The Amateur Radio Emergency Data Network: AREDN
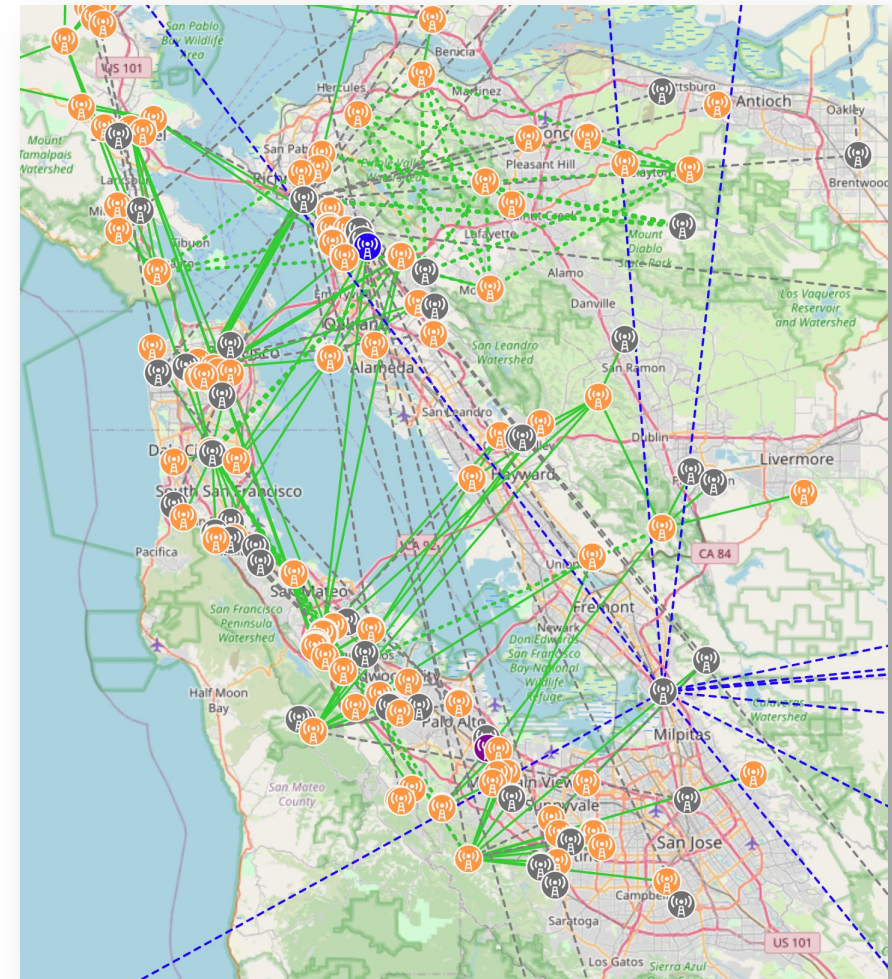
Bob Iannucci, W6EI
January 13, 2024
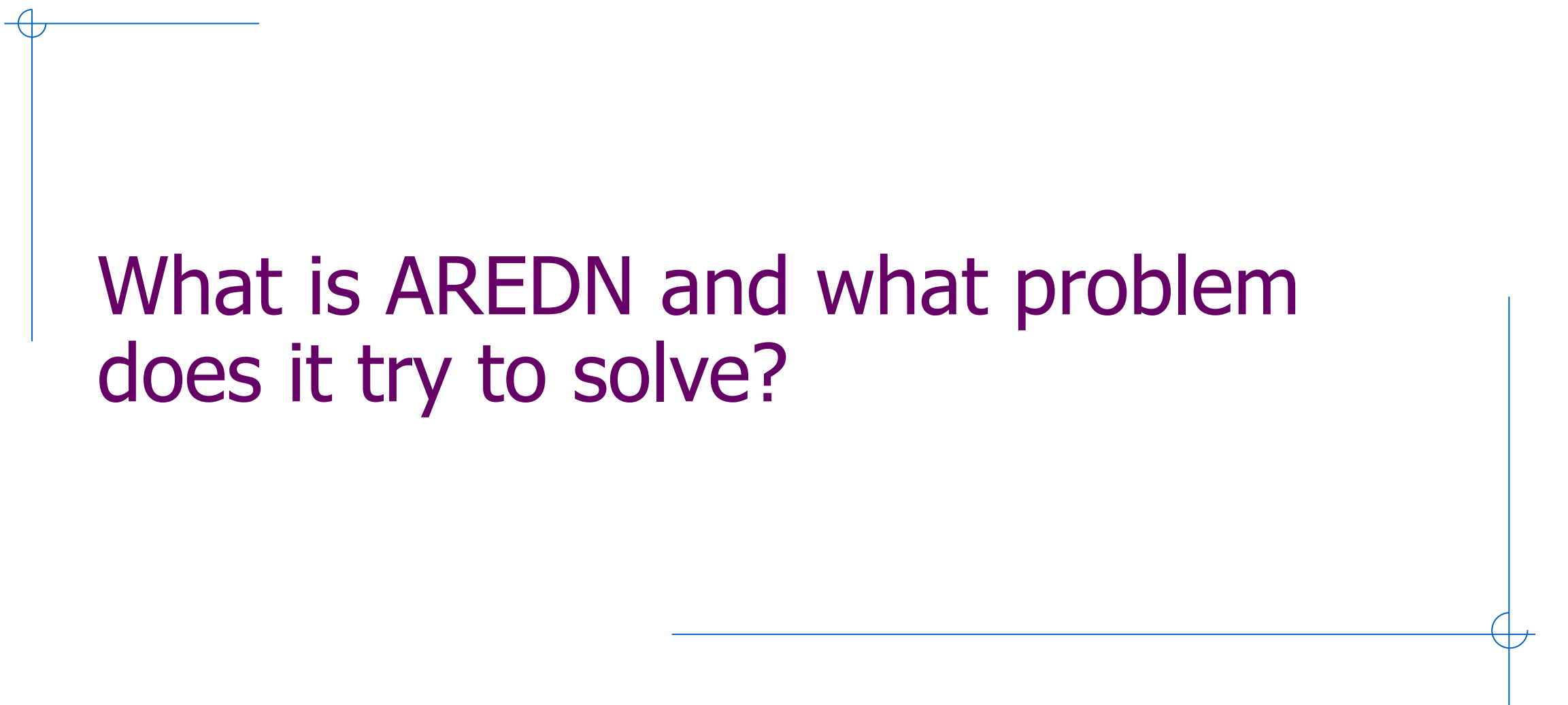

Bay Area portion of the AREDN network

What we'll cover today

❖What is AREDN and what problem does it try to solve?

❖History of the project and current status

❖Some FCC Part 97 considerations

❖AREDN core technology

❖AREDN network structure

❖Getting on the AREDN network

Notes

❖ This presentation is only an intro to AREDN

❖ AREDN is widely deployed and extensively developed

❖ If you are interested in going deeper, the AREDN mesh website and doc pages are your next step

- ▪ http://arednmesh.org

❖ It's pretty easy to get started, and I encourage you to do so!

What is AREDN and what problem does it try to solve?

An evolution of expectations

❖ The internet shifted society from analog voice to data comm

- Social media, group chat, email, image sharing, video conferencing, webcams, websites, databases, wikis, GPS-based tracking and mapping

❖ In an emergency, society will expect data comm continuity

- Or at least replacement services that are comparable

❖ This compels hams to re-think how we provide comm when all else fails

❖ See "A Survivable Social Network"

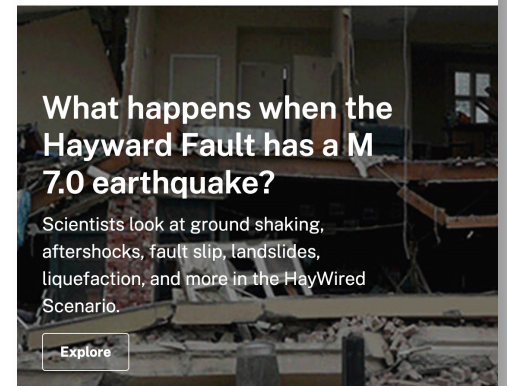https://ieeexplore.ieee.org/document/6699009

Consider a major earthquake here

❖ Most cell sites are not prepared to survive > 12 hours

❖ Lifeline services (electricity, gas, internet, …) will be disrupted

❖ The scope of damage will overwhelm ham analog voice

- Thousands of people in need in every city
- City-level EOC/DOC hams and packet radio can process ~1 message a minute
- Aggregation and tracking at county level will be worse

❖ Expectations of message volume, accuracy, multi-media content won't be met

❖ See "HayWired Scenario"

HayWired Scenario ACTIVE

By **Science Application for Risk Reduction**
January 18, 2018

What happens when the Hayward Fault has a M 7.0 earthquake?
Scientists look at ground shaking, aftershocks, fault slip, landslides, liquefaction, and more in the HayWired Scenario.

Explore

https://www.usgs.gov/programs/science-application-for-risk-reduction/science/haywired-scenario

Resilient 100% data-based ham-comm

❖Enable hams to communicate via data, accurately and swiftly

   ▪ e.g., to serve community and public service agencies

❖Capture point-of-emergency details (text, photos)

❖Share situational awareness information

❖Ham-organized WiFi hotspots to collect and upload

❖But upload how? and to where?

AREDN's contribution: high speed mesh
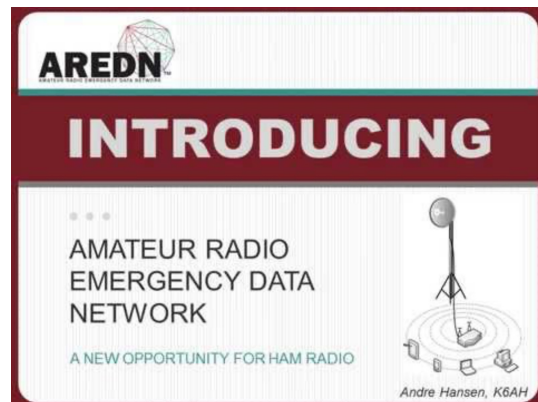
❖ Built by and for hams

❖ Built on widely available hardware

❖ 100% TCP/IP – existing SW packages that rely on IP-based comm can be used without change

  ▪ workgroup text chat, social media work-alikes, image/video repositories, websites, wikis, and even IP-based voice comm

❖ Dynamic route discovery so nodes can come and go

❖ Can be ad hoc (e.g., for a special event) or permanent (e.g., for supporting agencies and community disaster preparedness)

History of the AREDN project and current status

AREDN

❖A team of hams undertook the task of extendeding the Broadband Hamnet (BBHN). This became AREDN and was announced in 2015

https://www.youtube.com/watch?v=fkl5Nbnz24Y

Current AREDN map
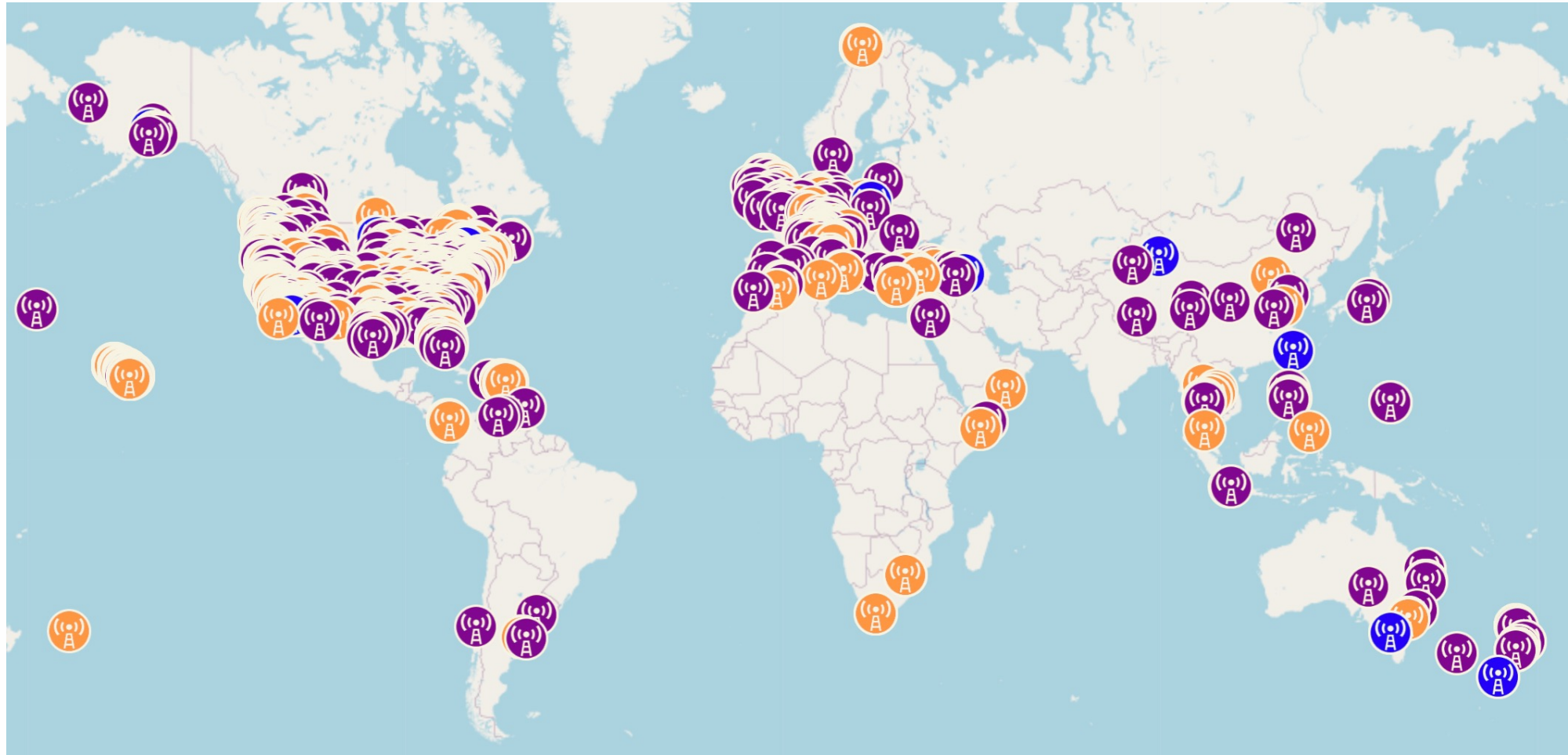
Some FCC Part 97 considerations

Operating Parameters

❖ We operate under Part 97 and, as such, can do things that Part 15 WiFi devices can't

- Running at higher power

- Running in channels that are not authorized for Part 15 but are for Part 97

❖ BUT we also can't do things that some Part 15 devices can

Band plan

Refer to your local band plan for coordination

900 MHz	Channel	4	5	6	7
	Freq	907	912	917	922
	Status	Shared with unlicensed			

2.4 GHz	Channel	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
	Freq	2.397	2.402	2.407	2.412	2.417	2.422	2.427	2.432	2.437	2.442	2.447	2.452	2.457	2.462
	Status	Unshared		Cannot Use	Shared with wifi/unlicensed										

3.4 GHz	Channel	76	77	78	79	80	81	82	83	84	85	86	87	88	89
	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	3.440	3.445
	Status	Amateur Radio secondary allocation													

90	91	92	93	94	95	96	97	98	99
3.450	3.455	3.460	3.465	3.470	3.475	3.480	3.485	3.490	3.495
~~ Estimated elimination early 2022 ~~									

Relevant FCC rulings include FCC-20-138A1 and FCC-21-321A1 (as of 20210320)

5.8 GHz	Channel	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148
	Freq	5.655	5.660	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	5.730	5.735	5.740
	Status	Shared with Unlicensed National Information Infrastructure [U-NII-2C]															Shared with U-NII-3		

149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166
5.745	5.750	5.755	5.760	5.765	5.770	5.775	5.780	5.785	5.790	5.795	5.800	5.805	5.810	5.815	5.820	5.825	5.830
Shared with Unlicensed National Information Infrastructure [U-NII-3]																	

167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184
5.835	5.840	5.845	5.850	5.855	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
Shared with U-NII-3				Shared with Unlicensed National Information Infrastructure [U-NII-4]									Shared with vehicle ITS				

Relevant FCC rulings include FCC-20-164A1 (as of 20210320)

Encryption

❖**I am not a lawyer**

❖97.113(a)(4) bars
  - "… messages in codes or ciphers intended to obscure the meaning thereof, except as otherwise provided herein..."

❖https:// ssh: use encryption
  - On the mesh, http:// and telnet: are the safe alternatives
  - Many open source packages we use on the mesh allow for http://

❖Opinion "Data Encryption is Legal"
  - https://www.n5dux.com/ham/files/pdf/Data%20Encryption%20is%20Legal.pdf

❖FCC RM-11699
  - https://hamwan.org/Administrative/HamWAN%20Response%20to%20FCC%20RM-11699/RM-11699%2009-17-2013%20Wireless%20Telecommunications%20Bureau%207520944376.pdf

Encryption, continued

❖ But on-mesh is not the whole story

❖ Consider this scenario:

- A large earthquake has struck the Peninsula. Cellular and internet are out. There is a need by a public service agency to access resources on the public internet, but the internet outage prevents them. They turn to a local AREDN-enabled ham for help. This ham is aware of a node on the mesh that has gotten permission to use Starlink for its WAN port to support recovery efforts.

- OK or not OK?

❖ Hams have experimented with **proxies** so that the on-AREDN traffic is not encrypted

AREDN core technology

An AREDN node, simplified

❖ COTS hardware

❖ Reflashed with AREDN firmware

❖ Air interface: AREDN mesh

❖ Wired interface:

  ▪ LAN: local servers and clients, each with a mesh address

  ▪ WAN: optional uplink to the public internet

  ▪ Node-to-node: if you have more than one node at your site, they interconnect via the wired interface

  ▪ Tunnel via WAN: connection to another AREDN node over the public internet

mesh radio interface

COTS hardware
(many alternatives)
running AREDN
firmware

1   8

LAN

WAN

node-to-node
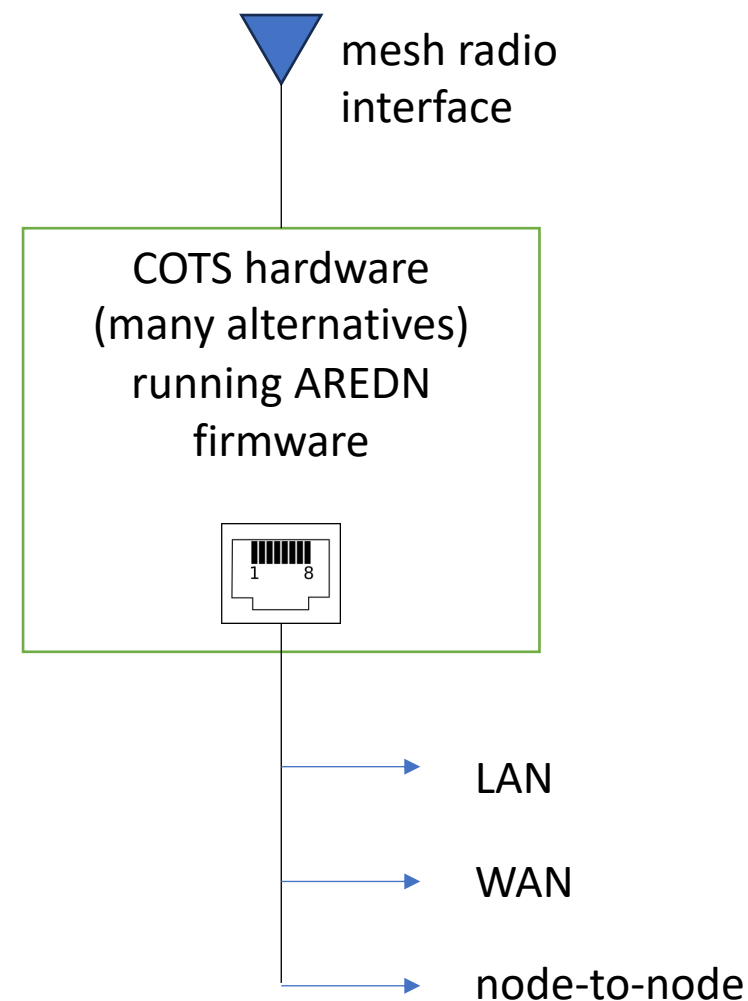
Many variants of COTS hardware

Ubiquiti Rocket (external antennas needed ~$90)

Ubiquiti NanoStation (internal antenna) ~$80

MikroTik 5 GHz node with integrated dish antenna ~$110

https://www.arednmesh.org/content/supported-platform-matrix

Manufacturer/Model	900Mhz	2.4Ghz	3Ghz (5)	5.8Ghz
Current As of AREDN™ 3.22.12.0 (updated on 12/19/2022)		Band		
Mikrotik (www.mikrotik.com)				
LHG (Lite Head Grid)		RBLHG-2nD		RBLHG-5nD
LHG HP/XL		RBLHG-2nD-XL		RBLHG-5HPnD-XL
LHG HP				RBLHG-5HPnD
Basebox		RB912UAG-2HPnD		RB912UAG-5HPnD
hAP AC Lite (and TC)		RB952Ui-5ac2nD		RB952Ui-5ac2nD (AP only, no mesh)
LDF (Lite Dish Feed)		RBLDF-2nD		RBLDF-5nD
QRT				RB911G-5HPnD-QRT
SXT		SXTsq-2nD		SXTsq-5nD / SXTsq-5HPnD
mANTBox		RB911G-2HPnD		RB911G-5HPnD
Ubiquiti Networks (www.ubnt.com)				
AirGrid (XM revision/old)		M2		M5
AirGrid (XW)				AG-HP-5Gxx
AirRouter		M2		
AirRouter HP		M2		
Bullet		M2		M5
Bullet Titanium		M2		M5
Bullet (XW)		M2		
LiteBeam				M5
NanoBeam (XW)		NBE-M2-13		NBE-M5-16/19
NanoBridge	M9	2G18	M3	5G22/5G25
NanoStation Loco (XM)	M9	M2		M5
NanoStation Loco (XW)		M2		M5
NanoStation (XM) Airmax		M2	M3	M5
NanoStation (XW) Airmax		M2		M5
PicoStation		M2		
PowerBeam (3)		PBE-M2-400		PBE-M5-300 400 400ISO
PowerBeam				PBE-M5-620
PowerBridge				M5
Rocket (XM)	M900	M2	M3 (5)	M5
Rocket (XW)		M2		M5
Rocket Titanium (TI)		M2		M5
Rocket Titanium (XW) (4)				M5
TP-Link (www.tp-link.com)				
CPE (v1.0)		CPE210		CPE510/CPE520
CPE (v1.1)		CPE210		CPE510
CPE (v2.0)		CPE210		CPE510
CPE210 (v3.0)		CPE210		
CPE220 (v2.0 and v3.0)		CPE220		
CPE610				CPE610
WBS210 (v1.0)		WBS210		
WBS510 (v2)				WBS510
GL.iNET (www.gl-inet.com)				
AR150		AR150		
AR300M16		AR300M16		
AR750 (Creta)		AR750		AR750 (AP only, no mesh)
USB150		USB150		
Meraki				
MR16		MR16**		

Guts 'n' Oily Goo

❖The AREDN air interface uses Optimized Link-State Routing protocol (OLSR)

❖Flooding the network indiscriminately to figure out routing would be bandwidth-wasteful

❖A more limited form of flooding is done instead

Guts 'n' Oily Goo

❖Each node periodically transmits a "Hello" message with its ID

❖Nodes listen for Hello messages and build a table of 1-hop neighbors

❖These tables are then transmitted

❖Nodes listen for these 1-hop tables and use them to build 2-hop neighbor tables

❖The 2-hop tables can be simplified in most cases because of redundancies

❖A second layer of hierarchy discovers the overall topology

❖In the end, each node knows the next hop for every destination

AREDN network structure

Network structure

5.8 GHz

5.8 GHz

Fixed AREDN Backbone
- On High-ground
- Collocated sectors
- Delivers AREDN to distributed Mid-Mile nodes, or directly to deployed hams

5.8 GHz

2.4 GHz temporarily

Fixed or Deployed Mid-Mile Node
- Placed on strategic hilltops
- Could be deployed mobile
- Delivers AREDN to deployed hams

2.4 GHz

Ham-Deployed Last-Mile Node
- Delivers User access to AREDN

WIFI Access Point (generic)

User devices

WIFI Access Point (generic)

User devices

Palo Alto Fire Station 8 AREDN site

Great LoS for the City of Palo Alto and others as well as East Bay

Capabilities of both a backbone node (~150 Mbps) and a mid-mile node

Mains, battery and solar power

Services

❖ AREDN provides basic network services (including name resolution, routing, and data transport)

❖ This by itself does not help in emergencies until it is paired with network-based services

- Mattermost – Slack workalike

- Apache (and other) web servers

- DocuWiki

- FreePBX (VoIP server)

Server-in-a-box

❖Many services can be provisioned using a small, low-power fanless computer like an Intel NUC

❖Easy to pair with a COTS UPS to provide continuity of services

❖Proxmox is a virtualizer that enables many services to run in their own virtual machine

Mattermost – chat server

FreePBX – VoIP server

Proxmox virtualizer

Getting on the AREDN network

Participating in AREDN

❖ Built by and for hams

- Operates under Part 97

- Not for use by non-hams

❖ An emergency data network

- Not a replacement for your commercial home ISP

- BUT… within your local ham community, should be used regularly

❖ Build your own local network and/or join a larger AREDN mesh

Joining the Bay Area Mesh

❖Find a node to which you have line-of-sight (LoS)

❖Rule of thumb: "15 miles or one tree"

❖Check the propagation along the path

❖Pick hardware that suits your path and situation

❖Reflash and go through setup steps

❖Mount and aim antenna

Find a nearby node or two

❖ Start with the AREDN mesh map
  ▪ http://usercontent.arednmesh.org/K/5/K5DLQ/livemap2.html#12/37.3755/-122.1377

❖ High-ground stations (e.g., Palo Alto Fire Station 8; Black Mtn) may be your best choice
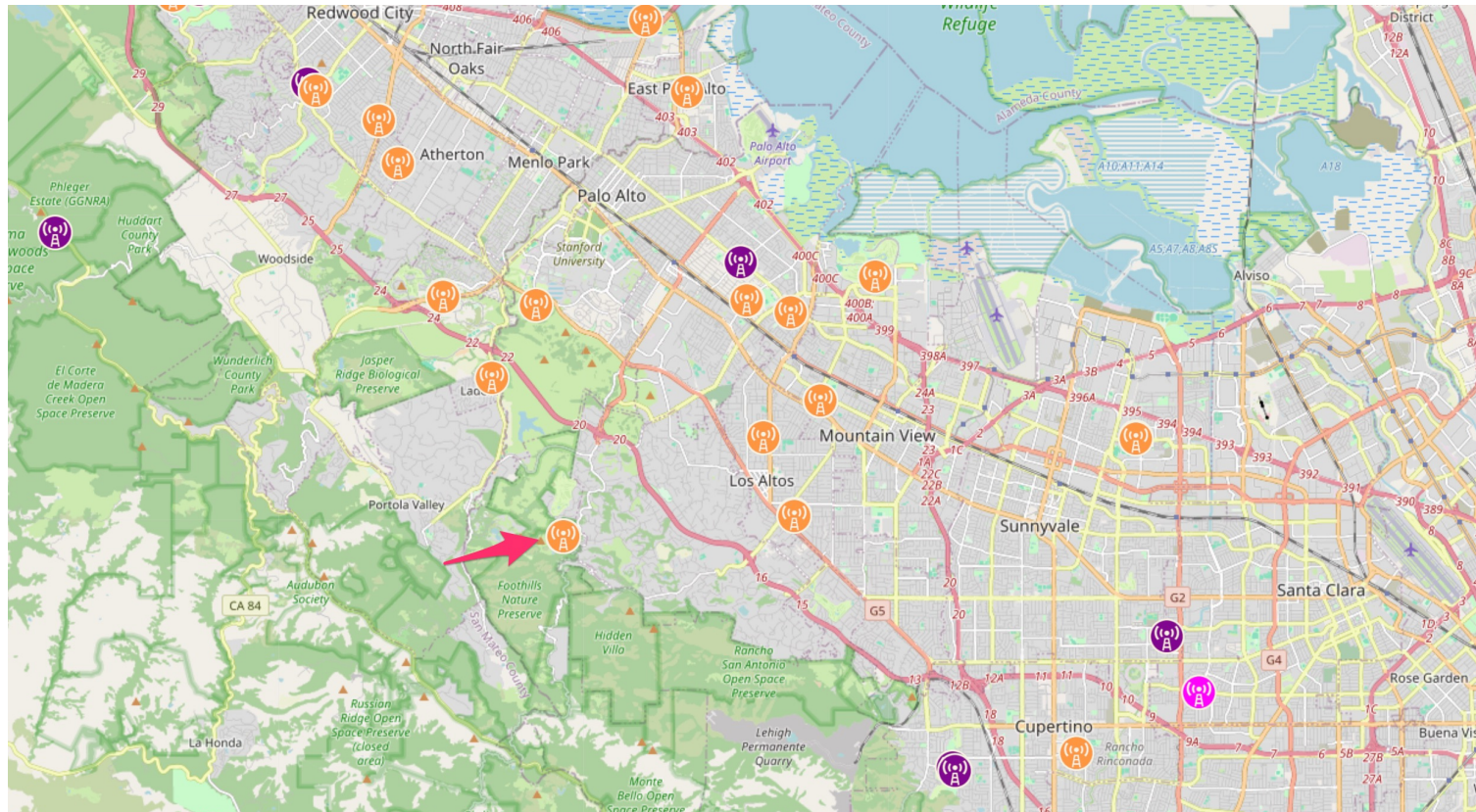
Check propagation

❖Ubiquiti online tool: https://ispdesign.ui.com/#

❖Tinker with antenna gain, height and other parameters

❖Accounts for Fresnel zone effects but not vegetation

Distant LoS nodes may be better than nearby non-LoS nodes
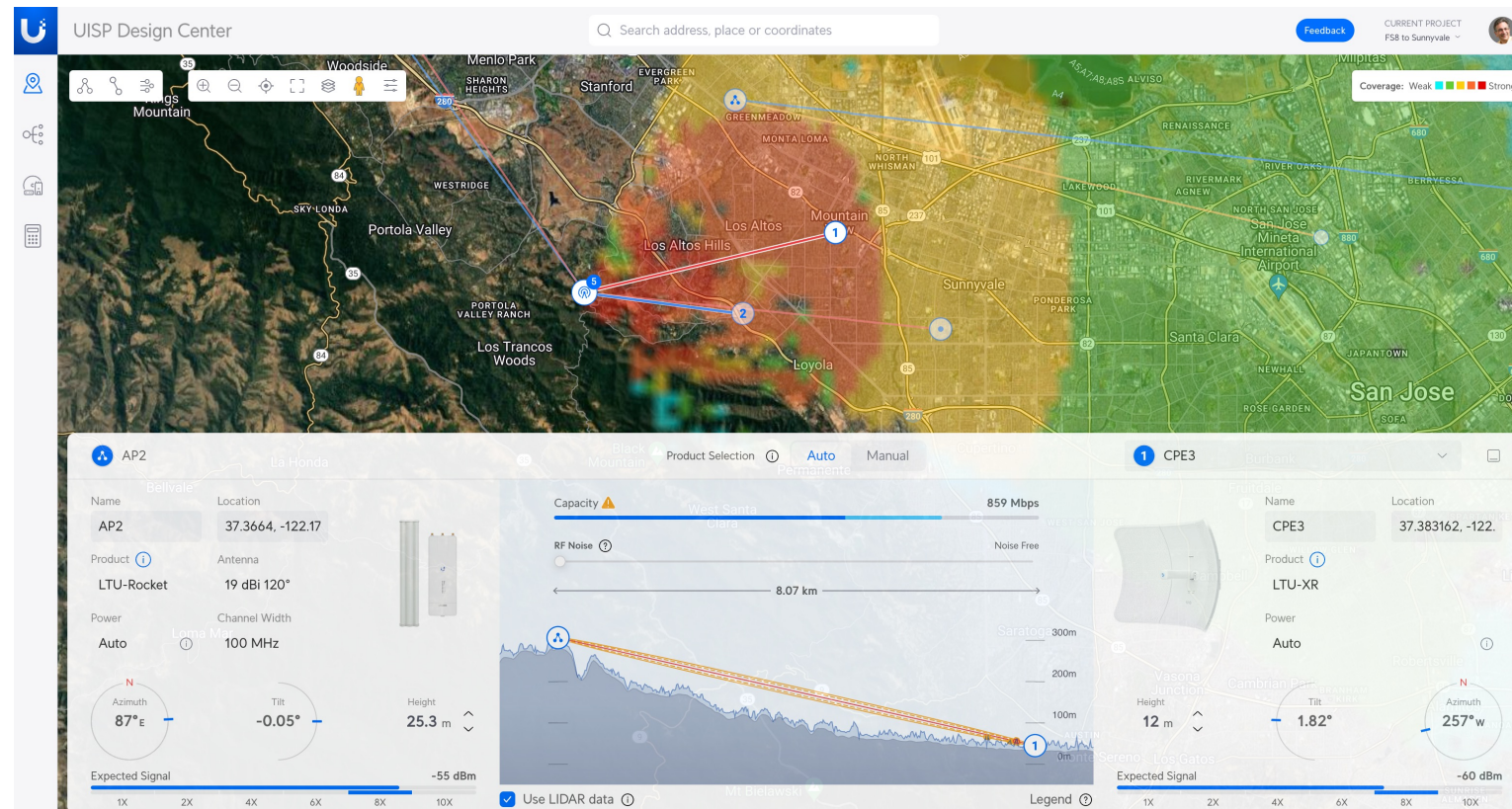
Pick your hardware

❖LoS is almost always the most important consideration

❖If you are in range of multiple nodes, AREDN will automatically pick the best path… but this usually means an omnidirectional antenna

❖The Ubiquiti path planner will let you explore the need for directionality / greater gain

Reflash and set parameters

❖ Read and follow the installation instructions for your chosen hardware

❖ Once flashed and booted, use the GUI to set up your node

❖ The channel of your node must match the channel of the node(s) to which you want to connect!

https://arednmesh.readthedocs.io/en/latest/arednGettingStarted/installing_firmware.html

Mount and aim your antenna

❖There's good [documentation](#) on this. Read it carefully.

❖The firmware has a built-in function that lets you tweak the aim by providing audible feedback on signal strength.

❖If you are using a dish-type antenna in particular, pay attention to wind loading and providing suitable mechanical support.

❖Congratulations! You are now on the mesh.

https://arednmesh.readthedocs.io/en/latest/arednHow-toGuides/dish-aiming.html
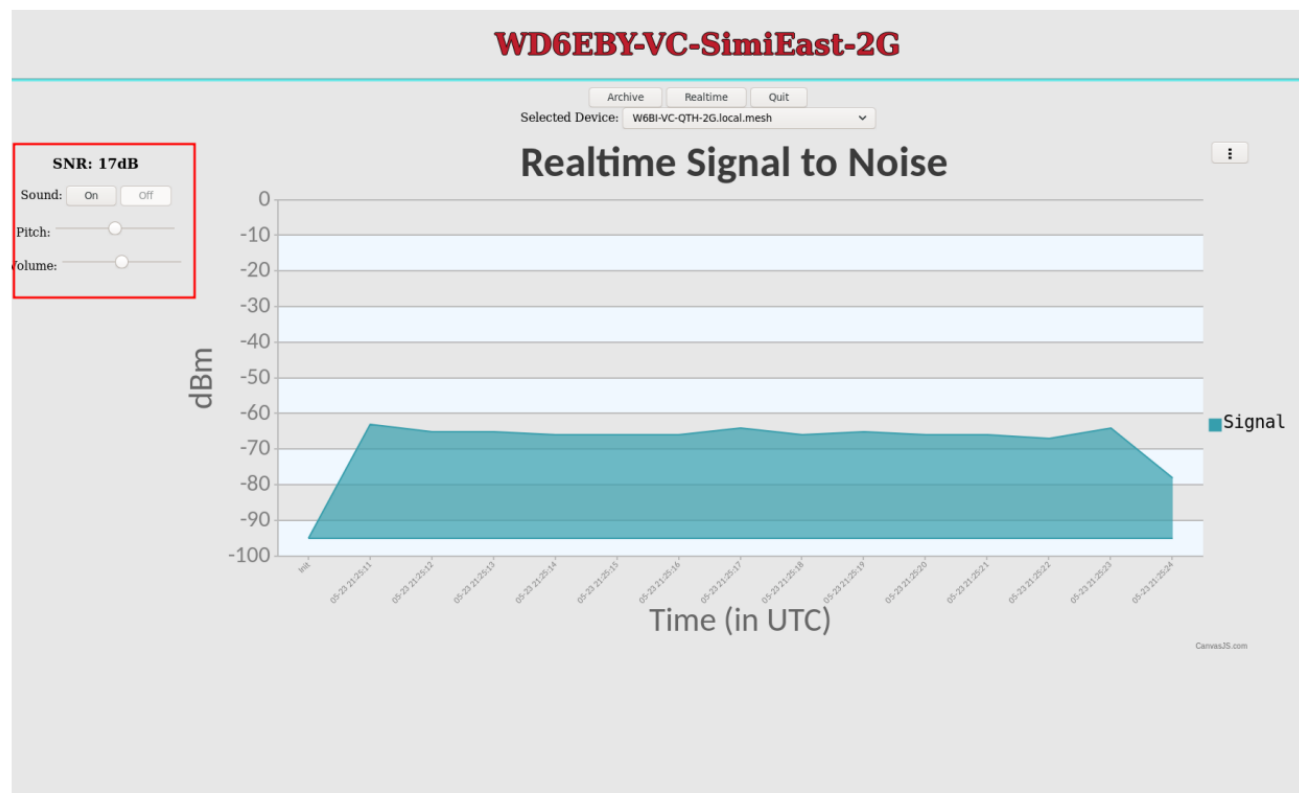
Summary

❖ AREDN is a data-oriented mesh network for EmComm

❖ Continuous development since 2015

❖ Subject to Part 97 R&R

❖ Built on COTS hardware with replacement firmware

❖ Thre-tier network structure

❖ Easy and inexpensive to get started