Using AREDN Software to Create a Ham Radio IP Network

Updated 1/4/2023 – Vers. 5.2

Orv Beach, W6BI

w6bi@arrl.net / orv.beach@gmail.com

Technical Specialist, ARRL Santa Barbara Section

AREDN Ambassador

Ham Radio IP Networking with AREDN Software

Comparing speeds (modulation rates, not throughput)
- Packet radio is 1200 baud (1 baud = 1 bit/second)
  - That's .0012 Megabits/second (!)
- PACTOR IV is up to 5,200 bits/second (but not normally allowed in the U.S.)
- VARA FM (software modem) can be up to 25 kilobits/second
- Ham radio network links can be more than 100 Megabits/second
- AREDN networking uses commercially available access points from Ubiquiti, TP-Link, Mikrotik and GL.Inet
- The access points are loaded with custom firmware from AREDN; they become ham radios.
- They can then be used to create a ham radio IP network (the "Hamnet")

Amateur Radio Emergency Data Network (AREDN) Software as of 1/4/2023

Supports:

- Four brands of equipment, 80+ different models, across four ham bands
- Internet tunneling between nodes, to bridge RF gaps (requires addition of Mikrotik hAP AC Lite to shack network)
- Allows operations in Part 97 (ham) channels
- MIMO (Multiple Input / Multiple Output) + 802.11n 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 in the near future.

Line of Sight

"Microwaves can go 1̶5̶ miles or through one tree"
2̶5̶
35

Two's Company

Tree's a Crowd...

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

Plain old Email

- Email servers & clients, using standard SMTP

  - Thunderbird, etc.
  - Web clients are available (e.g., Roundcube)
  - Requires tweaks to AREDN node config

- Winlink and a ham radio network were made for each other!

Winlink
(Winlink Global Radio Email)

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

- **On HF**
- ALE (Automatic Link Establishment)
- AX.25 Packet Radio
- Robust Packet (proprietary SCS protocol)
- 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
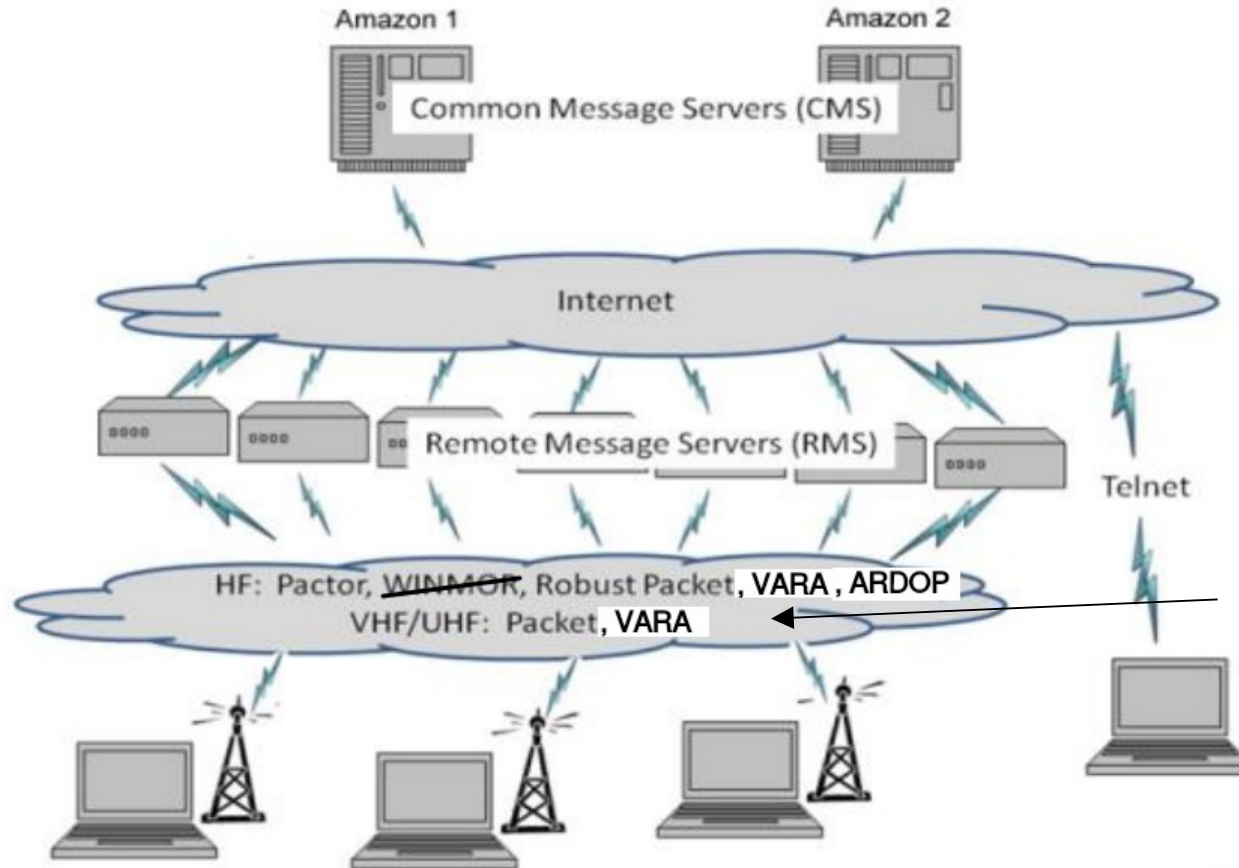
Ham networking goes here

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
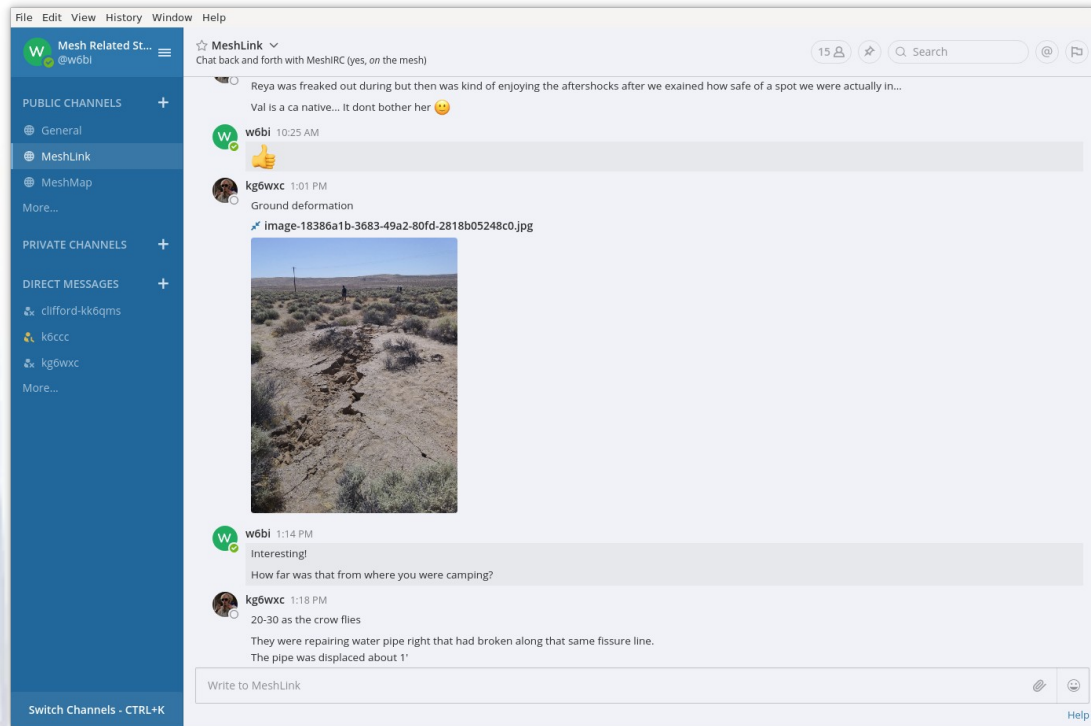
Communication "Hubs"

- 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
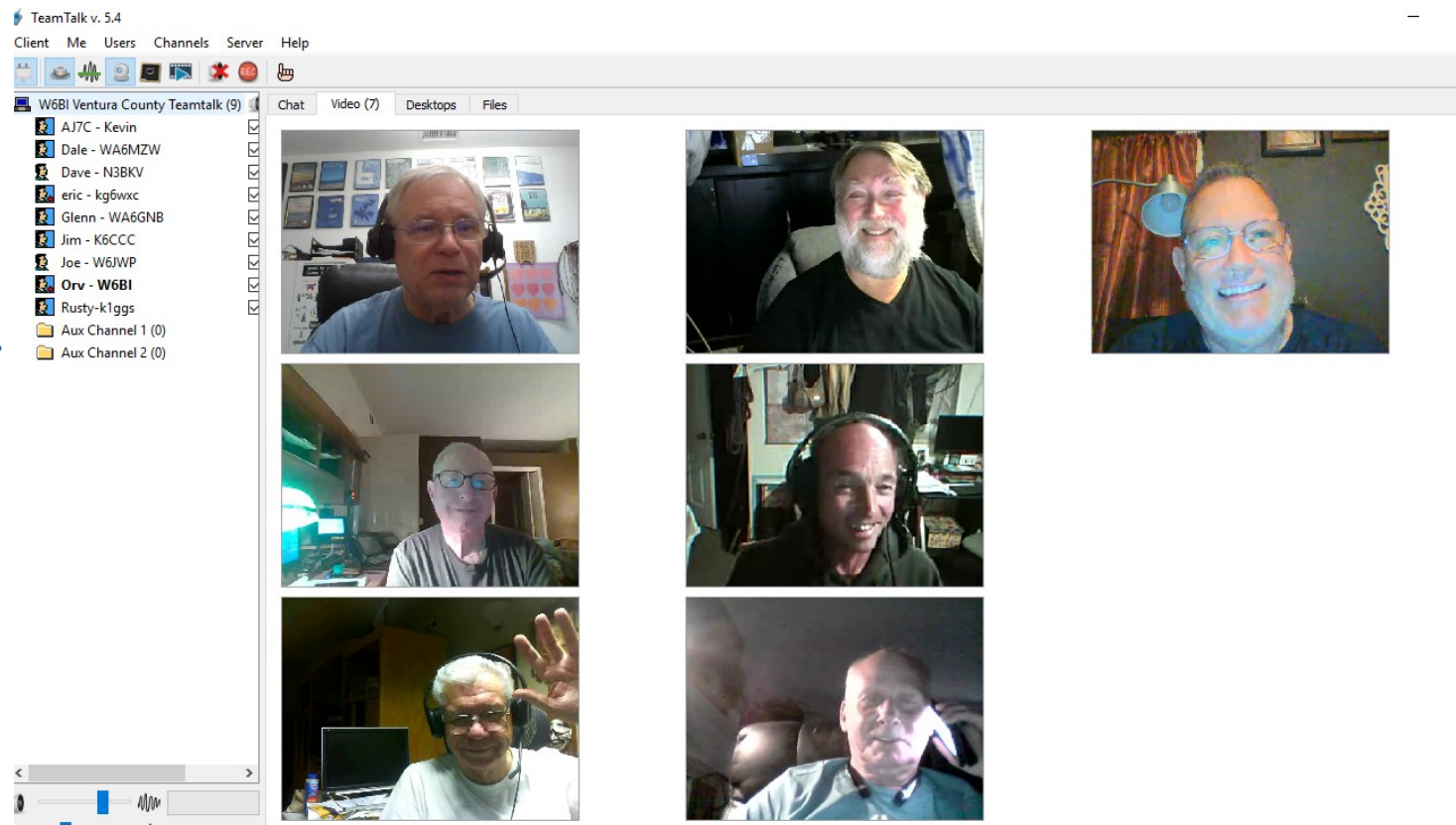
Video – Webcam Examples

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, etc.
Allstar, Dstar & DMR repeaters can be linked via the hamnet, too
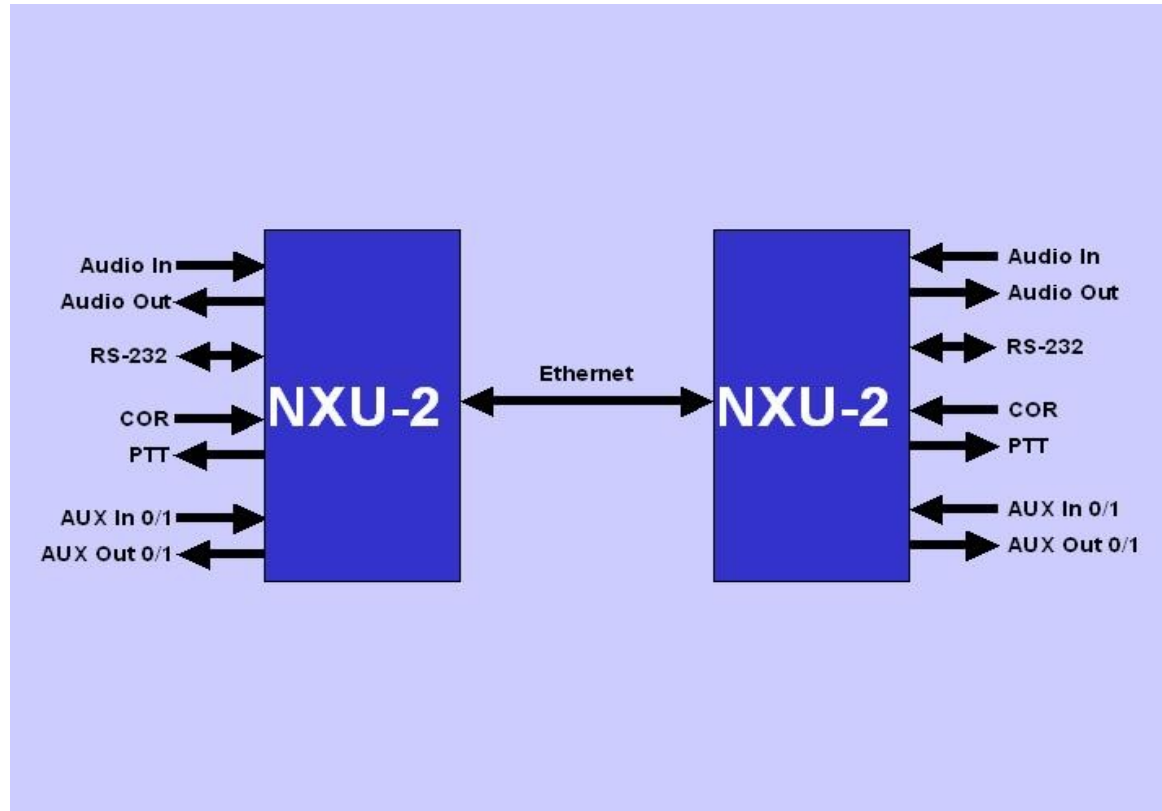
Put your Weather Station on the hamnet!
Example uses Weewx software (weewx.com) on an RPI

Weewx gone wild - highly-customized

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

bzflag ("tank") game!

Texas Hold 'Em server :-)

Network maps from KG6WXC mapping software – Washington/Oregon
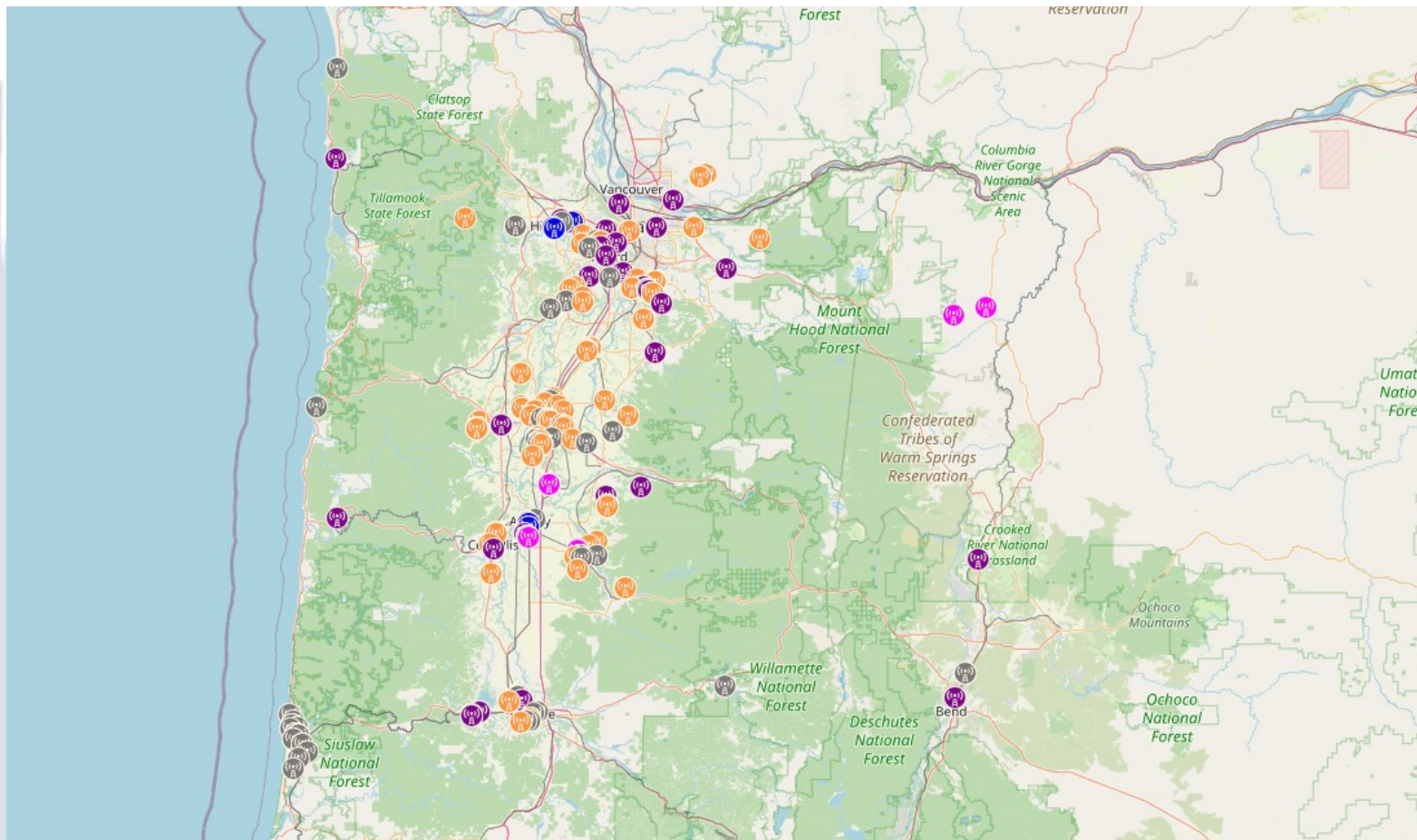
Orange – 5 GHz
Purple – 2 GHz
Blue – 3 GHz
Pink 900 MHz
Grey – no RF

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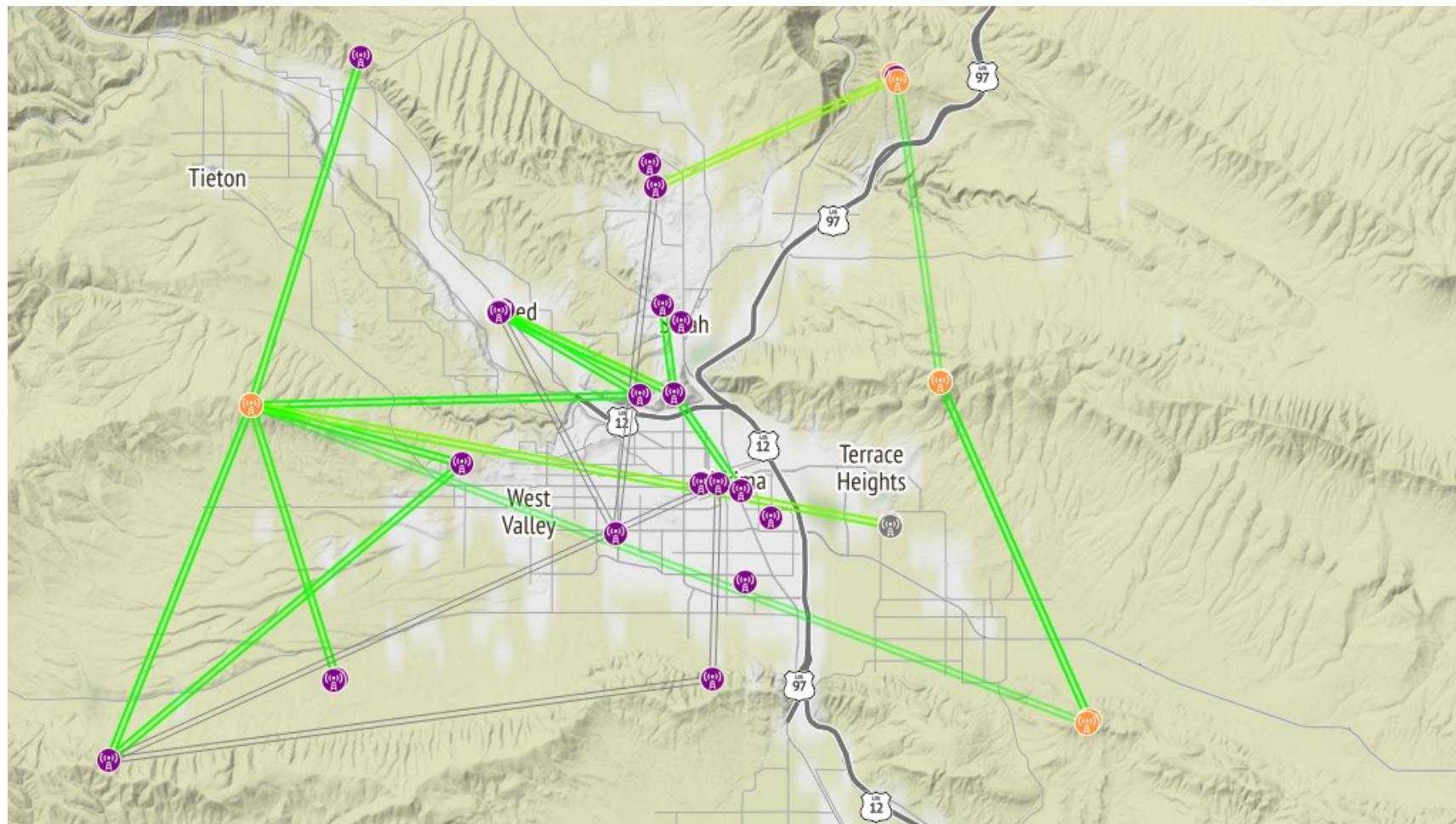
Network map – Salt Lake City, Utah
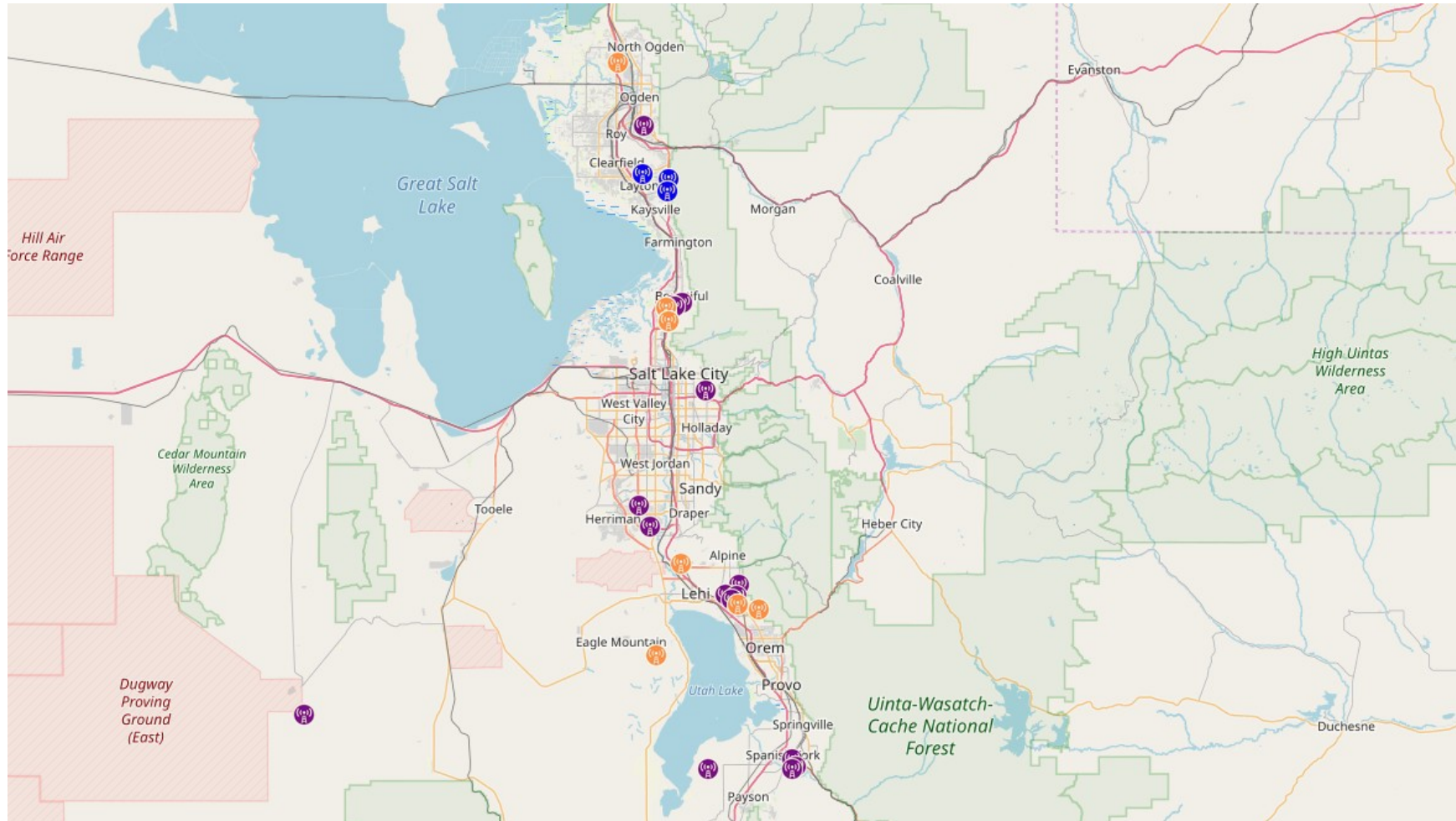
Network map – BAM (Bay Area Mesh) - San Francisco, CA
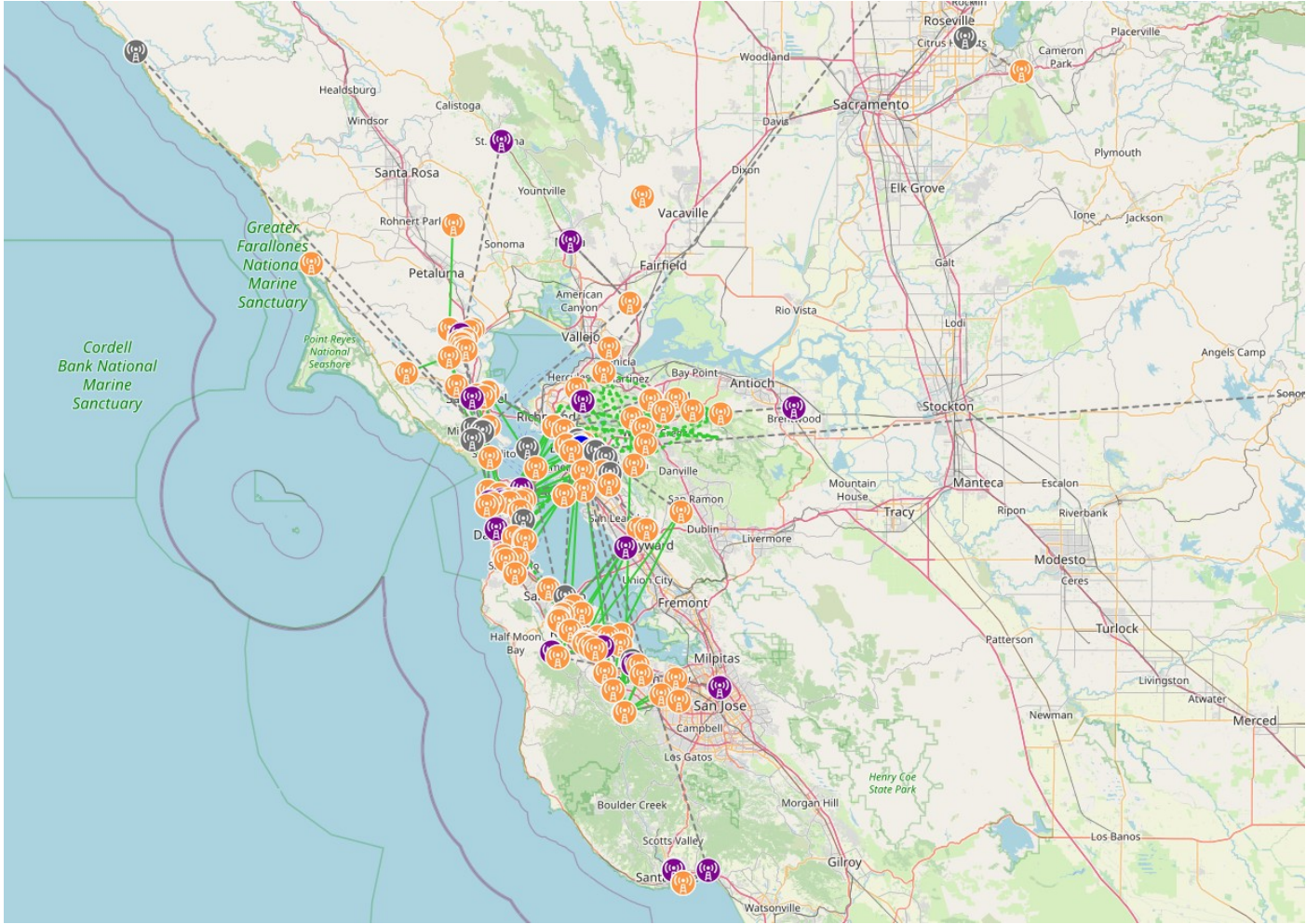
Network map – Hawaiian Islands
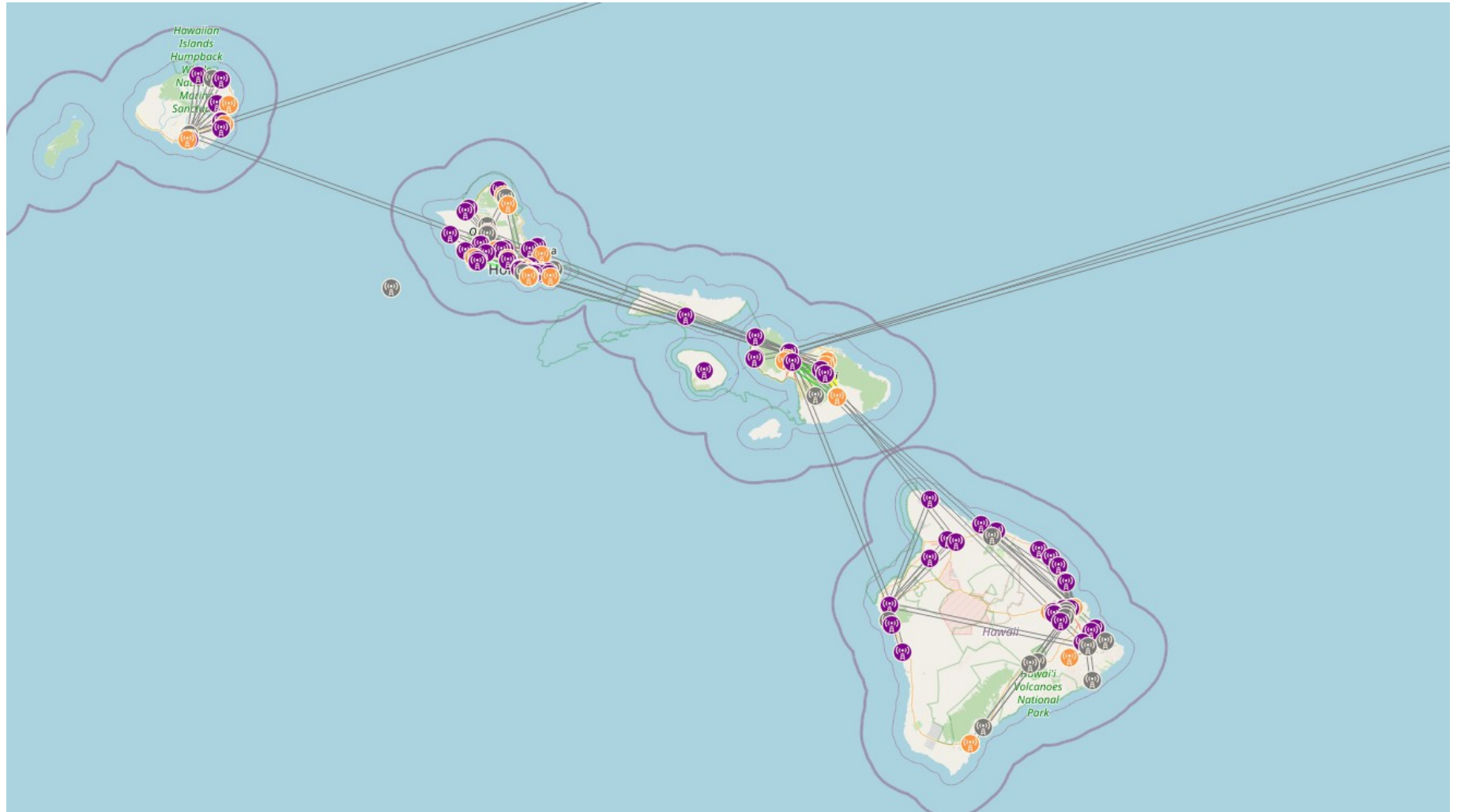
Network map – Phoenix area
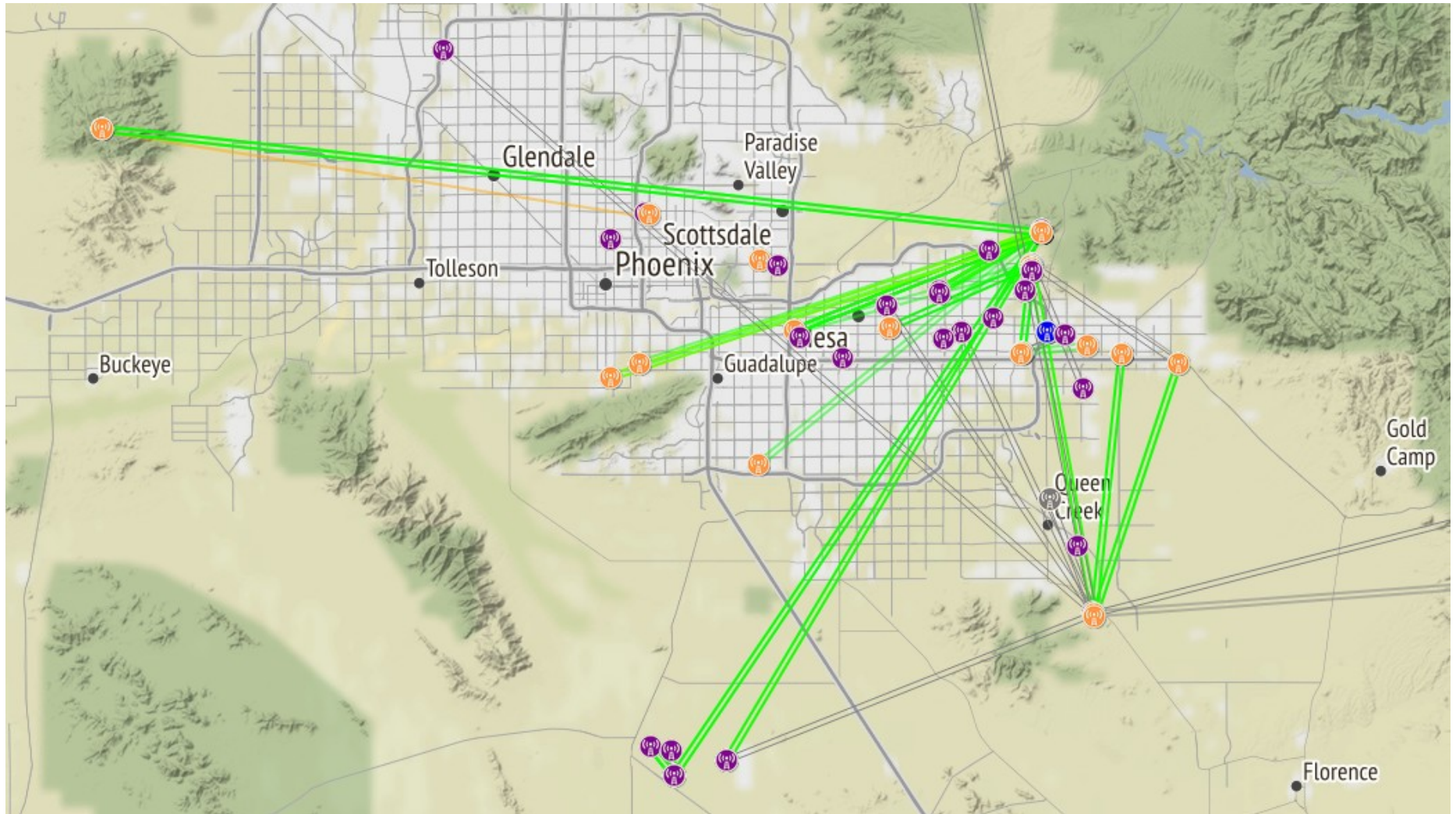
Network map – Southern California
About 425 nodes (hilltop & ground level) in area shown
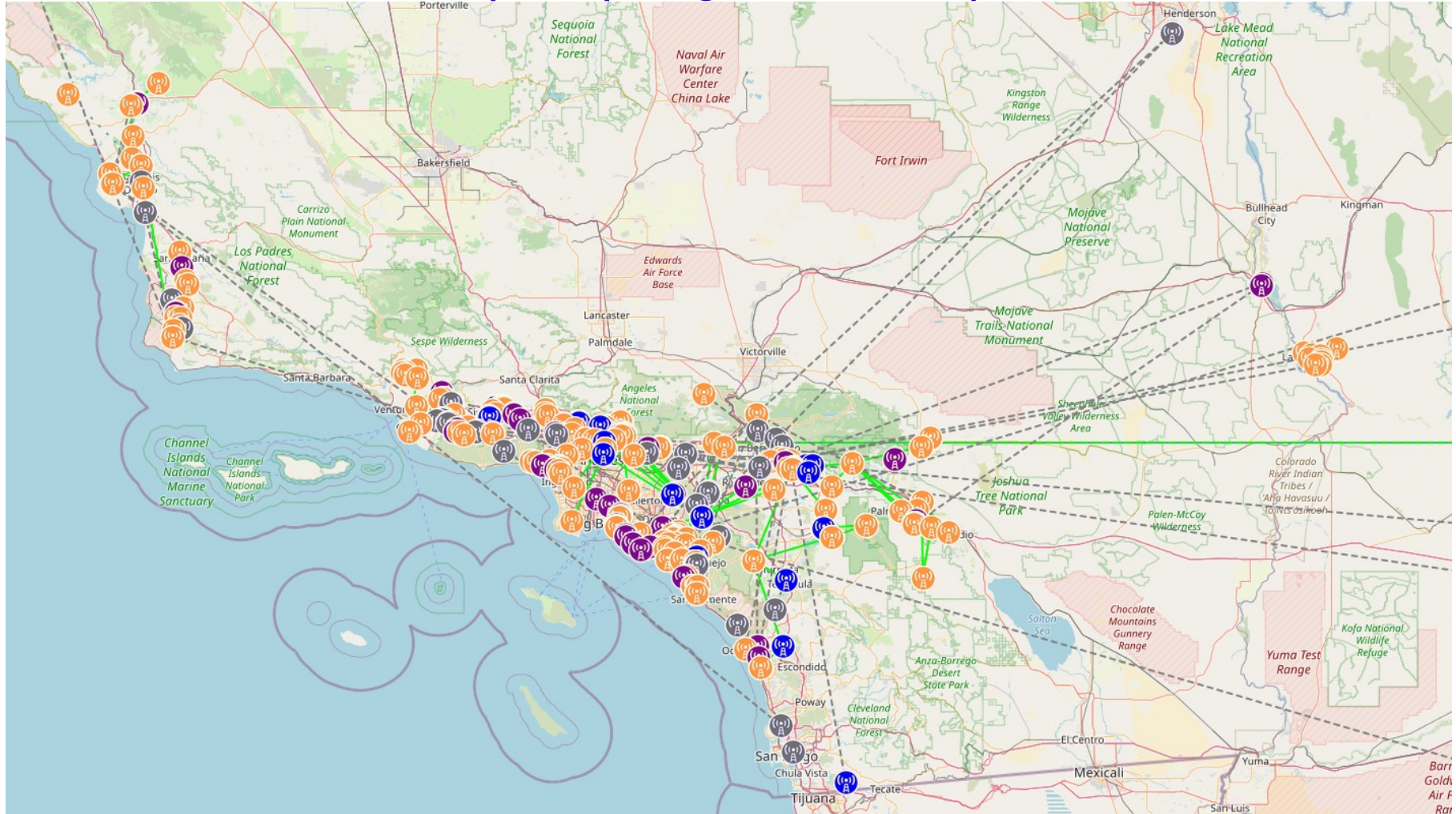
Equipment

What's out there??

About Modern Access Points/AREDN Nodes

- Available for use in four amateur bands

  - Not expensive

  - (Mostly) designed for outdoor use: weatherproof

  - 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)

  - MIMO + 802.11n – much better performance than older gear

  - POE (Power Over Ethernet): only one cable required to node

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 Support Platform Matrix that has flagged supported devices that are no longer recommended for new deployments*
- Now (1Q23) limited support for 802.11ac devices.   Check AREDN Nightly Build page for latest info.

Old School (ca 2012)
One wireless transceiver, only 60 mW Tx power
Not MIMO, not 802.11n, only 4 MB of Flash, 16 MB of RAM, not weatherproofed
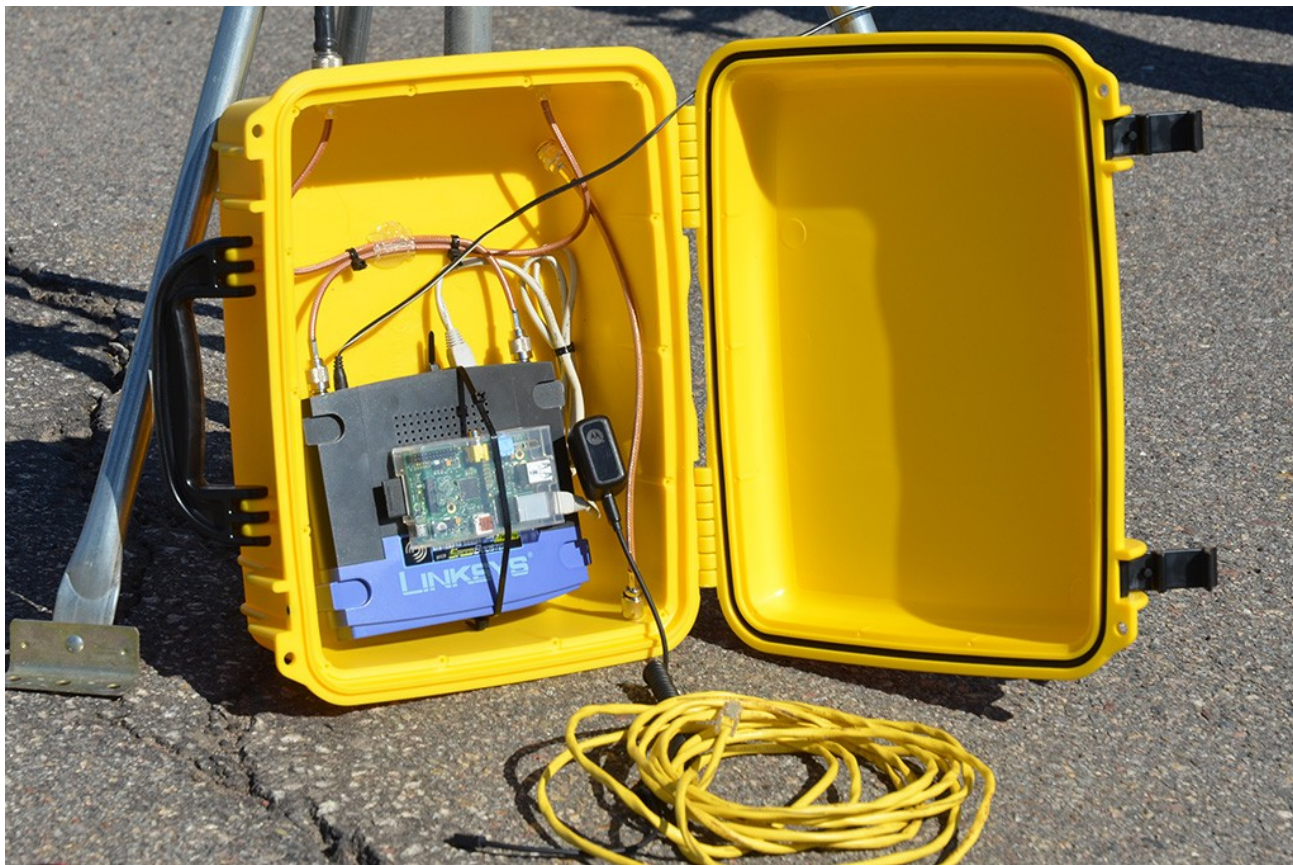
The next brand of access points supported by AREDN was Ubiquiti
The Ubiquiti Bullet
600 mW output

Ubiquiti Bullet – not MIMO, only 32 MB of RAM

The next generation for the home QTH was the Ubiquiti Nanostation M2* & M5*

*No longer recommended (by me) for new purchases

Mikrotik SXTsq 2, 5

Short Haul - ~10-12 miles. Faster CPU, narrower beamwidth than Nanostations

Make sure you buy this too!

Ubiquiti PowerBeam M5 300 (mm dia.), M5 400 & M5 620
Each has higher gain (but narrower beamwidth) than the previous version. Recommended.
(Starting to get scarce new; many now showing up on eBay after being replaced by WISPs – generally good buys)

Mikrotik LHG 5, LHG HP LHG 5 XL

Becoming very popular. Lighter weight than equivalent Ubiquiti – better for portable work

Mikrotik LDF (Light Dish Feed) 5

Inexpensive, 9 dBi gain.

(1Q23 – not yet supported in latest nightly builds)

- Mikrotik LDF 5 (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

TP-Link – less popular but work very well

- CPE 210, 220, WBS-210 - 2.4 GHZ
- CPE 510, WBS 510 - 5.8 GHz
    – Like Nanostations

- CPE 610 – dish for 5.8 GHz
    – No longer in production; available via eBay
    – Replacement (CPE710) now supported
      in nightly build (1Q23)

GL.iNet Products

AR750 (both Creta & Slate)

- 2.4 GHz & 5.8 GHz* MIMO
- Range: several hundred yards (no external antennas)
- Useful for Field Day logging or remote access on a network site.
- USB-powered
- Will run for a long time when plugged into a USB battery pack (for use as a relay site).

*WiFi only; mesh not supported

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 AC Lite slides)

- Clear line of sight, because…

Line of Sight

"Microwaves can go 15 miles or through one tree"

25
35

But two's company, tree's a crowd...

Mikrotik hAP AC Lite
The Swiss Army Knife of ham networking
A valuable addition to a ham shack network

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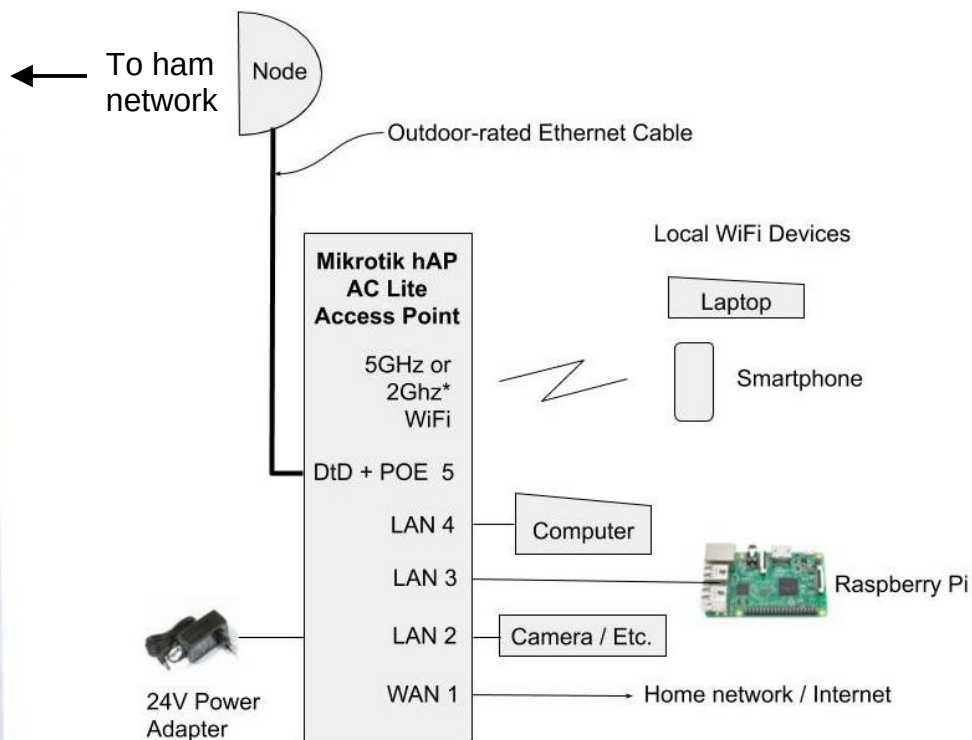
To ham network

- Port 1 – Wired connection to home network
- Ports 2-4 – other devices on your ham network
- Port 5 provides POE power plus 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.

hAP ac2 & ac3 now supported in nightly builds
Faster CPU w/4 cores, Gigabit Ethernet ports

Home Installation example
2 GHz & 5 GHz Nanostations, (for redundancy)
Station is three miles from hilltop site

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 up the mast 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
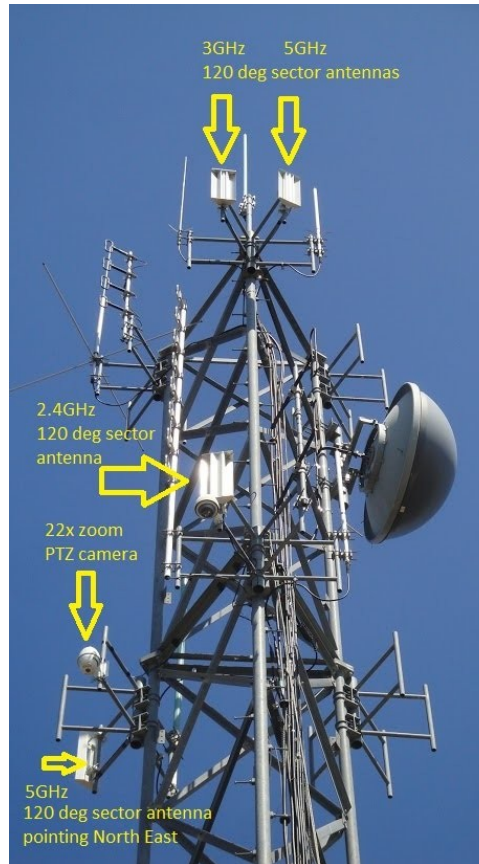
Ham Radio Allocations – 2.4 & 3 GHz

AREDN Offers 2 <u>Non-Shared</u> Channels on 2.4 GHz

2.4 GHz	Channel	-2	-1	0*	1	2	3	4	5	6
	Status	Ham Band			Shared Ham and ISM/WiFi Band					
	Freq	2.397	2.402	2.407	2.412	2.417	2.422	2.427	2.432	2.437

*Not available for use

Only one usable 10 MHz channel. Splatter from Part 15 limits usefulness

Channel	76	77	78	79	80	81	82	83	84	85	86	87
Status	Ham Band (continues indefinitely, pending future FCC action)											
Freq	3.380	3.385	3.390	3.395	3.400	3.405	3.410	3.415	3.420	3.425	3.430	3.435

	88	89	90	91	92	93	94	95	96	97	98	99
			Eliminated early 2022									
	3.440	3.445	3.450	3.455	3.460	3.465	3.470	3.475	3.480	3.485	3.490	3.495

Ham Radio Allocations – 5 GHz

52 Channels, <u>14 Non-Shared</u>, on 5.8 GHz

5.8 GHz	Channel	133	134	135	136	137	138	139	140	141	142	143	144	145
	Status	Ham Band shared with U-NII-2C/wifi/unlicensed												
	Freq	5.665	5.670	5.675	5.680	5.685	5.690	5.695	5.700	5.705	5.710	5.715	5.720	5.725

146	147	148	149	150	151	152	153	154	155	156	157	158
Ham Band shared with U-NII-3/wifi/unlicensed												
5.730	5.735	5.740	5.745	5.750	5.755	5.760	5.765	5.770	5.775	5.780	5.785	5.790

159	160	161	162	163	164	165	166	167	168	169	170	171
Ham Band shared with U-NII-3/wifi/unlicensed											Ham Band	
5.795	5.800	5.805	5.810	5.815	5.820	5.825	5.830	5.835	5.840	5.845	5.850	5.855

172	173	174	175	176	177	178	179	180	181	182	183	184
Ham Band												
5.860	5.865	5.870	5.875	5.880	5.885	5.890	5.895	5.900	5.905	5.910	5.915	5.920

Refer to your local band plan for coordination; ★5825 to 5850 Shared under Part 15.247 with a limited number of WISP operators and may be encountered at tower sites

11/2020 – FCC removed DOT's primary allocation (they hadn't started using it). We kept our secondary allocation but the FCC is now letting Part 15 users expand into channels 167-184. Over time, expect channel noise levels to rise in those channels. Plan on deploying higher gain devices than you currently need to future-proof installations (e.g., dishes instead of Nanostations).

Note – WISPS are limited to 1000mW EIRP in channels 133-145, whereas ham are not – consider these channels for hilltop backbone links.

The AREDN node interface (main screen)

K6PVR-VC-SimiEast-5G

Location: 34.260 -118.642

90 degree sector and Rocket M5 servicing east Simi Valley. Antenna bearing approximately 300 degrees

Help · Refresh · Mesh Status · Neighbor Status · WiFi Scan · Setup · Select a theme

Wifi address	10.198.175.154 / 8	**Signal/Noise/Ratio**	-64 / -95 / 31 dB Charts
LAN address	10.53.124.209 / 29	**firmware version**	1901-737bd10
WAN address	none	**model**	Ubiquiti Rocket M5 XW
default gateway	10.200.237.222 W6BI-VC-QTH-5G	**system time** **uptime**	Mon Nov 14 2022 11:07:53 PST 0:04
SSID	AREDN-10-v3	**load average**	0.36, 0.33, 0.15
Channel	170	**available space**	flash = 2448 KB memory = 35700 KB
Bandwidth	10 MHz	**Host Entries**	Total = 1536 Nodes = 557

The AREDN node interface – mesh status page

K6PVR-VC-SimiEast-5G mesh status

Location: 34.260 -118.642

90 degree sector and Rocket M5 servicing east Simi Valley. Antenna bearing approximately 300 degrees

Help Refresh Auto Quit

Node Name	Lan Hostname				Service Name
K6PVR-VC-SimiEast-5G					
	simieast-srv				Site-Info
	simieast-phone				Simi-east-ptz-cam
	simieast-cam1				Teamtalk
	k6pvr-tt-svr				

← This node

Current Neighbor	Lan Hostname	LQ	NLQ	TxMbps	Service Name
K6PVR-VC-SimiEast-2G (dtd)		100%	100%		
K6PVR-VC-SimiEast-3G (dtd)		100%	100%		
KJ6GEU-VC-QTH-5G		29%	98%		VoIP Phone 10*180*19*163
W6BI-VC-QTH-5G		82%	91%	65.0	
	Pt-15-WAP				
W6BI-VC-SVPD-5G		57%	99%	54.9	
WA6GNB-VC-QTH-5G		72%	100%		
WB2YXY-VC-5G		48%	98%	26.0	
	wb2yxy-mesh-server				NTP (GPS w/ 1PPS stratum 1)
					IPERF & IPERF3
					Node info
					Weather station
					IRC
					FTP
					Webcam snapshots
	wb2yxy-mesh-pbx				Asterisk PBX (10.38.100.194)

← Local neighbors and the services they are providing

Remote Nodes	LAN Hostname	ETX			Service Name
K6PVR-VC-West-SouthMtn-SE-5G (tun*2)		0.20			
N6FL-VC-Reeves-Rd-to-Black-Mtn-Link-5G		0.30			
N6FL-VC-Ojai-East-5G		0.30			
K6PVR-VC-West-SouthMtn-W-5G		0.30			
N6FL-VC-OjaiEast-W-Sector-2G		0.30			
K6PVR-VC-Camarillo-Hills-SW-5G (tun*4)		0.30			
K6PVR-VC-Sulphur-to-Oxnard-5G		0.30			
K6PVR-VC-RasnowPk-N-Sector-5G (tun*1)		0.40			
K6PVR-VC-ResourceServer (tun*1)		0.40			
	k6pvr-linux				k6pvr-linux-srv

← Remote nodes (more than one hop)

The mesh status page

K6PVR-VC-SimiEast-5G mesh status

Location: 34.260 -118.642
90 degree sector and Rocket M5 servicing east Simi Valley. Antenna bearing approximately 300 degrees

Help Refresh Auto Quit

Node Name	Lan Hostname				Service Name
K6PVR-VC-SimiEast-5G					
	simieast-srv				Site-Info
	simieast-phone				Simi-east-ptz-cam
	simieast-cam1				Teamtalk
	k6pvr-tt-svr				

Current Neighbor	Lan Hostname	LQ	NLQ	TxMbps	Service Name
K6PVR-VC-SimiEast-2G (dtd)		100%	100%		
K6PVR-VC-SimiEast-3G (dtd)		100%	100%		
KJ6GEU-VC-QTH-5G		29%	98%		VoIP Phone 10*180*10*180
W6BI-VC-QTH-5G		82%	91%	65.0	
	Pt-15-WAP				
W6BI-VC-SVPD-5G		57%	99%	54.9	
WA6GNB-VC-QTH-5G		72%	100%		
WB2YXY-VC-5G		48%	98%	26.0	
	wb2yxy-mesh-server				NTP (GPS w/ 1PPS stratum 1)
					IPERF & IPERF3
					Node info
					Weather station
					IRC
					FTP
					Webcam snapshots
	wb2yxy-mesh-pbx				Asterisk PBX (10.38.100.194)

Remote Nodes	LAN Hostname	ETX			Service Name
K6PVR-VC-West-SouthMtn-SE-5G (tun*2)		0.20			
N6FL-VC-Reeves-Rd-to-Black-Mtn-Link-5G		0.30			
N6FL-VC-Ojai-East-5G		0.30			
K6PVR-VC-West-SouthMtn-W-5G		0.30			
N6FL-VC-OjaiEast-W-Sector-2G		0.30			
K6PVR-VC-Camarillo-Hills-SW-5G (tun*4)		0.30			
K6PVR-VC-Sulphur-to-Oxnard-5G		0.30			
K6PVR-VC-RasnowPk-N-Sector-5G (tun*1)		0.40			
K6PVR-VC-ResourceServer (tun*1)		0.40			
	k6pvr-linux				k6pvr-linux-srv

Local linked neighbors (not direct RF; DtD via Ethernet cable, or other)

LQ – Link Quality
NLQ – Neighbor Link Quality

TxMbps - Modulation rate times actual packet success rate

Local RF neighbors

Services provided by this node

ETX=1/(NLQ*LQ) per hop. End to end ETX is sum of the ETXes of all the hops.

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 4,100 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.

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 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!**