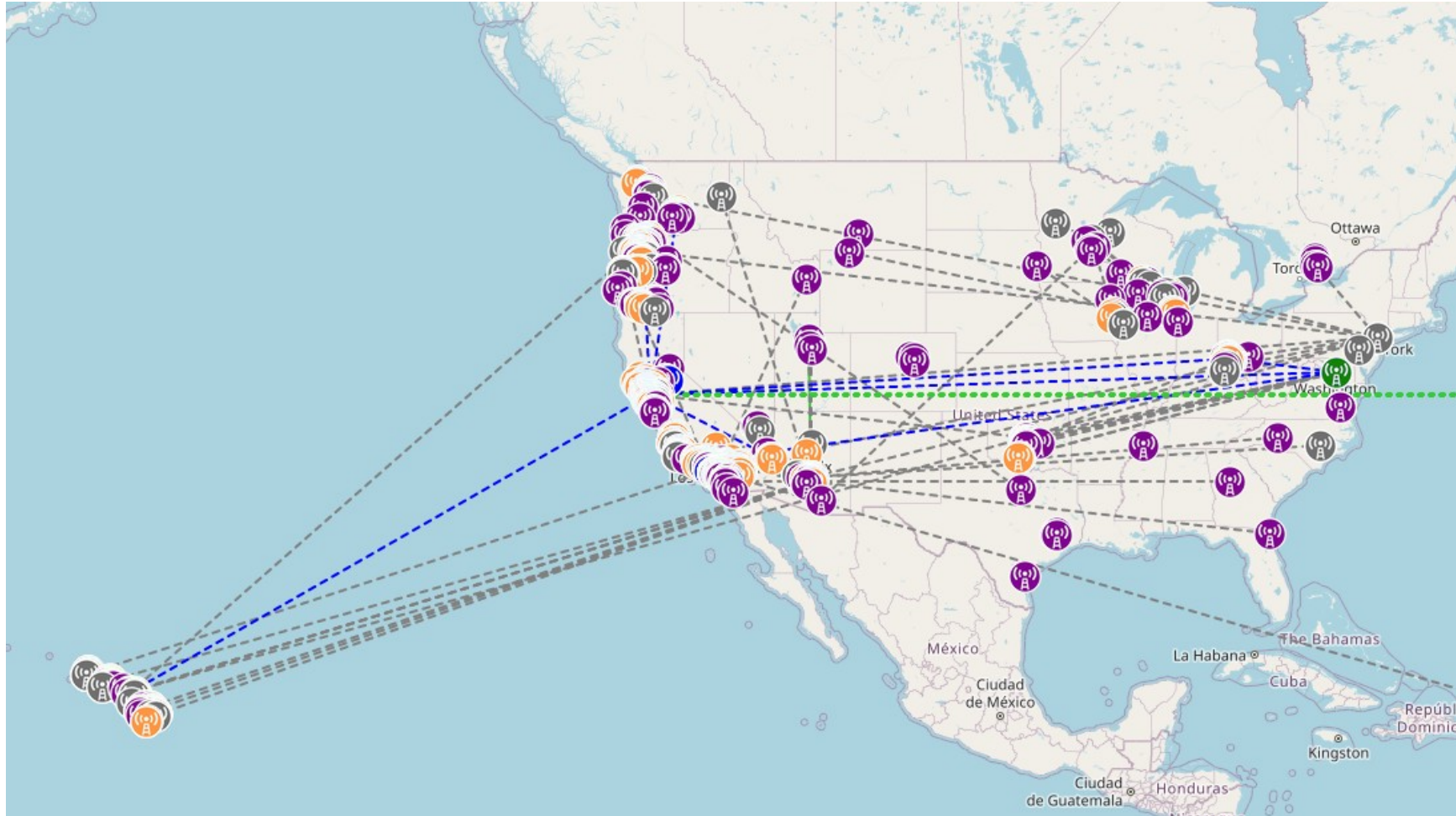
Network map - Washington/Oregon
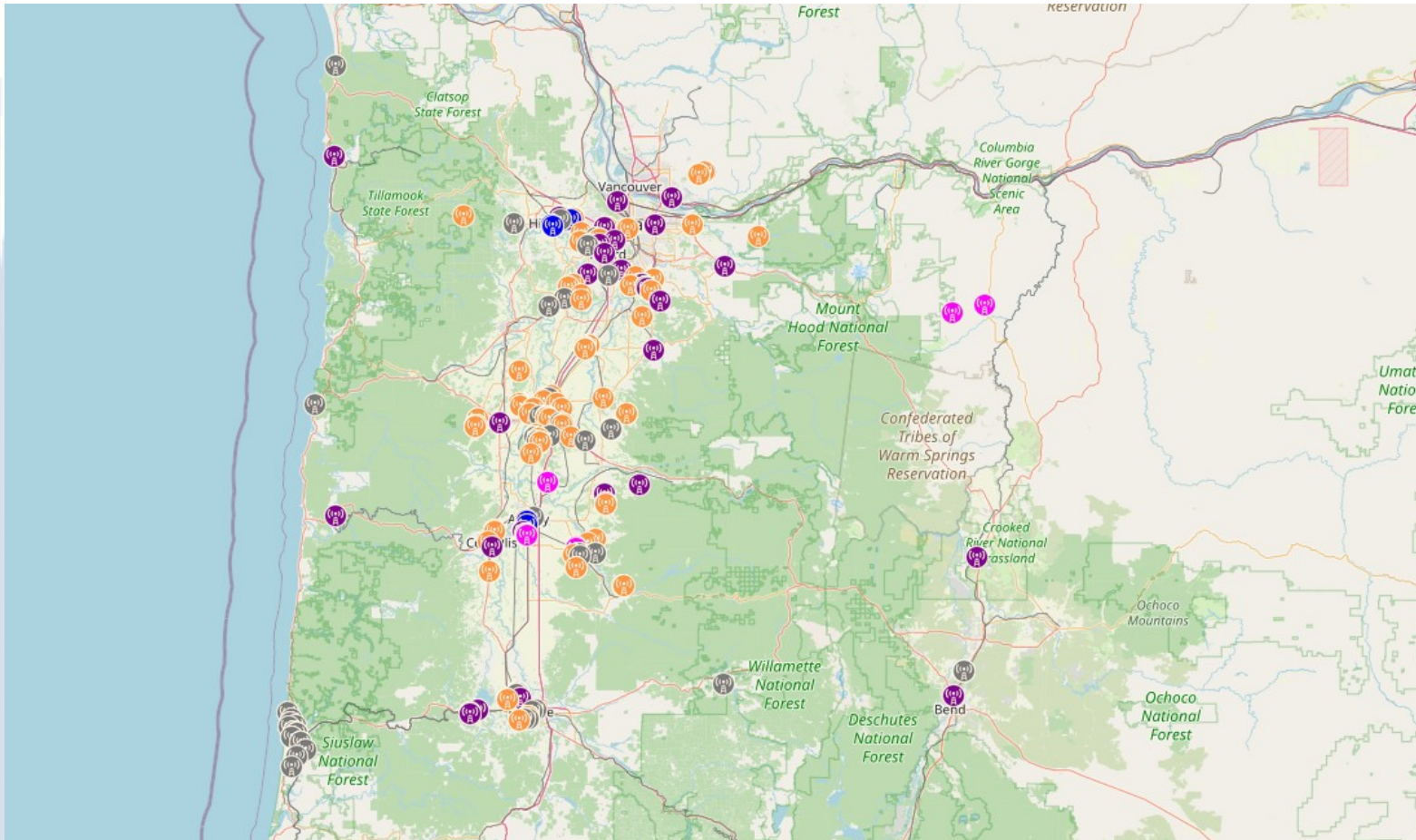
Orange – 5 GHz
Purple – 2 GHz
Blue – 3 GHz
Pink 900 MHz
Grey – no RF
(usually a Hap
ac)

Network map – Yakima, WA
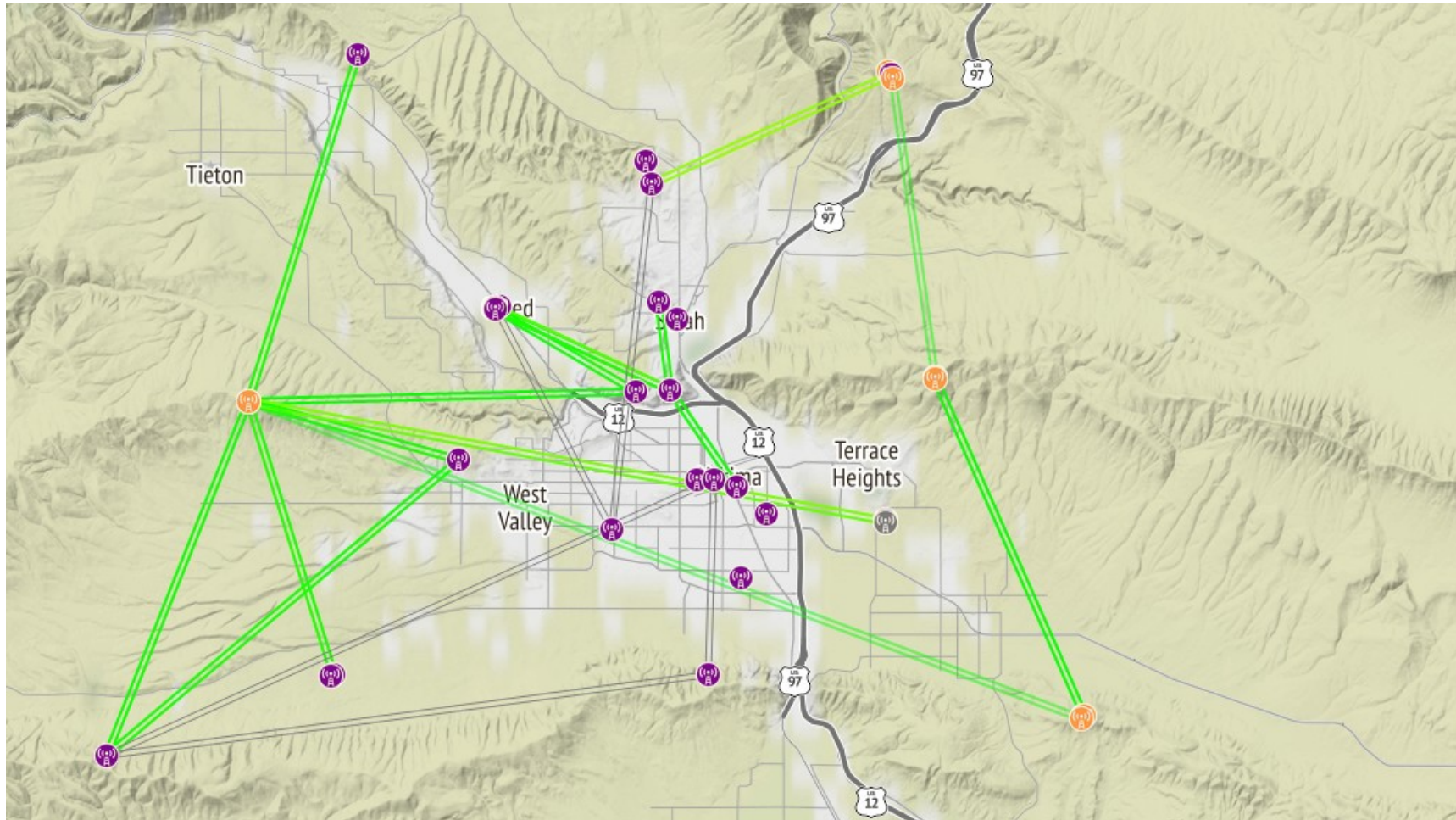
Network map – Salt Lake City, Utah
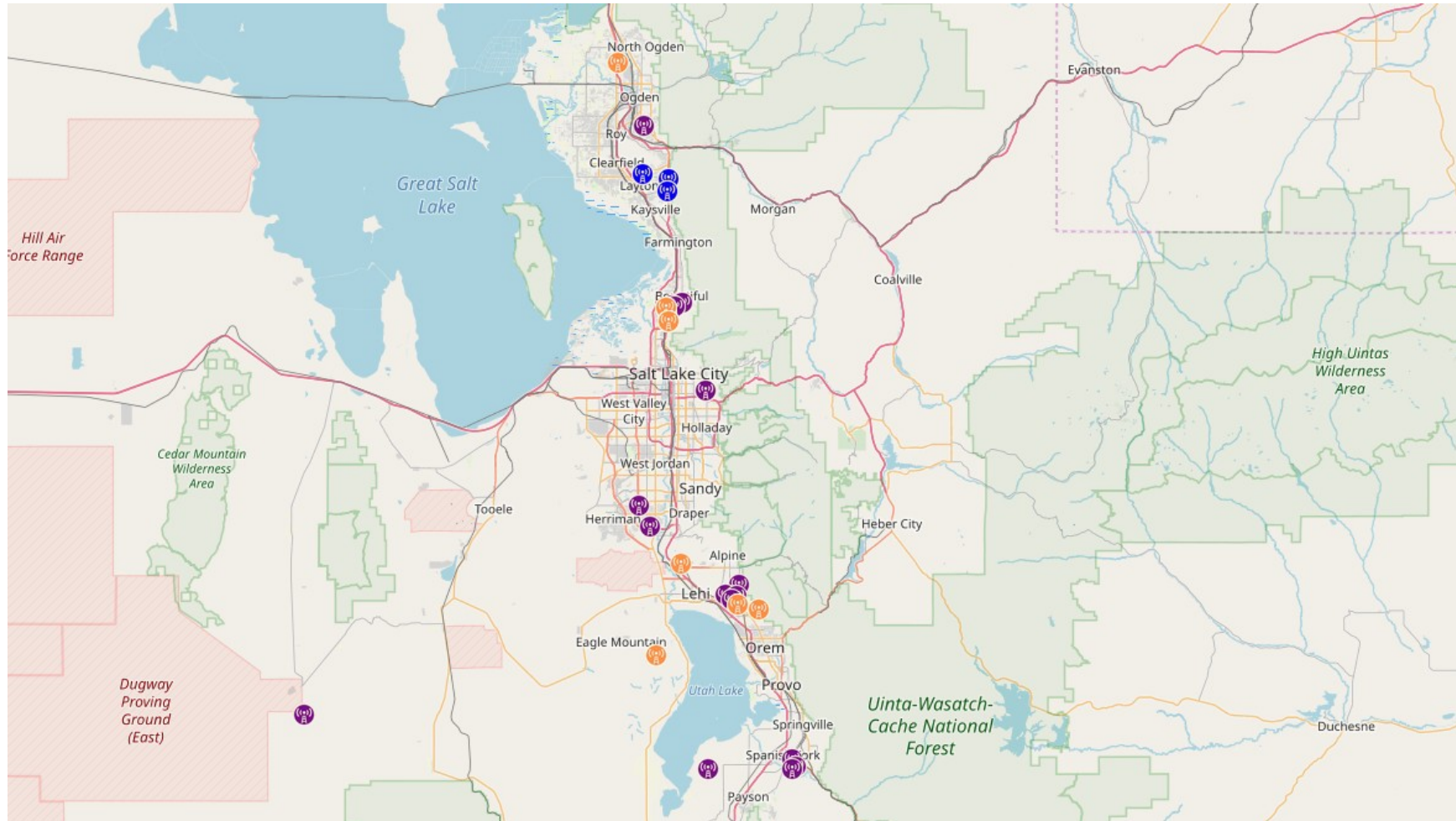
Network map – BAM (Bay Area Mesh) - San Francisco, CA
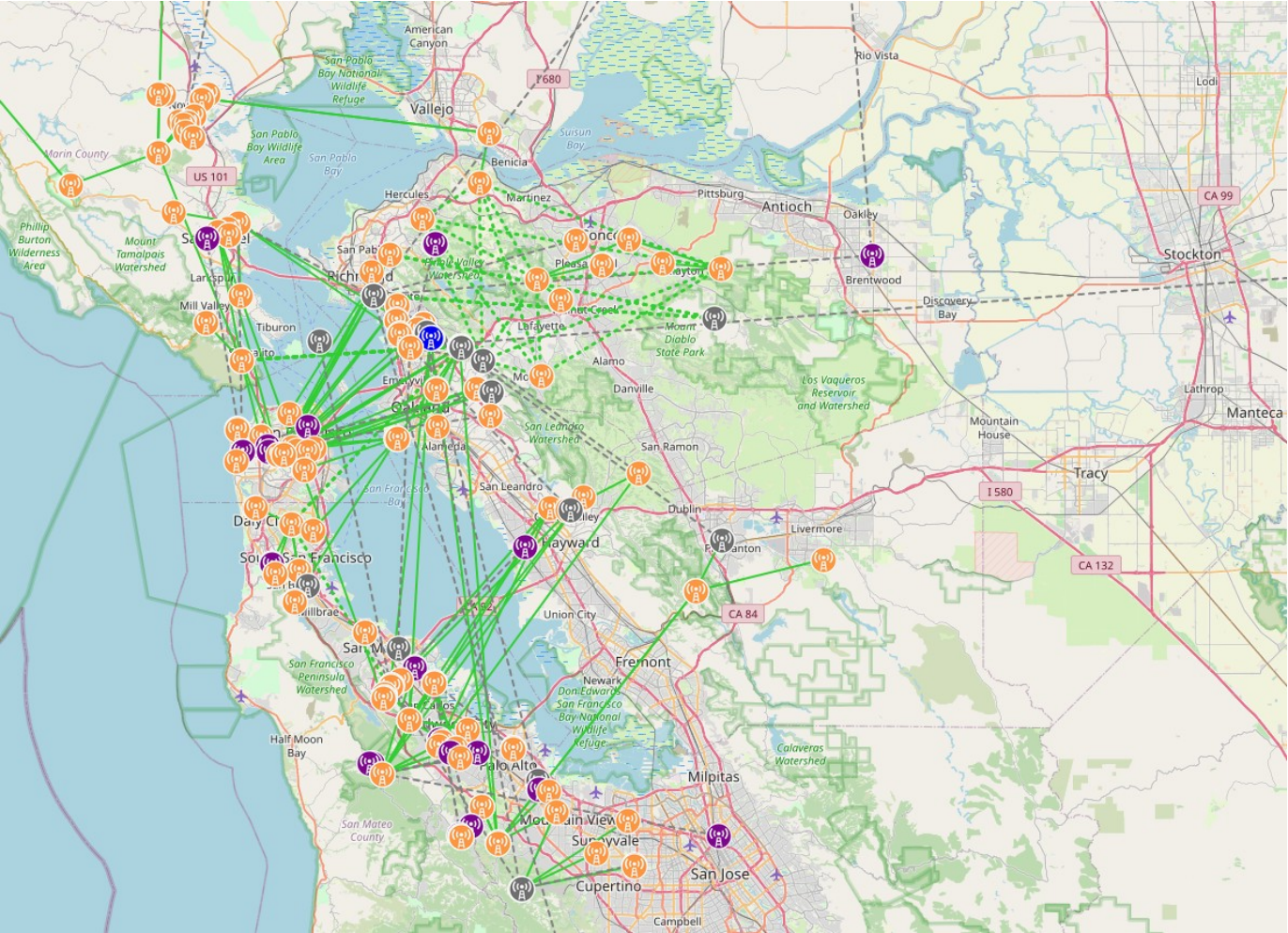
Network map – Hawaiian Islands
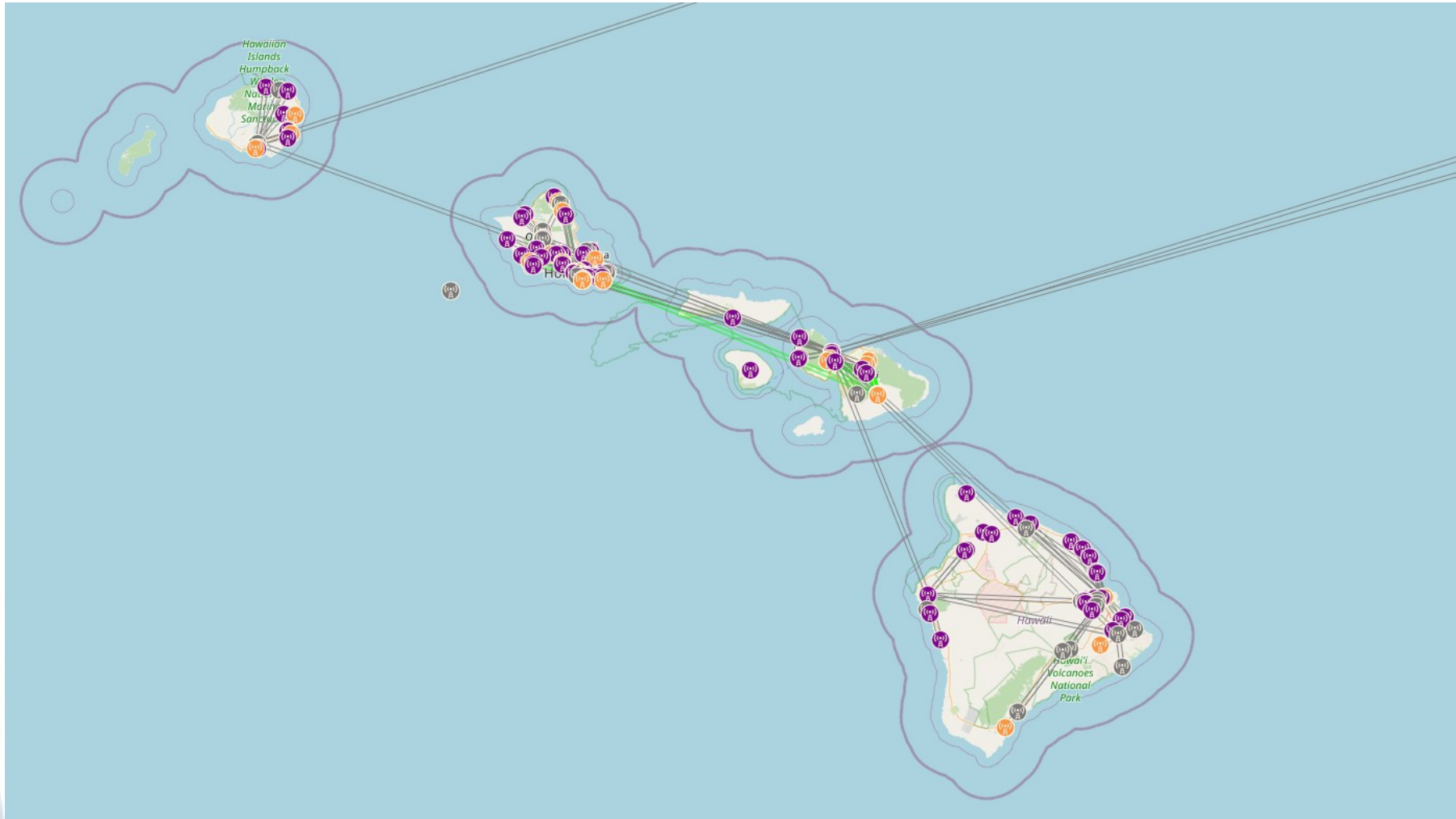
Network map – Phoenix area
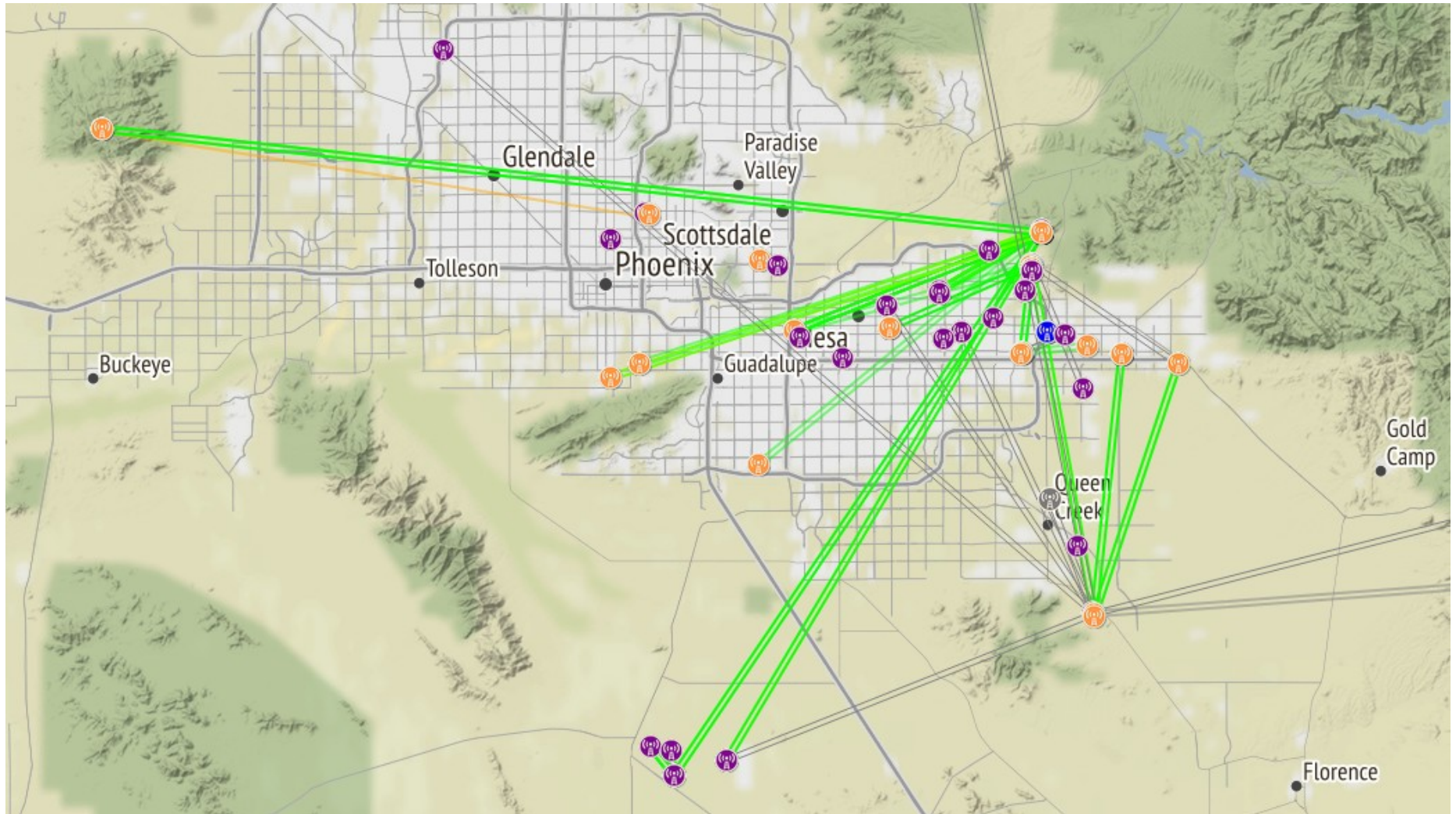
Network map – Southern California
About 425 nodes (hilltop & ground level) in area shown
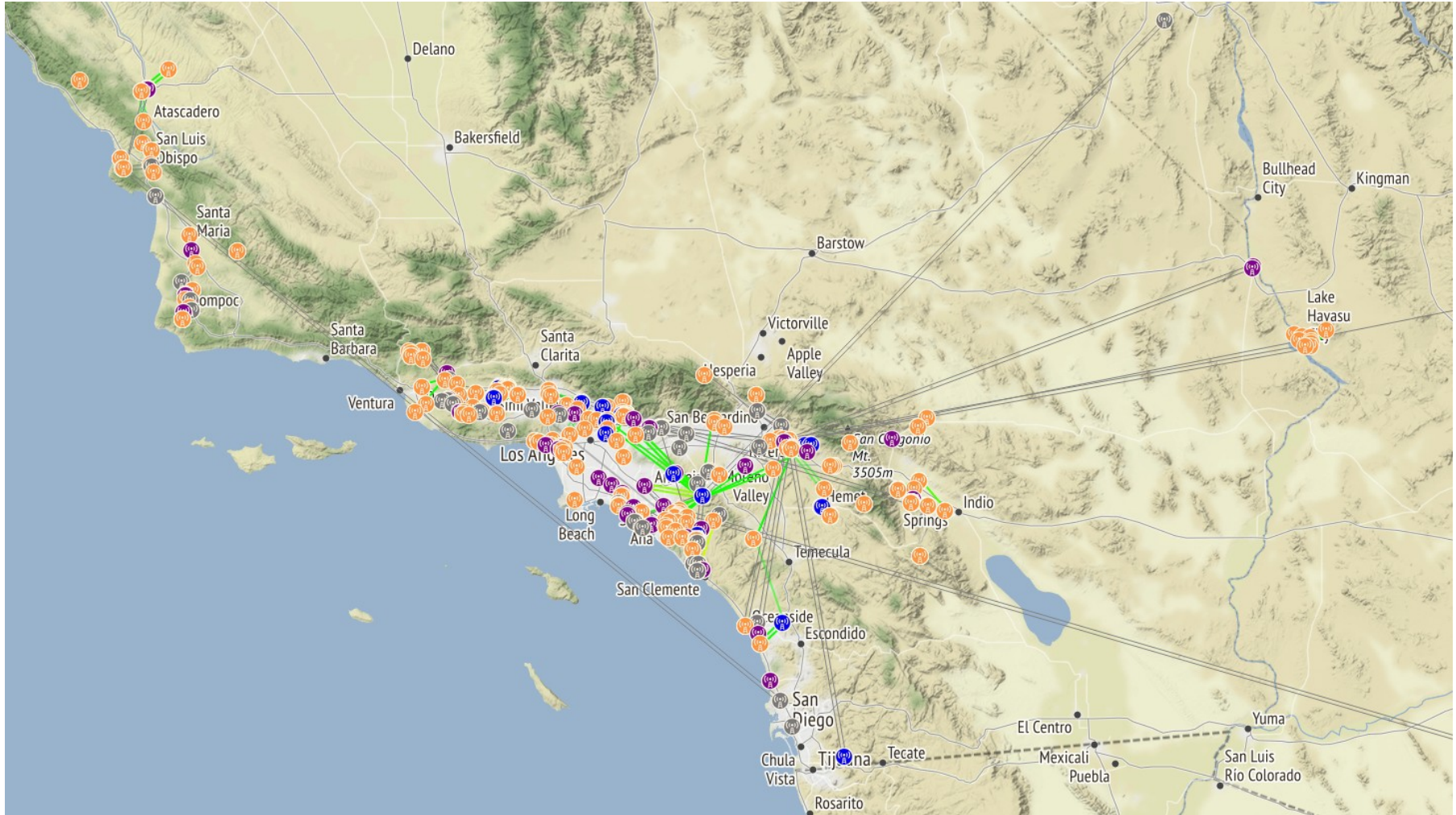
Equipment

What's out there??

About Modern Access Points/AREDN Nodes

- Available for use in four amateur bands

  - (Mostly) not expensive

  - Mostly designed for outdoor use: weatherproof, use POE for power

  - Sophisticated software-defined transceivers (two for MIMO! - Multiple Input Multiple Output).

  - Built-in gain antennas in many models, one vertically-polarized, one horizontally polarized for two simultaneous data streams – on the same channel!

  - Typically 600 mW Tx power (split between two channels)

  - 802.11ac gear – better performance than the older 802.11n gear. Recommended for new purchases.

About Modern Access Points/AREDN Nodes

- *Use caution buying used equipment*
    - ▶ *Don't purchase if they only have 8 MB of flash or 32 MB of RAM; future versions of AREDN firmware may not fit in older 32 MB devices (**many of these older devices have been sunsetted by OpenWrt, and hence AREDN support for them will cease in the future**)*
    - ▶ *Don't purchase if they're not MIMO:*
        - – *poor performance compared to modern devices*
        - – *don't interoperate optimally with MIMO gear (think water & oil);*
    - ▶ *The AREDN website (arednmesh.org) has a Supported Platform Matrix that has flagged supported devices that are no longer recommended for new deployments*
  - Now (1Q23) there's support for some 802.11ac devices.   Check AREDN Nightly Build page for latest info.

Ubiquiti NanoBeam AC 5 gen2 19 dBi gain

Ubiquit LiteBeam ac Gen2 23 dBi gain

For Longer Distances
(or faster throughput)

Ubiquiti PowerBeam AC 500

MikroTik RBLHGG-5acD, MikroTik RBLHGG-5acD-XL

Mikrotik LDF 5ac (Light Dish Feed)
Inexpensive, 9 dBi gain.

- Mikrotik LDF 5 ac (5 GHz) installed at dish feedpoint using universal mount (~$8 from Amazon) ~23 dBi gain

- Ideal for hams under an HOA, as satellite dishes are allowed!

- LDF 2 (2 GHz) now also supported by AREDN software

Mikrotik LDF 5
Installed in portable (foldable!) satellite TV dish – from K9CQB

Other Network Station Requirements

- Shielded (per Ubiquiti) <u>outdoor</u> network cable. Could be unshielded if lightning isn't an issue in your area (IMO)
  - Pre-terminated lengths are available if you're uncomfortable terminating RJ45 cables

- Needs a dedicated computer for mesh network, because it's a standalone network with no connection to home network (but there's a way around that – see Mikrotik hAP Lite slides)

Mikrotik hAP AC Lite (no longer recommended)
The Swiss Army Knife of ham networking
A valuable addition to a ham shack network

hAP ac2 & ac3
Faster CPU w/4 cores, Gigabit Ethernet ports, more RAM

(No POE on Port 5)

A Mikrotik hAP Ac Lite/2/3 running AREDN software integrated into your home network – recommended!
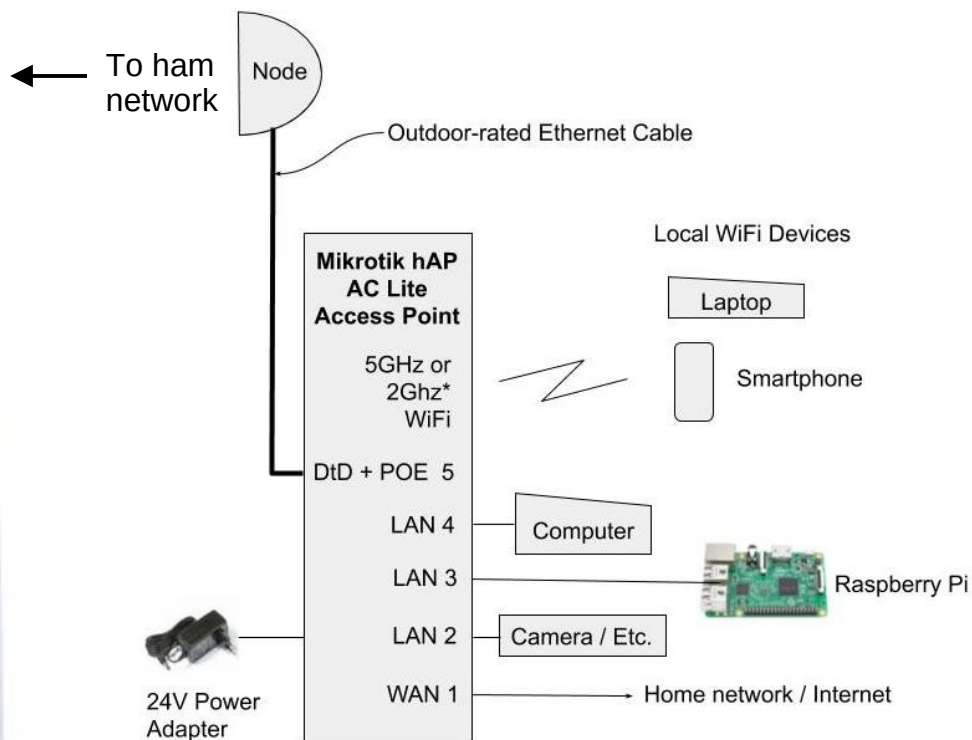
To ham network

- Port 1 – Wired connection to home network

- Ports 2-4 – other devices on your ham network

- Port 5 provides POE power plus a DtD (Device to Device) link for routing info to/from node – your link to the mesh network

- 2 & 5 GHz internal radios can be used as ham network node (2 GHz only), a wireless access point or a wireless access client.

- Wired this way, devices on ports 2-4, or connected via the internal wireless access point, have access to both the hamnet and the internet.

- The AREDN software firewalls the hamnet off from your home network.

Home Installation example
Ubiquiti Nanostation & Mikrotik dish
Ethernet cable goes to Nanostation main port. Secondary port goes to Mikrotik dish, providing POE and network connectivity. Only one Ethernet cable is required!

Home Installation example

Ubiquiti Powerbeam for network backbone link;
Ubiquiti Rocket + sector antenna for local redistribution

Hilltop equipment – Ubiquiti 120 degree sector antenna with Rocket M5 5.8 GHz node attached on back

Small site Example - North Orange County, California
120 degree sector antennas & nodes for 2.4, 3 & 5 GHz

Medium Site Example – Chatsworth Peak, California
User access points on 2.4 & 5 GHz; dish for backbone link; PTZ camera

Another medium-sized site (post wind-storm)
(80% FM repeaters, 20% networking) Verdugo Peak, California

Large site (commercial) Pleasants Peak, California
Yellow-highlighted gear is for mesh network. 360 degree user access, backbone links (not shown) + PTZ camera
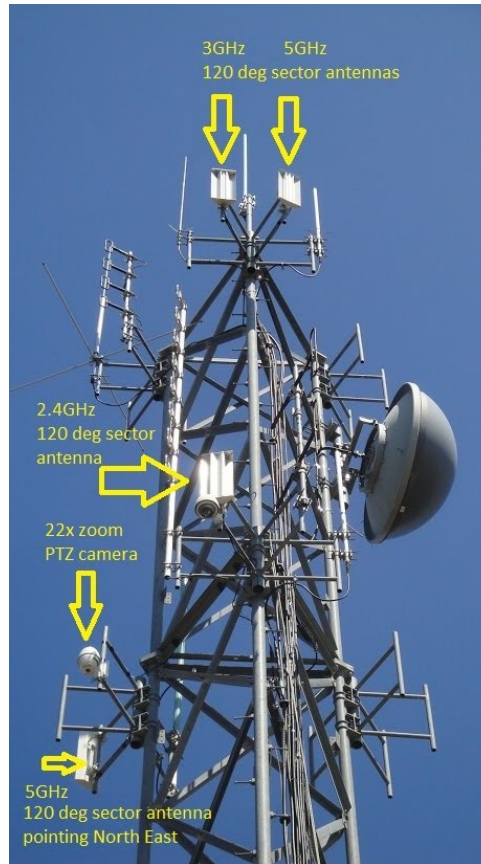
Coverage Tools (can two sites 'see' each other?)

- heywhatsthat.com – easy to use

- https://www.scadacore.com/tools/rf-path/rf-line-of-sight/ - easy

- https://ispdesign.ui.com/# - easy to moderate

- Radio Mobile - complex
    - http://www.ve2dbe.com/english1.html

- Radiofresnel.com – for calculating Fresnel zones

- Mapping and Distance - https://www.acscdg.com/

How do I Get Started?

- Ask around your club; ask around repeaters and/or mailing lists

- Get a link going (may require some tree trimming)

- Or tunnel someplace, if no RF link

- Make friends with repeater owners! (Especially if their site is line of sight to you) Point out the advantages of being networked :-))

- Join the AREDN forums and/or any local mailing lists. Read!

Important notes!

- Do **not** stand in front of the radio for extended periods of time when it's powered on. NEVER look into the focus of the radio when it's powered on. The small dishes have 80 - 100 watts of ERP at 5.8 GHz!

- The Mikrotik Basebox 2 has 30 dBm of power output. When fed to a Mikrotik 30dBi gain dish that's **1 KW** of ERP. **Use caution!**

Where to get AREDN Ham Network Info

- Amateur Radio Emergency Data Network (arednmesh.org)

    - List of supported products

    - Software downloads (production & nightly builds)

    - How-Tos

    - FAQs

    - Extensive, detailed documentation

    - Forums – more than 4,400 users

  - Social media sites: Facebook, Mastodon, Slack, Discord, etc.

  - AREDN channel on YouTube

      - * Beware of older HSMM and AREDN YouTube videos; they can be way out of date.