AMATEUR RADIO EMERGENCY DATA NETWORK
AT THE CENTER OF EMERGENCY COMMUNICATIONS PREPAREDNESS

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Abstract

This paper builds on an AREDN paper submitted by the author and published in the proceedings of the ARRL and TAPR 34th Digital Communications Conference 2015[(1)]. Where that paper introduced the technology and the work of the AREDN Project software development team, this paper picks up where that leaves off and describes techniques for deploying AREDN in support of AUXCOM.

Breaking the network down into layers: strategic fixed locations, tactical deployments, and disaster-specific end-points; the author lays out straightforward implementation techniques which ensure multi-megabit connectivity between deployed teams and their central command and control.

Over the past 2 years, the AREDN Project has changed the complexion of High-Speed Multimedia (HSMM) from an experimental, hobby-oriented, novelty into a viable network technology suitable for restoring data network connectivity "when all else fails."

Keywords: AREDN, AUXCOM, EMCOMM, mesh, BBHN

Introduction

Digital transmission is quickly obsoleting traditional manual means of message passing. The paper-based ICS-213 transcription has given way to Winlink's electronic ICS-213 form. These forms are no longer conveyed verbally over VHF/UHF radio, but through digital techniques such as AX.25 packet, HF Pactor, Fldigi, and where available, the Internet.

These digital technologies are generally sufficient for text-based messages, but become overwhelmed with increasing traffic and message size/complexity.

Implementing a high-speed network infrastructure on which these messages can travel eliminates this congestion. It also provides the opportunity for additional digital services such as voice-over-IP (VoIP) telephony, chat rooms, image/video-based damage assessments/reports, etc. It is these that represent the compelling case for AREDN.

AREDN software repurposes commercially available radio/routers to operate under the grant of our ham radio licenses in the microwave bands. Multiple devices (nodes), separated by as much as 50 miles or more, work in concert (mesh) to form a high-speed network with data rates up to 144 Mbps, providing a TCP/IP medium for applications one would typically use on an intranet or the Internet. While technically capable, it is not intended to be a general Internet access alternative.

AREDN is written for Linux-based Wireless Internet Service Provider (WISP) devices by the AREDN Development Team (http://aredn.org) which publishes its work under the Free Software Foundation's General Public License, GPLv3 license.

The primary objective of the project is to empower the typical ham to become a deployed part of the network by acquiring a relatively inexpensive commercial router device, installing the AREDN firmware, entering the station's call-sign and an administrative password, and then pointing the node's antenna toward an existing network node in the infrastructure.

How this technology works was described in the author's previous paper[(1)].

To implement an AREDN network, nodes need to "see" each other. This is accomplished by elevating them on hills, towers, buildings, water tanks, etc. This is made much easier in barren terrain (void of tall vegetation) and in hilly/mountainous terrain. Taking the mountainous terrain example, let's look at how one would design an AREDN network.

Deploying an AREDN network in a Mountainous Terrain

The obvious challenges of this sort of terrain surround the obstacles the terrain presents for the longer-distance links. So the equally obvious solution is to utilize the vertical dimension for those longer links.

These “high-ground” locations are equally suited for extending network coverage to lower-lying “users”. That leaves remaining only those users who do not have direct line-of-sight to the high-ground locations which will need some sort of relay in order to connect to a high-ground node.

So we have just defined three node-types:

1. High-ground, which I’ll refer to as “Backbone” nodes or sites
2. Users, which I’ll call “Deployed” nodes
3. Relays, which I prefer to call “Mid-Mile” nodes

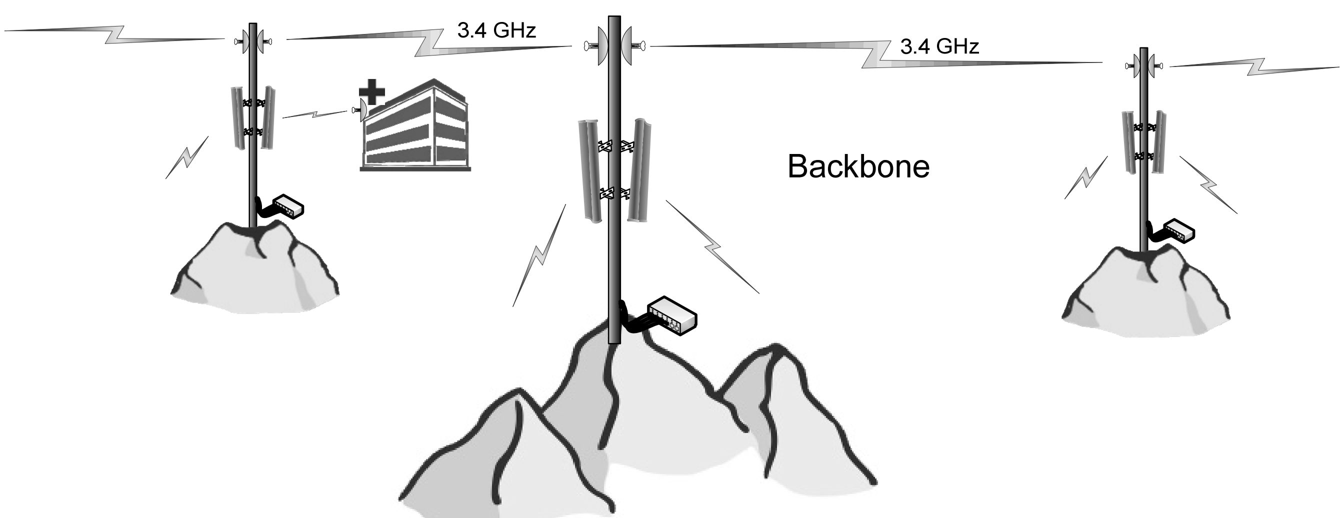
While they all use the same technology and AREDN software, they clearly serve different roles in the network. As it turns out, the Backbone is best put in place as a permanent infrastructure, the Deployed nodes are extemporaneous by definition, varying widely based on the nature of the emergency they support, and the Mid-Mile nodes will usually be a mix of both fixed and impromptu.

Let’s look at these in detail.

Fixed Backbone Node

Backbone nodes are permanent installations that extend the mesh to the extreme ends of the planned coverage area. For reliability they operate on the least congested band, 3.4 GHz, and are optimized for data throughput with high-gain dishes spanning distances of 50 miles or more Sector antennas with 90° or 120° coverage patterns are utilized to maximize their downstream accessibility to lower Nodes.

Participating ham-supported, public and private agencies access the Backbone via fixed nodes with gain antennas. These agencies make routine use of the network during simulated emergency drills.



Backbone nodes are often collocated with ham repeater sites. These are robust installations requiring a fair bit of planning and frequency coordination with other ham interests and commercial tenants. RF shielding can be required to mitigate interference. Weather will often dictate the use of protective radomes. If you are lucky, you will find a ham with a mountain cabin and a clear view to the coverage area and a willingness to host your site. Commercial towers will likely require professional climber/installers.

Antenna alignment is critical. The higher the gain the antenna is, the more precise the alignment. 2-3 degrees can make the difference between good and marginal links, so careful planning, installation and testing are a necessity. Sector antennas are more forgiving, but without spotter nodes already setup at the coverage extremes, it can still be difficult to align both azimuth and elevation. Sector antennas generally have a built-in electrical down-tilt of -1° to -2° in elevation.

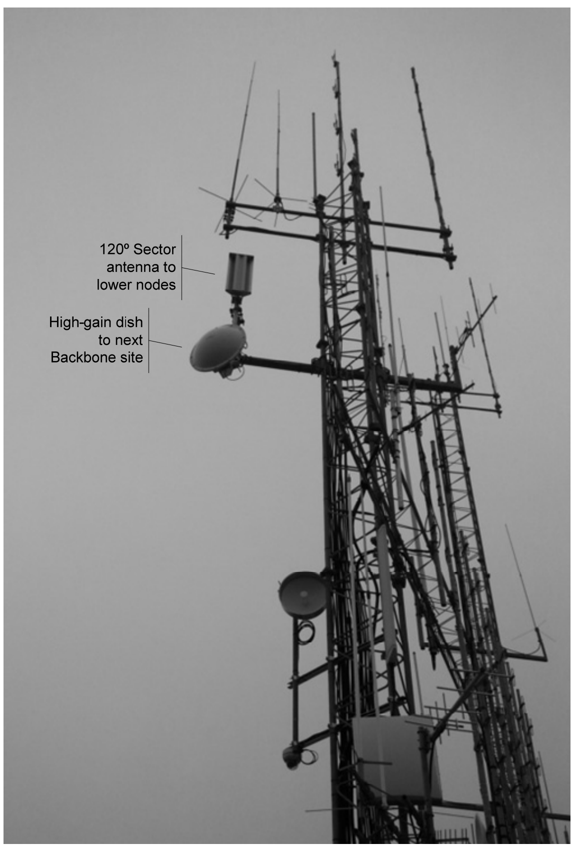


Figure 1

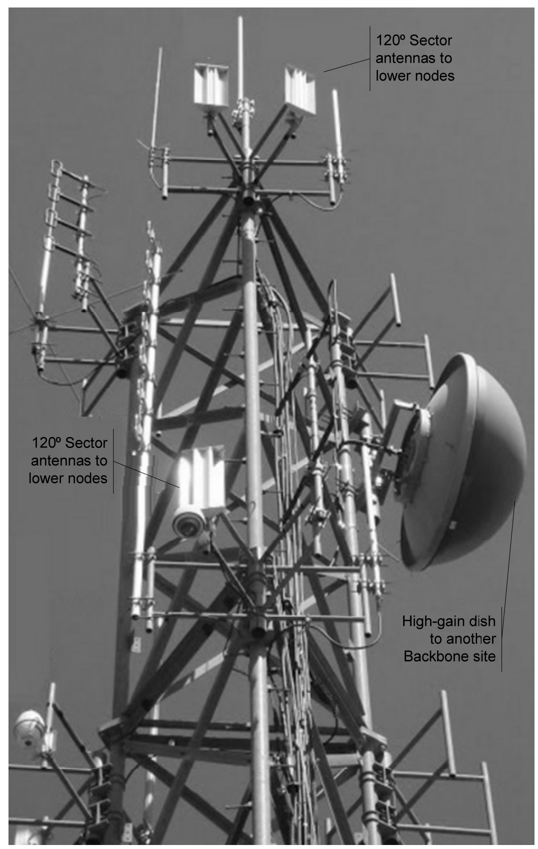


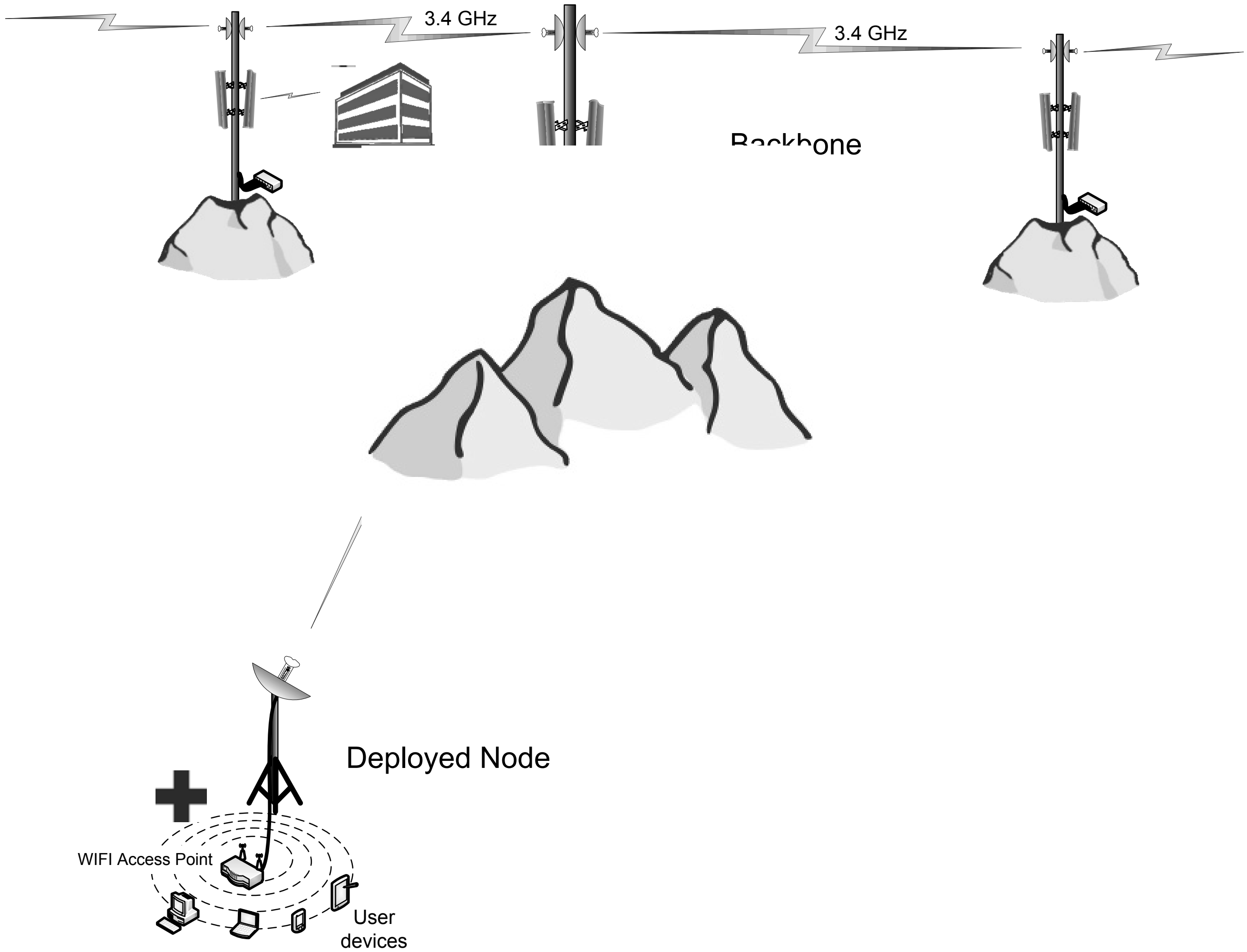
Figure 2

Figure 3

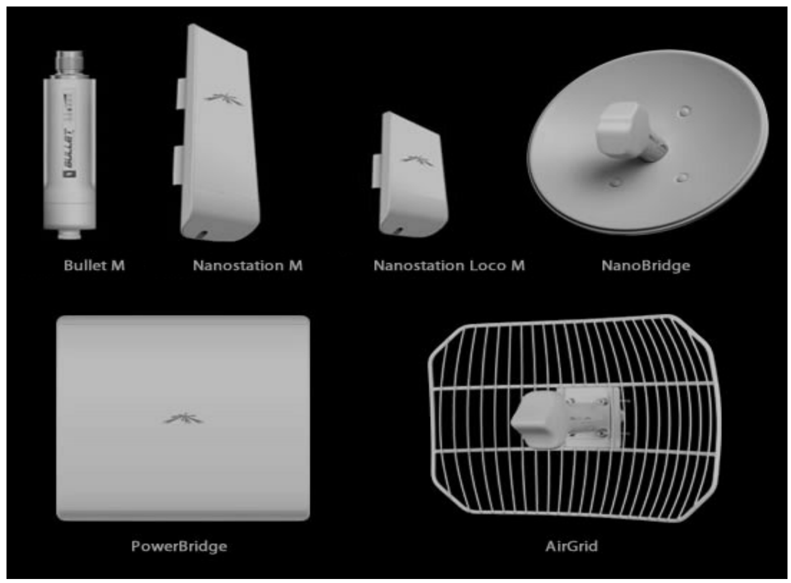
The preceding photos illustrate three typical backbone sites: Figure 1, on a ham club tower, Figure 2, on a commercial tower, and Figure 3, one on a mountain cabin. The arrow identifies the adjacent backbone node… which happens to be the node illustrated in Figure 1, some 48 miles in the distance.

Ham-Deployed Node

As the name indicates, this node is carried by the Ham deployed to a served-agency location requiring the pre-established data services. The "Go-Kit" is comprised of a 2.4 GHz node with a high-gain antenna pointed up to a Backbone node. The kit also contains a WIFI router to provide network access for the local devices on site. Batteries or a generator powers these devices.


3.4 GHz
3.4 GHz
Backbone
Deployed Node
WIFI Access Point
User devices


LINCOLN
KE6BXT


Bullet M
Nanostation M
Nanostation Loco M
NanoBridge
PowerBridge
AirGrid


County Emergency Services
Communications

Mid-Mile Node

This node is either fixed or vehicle deployed as necessary and per the specific network's design. It forms a "reachable" collection point for surrounding Deployed nodes and has the required higher-gain antenna to reach a higher ground-based Backbone Node. Sector antenna(s) allow broad downstream accessibility.

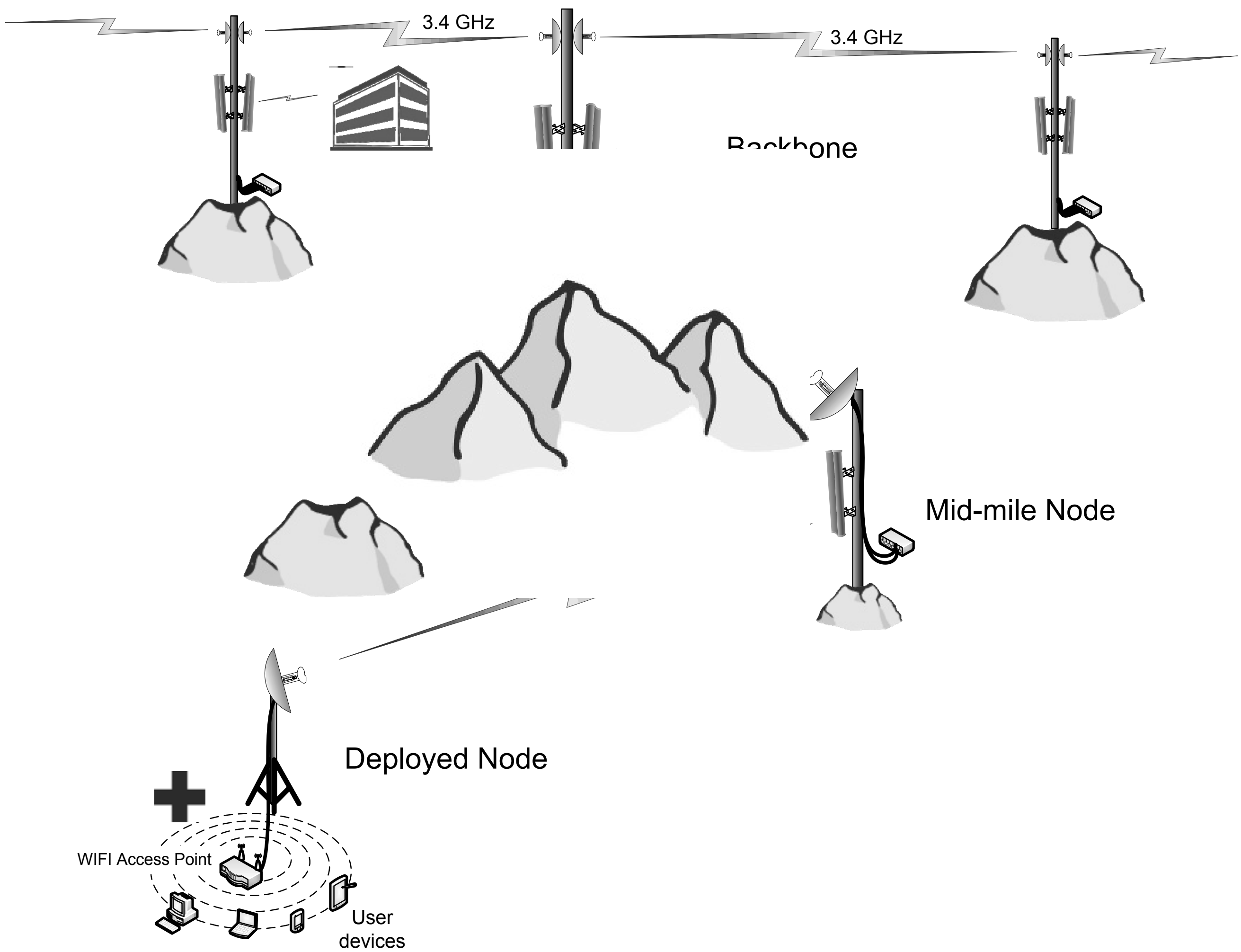


Figure 4 Arrow indicates location of backbone node

Figure 5 Arrow indicates location of agency deployment

Figure 6 A roof mounted Mid Mile node

Figure 7 & 4 Examples of a Mid Mile node on a hitch-mounted multi-section flagpole

Implementation Tips

In planning to deploy the core nodes it is advisable to use propagation prediction software such as Radio Mobile to avoid the hassle and expense of experimentation. The author dives into this tool in his previous DCCC Paper[(1)] described earlier in this paper. The Radio Mobile English language portal can be found at: http://www.cplus.org/rmw/english1.html

Sufficient proficiency in this tool will enable you to explore the variables of band, node-model receiver sensitivity, node-model power output, and antenna gain/options in either point-to-point (PtP) or point-to-multi-point (PtMP) topologies.

There are a few basic principles to keep in mind when laying out any AREDN network:

- Collocated nodes interfere with each other. This must be mitigated by one or more of the following techniques:
    - Choose different bands for inbound and outbound data.
    - If you must use the same band, then select frequencies which don't overlap. For example, if you are using 10 MHz bandwidth, then select adjacent frequencies at least 10 MHz apart.
    - Use shielding such as RF Armor (http://www.rfarmor.com).
    - Place the nodes as far apart as physically possible
- Coordinate with other ham users as well as collocated commercial interests.
    - Commercial interests are heavy users of the 5GHz band, however, in the US and many other countries, hams have a segment of the band to themselves. Explore the use of that segment with other hams.
    - There are no commercial users of the 3 GHz band in the US. You do need to be concerned about military radar, but that is not going to be an issue for most users.
    - Remember that coordination doesn't always mean finding another frequency. In at least one instance, AREDN interference with a ham moon-bounce (EME) contest was mitigated by a commitment to shut down offending nodes of the AREN network during the hours of the annual contest.
    - While full coordination with ham spectrum committees may not be necessary, making node frequency and location information available probably is. That way if they do experience interference, they have a means of researching the remote possibility it is one of your nodes.
- Microwave is line-of-sight communications, so not only do you need to see the other end of the link.
    - A Fresnel zone is an ellipse between the transmitter and receiver. The size of that ellipse is determined by the frequency and link distance. Any obstruction in the zone tends to cause the signal to take multiple paths to its destination and result in destructive interference. This is discussed at length in the author's previous work[(1)].
    - The 900 MHz band is somewhat tolerant to light vegetation. Higher frequency bands are not.

    - Longer paths need vertical height to account for the curvature of the earth.
- The environment will define whether the following are required:
    - Radomes to protect antennas from snow and ice.
    - Static surge suppressors to protect the node and other collocated equipment.
    - Ruggedized CAT5/6 Ethernet cable
    - A professional/certified tower climber

Node setup and configuration

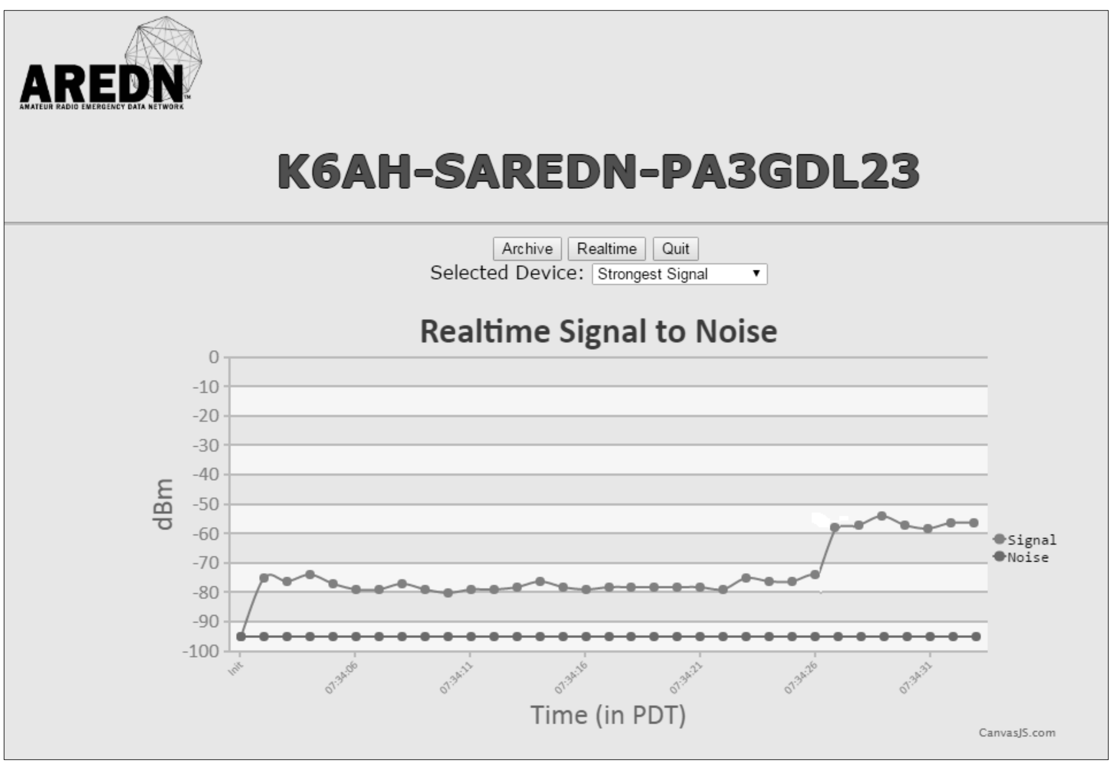
The downloading of AREDN software is well documented at the AREDN website: http://www.aredn.org/content/software

As is the installation: http://www.aredn.org/content/uploading-firmware-ubiquiti

Once the AREDN software is installed, use the node's Help page to complete the configuration: http://localnode.local.mesh:8080/help.html

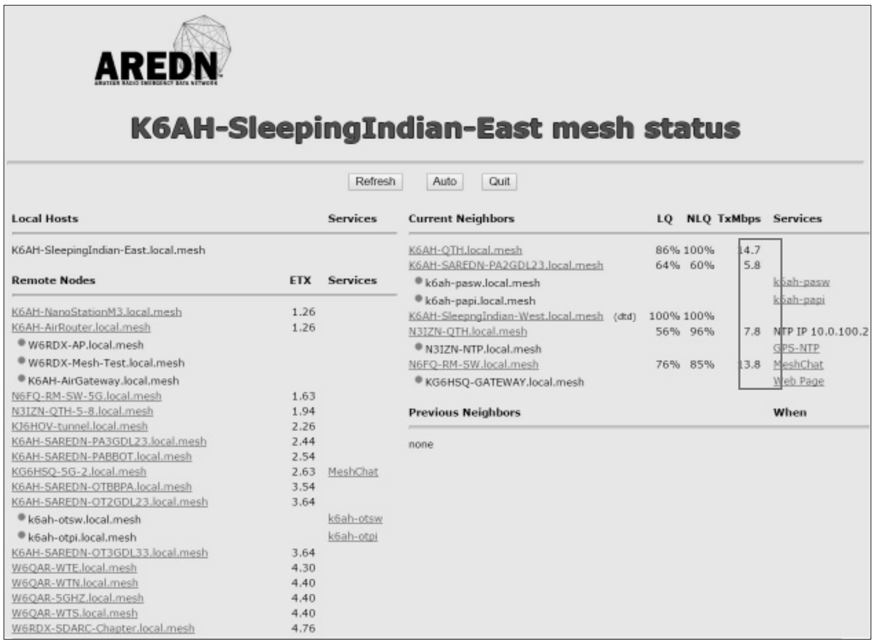
Aligning, Testing, and Managing Links

The higher the gain of your chosen antenna, the more critical its alignment is with the far end of the link. AREDN software includes tools to maximize the link. The Realtime Signal to Noise chart computes and displays the SNR each second. Moving the antenna back/forth followed by up/down will quickly identify the maximum.

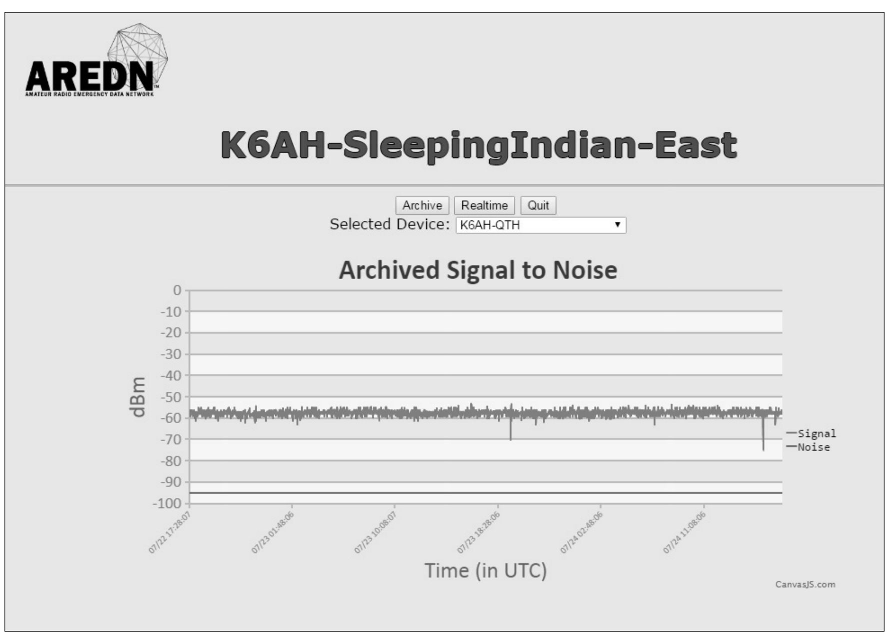


Note that this technique should also be used to confirm the signal maximum from the far-end's perspective, by monitoring the remote Realtime Signal to Noise during this peaking. I have heard commercial installers of wireless ISP equipment argue this is a better metric to monitor than the near-end.

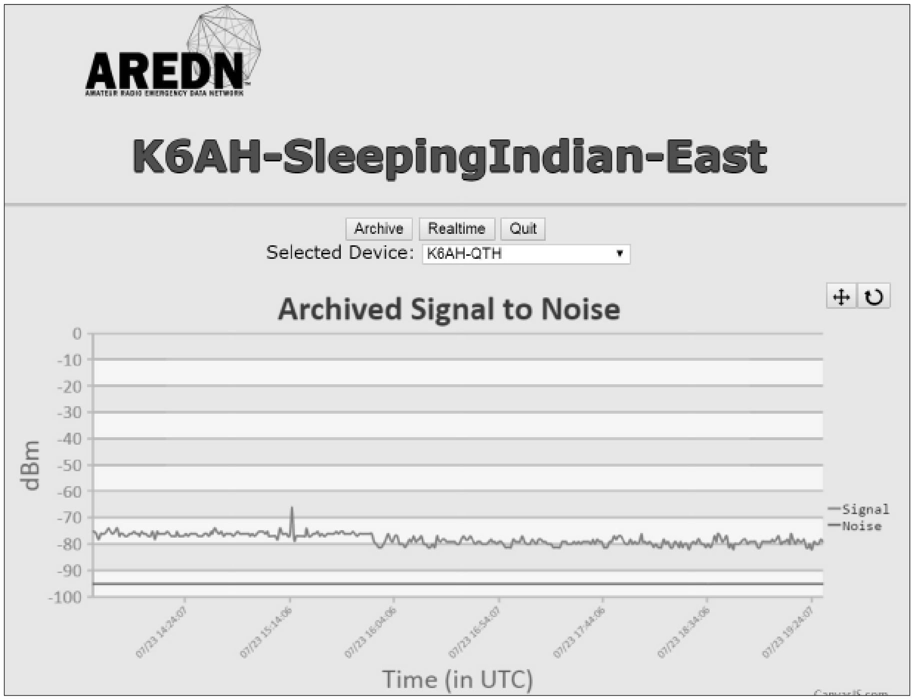
An SNR of 15 dB or greater is generally good enough to pass data at a rate of 10-20 Mbps. The AREDN node will attempt a variety of 802.11 modulation techniques to maximize the data throughput. The resultant throughput is calculated and displayed on the Mesh Status page in the TxMbps column.



The SNR is also displayable as a 24-hour archive. This is useful in understanding more transient interference issues.



This data can be expanded to detail a particular timeslot of interest. Hovering over a data point will display the raw data collected by the node at that time.



General Comments

MIMO (multi-in/multi-out) is a form of spatial multiplexing where the nodes high-data rate signal is split into two lower-rate signals and transmitted from different antenna on the same channel. These signals are kept separated by leveraging the null which exists between vertical and horizontal polarization domains. In short, when MIMO is employed on both ends of a link, it effectively doubles the data throughput of that link.

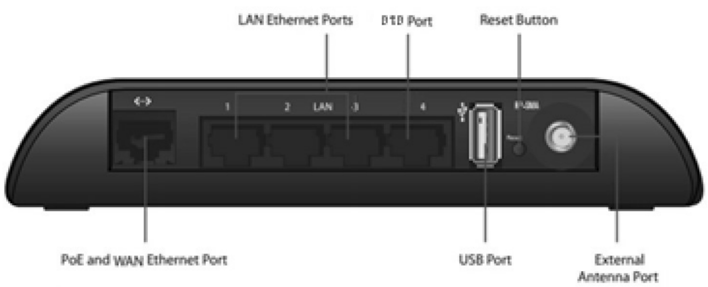
Having two antennas in opposing polarization domains also results in a higher tolerance for polarization distortions. In short, MIMO is generally always better than non-MIMO. AREDN-supported devices are a mix of both MIMO and non-MIMO types.

For a variety of understandable reasons, Ubiquiti does not acknowledge AREDN users as customers and will not support questions or issues which surface with their equipment while operating under AREDN software.

These devices require from 10.5 to 24 volts DC as measured at the device, supplied via an Ethernet cable utilizing Power over Ethernet (PoE).

Nodes may be connected back-to-back via Ethernet (called DtD, or Device-to-Device), or several may be connected in this fashion using a simple Ethernet switch. The routing protocol is routed to all DtD nodes forming a collocated cluster. Refer to the earlier section on Collocated Node Interference for more on this.

Desktop Nodes (AirRouter, AirRouter-HP)



These nodes are real handy. They are the equivalent of a Bullet (see below) and an Ethernet switch. AREDN has preassigned the ports for the following usage:

Port Label	Usage
WAN	Internet (default route), also PoE port
1, 2, and 3	Local Area Network (LAN)
4	Other local AREDN devices (device-to-device)

General Purpose Nodes

These are a mix of MIMO (NanoBean, Nanostation, NanoLoco) and non-MIMO devices (AirGrid, Bullet, PicoStation). Hams have a natural attraction to the AirGrid which matches a ham's impression of what a microwave dish should look like, and the Bullet, which can be attached to an antenna of your choosing via an N-Type connector. However, better results will be had by selecting the NanoStation which routinely makes 15-mile spans. There is simply too much to gain by using MIMO, which larger non-MIMO devices have a tough time overcoming.

Figure 8 Bullet **Figure 9 AirGrid** **Figure 10 NanoStation**

Broader Distribution Nodes

These are both Rocket-based devices. The Ubiquiti Rocket is a general purpose MIMO radio which can be mated with a variety of antenna choices. Here are two examples. Note that sector antennas come with 90° and 120° wide patterns.

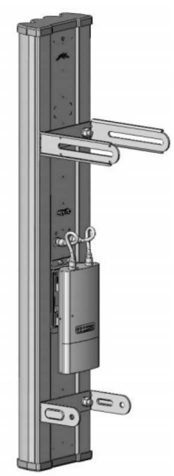


Figure 8 Rocket with Omni-directional antenna **Figure 9 Rocket with Sector antenna**

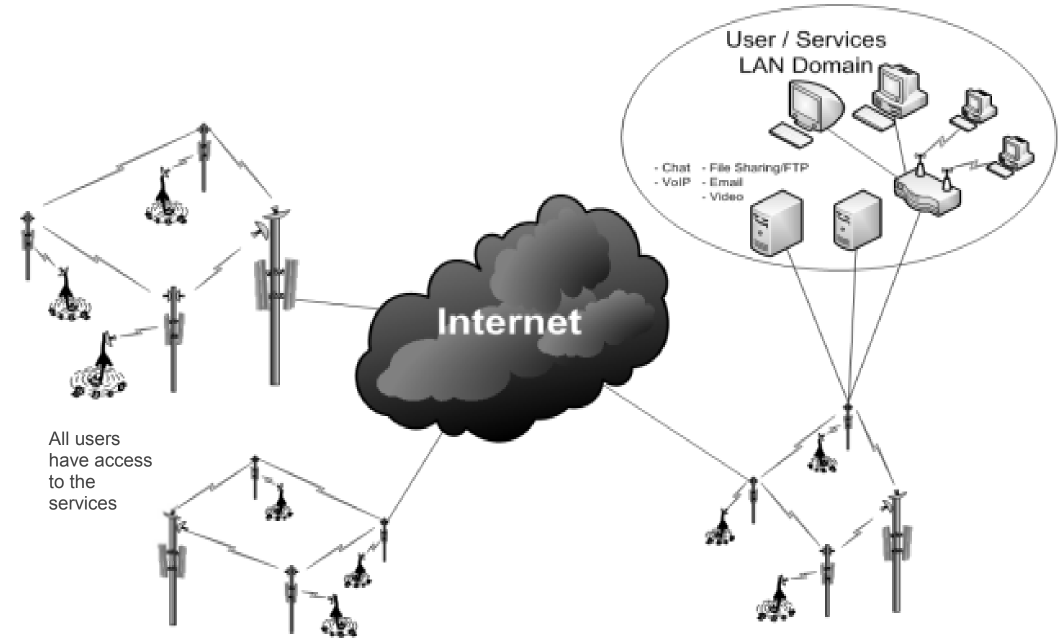
Long-haul Nodes

Longer haul devices require the extra gain achieved with dish reflectors

Figure 10 Rocket with RocketDish **Figure 11 NanoBeam** **Figure 12 NanoBridge**

Deployment Challenges

One of the most challenging aspects of a mesh implementation is inter-connecting "mesh islands" that have formed in the more-easily meshed areas. Without a competed mesh network, it is difficult to justify the expense/effort of building out network services (email, Voice-over-IP (VoIP) telephony, web-based utilities, etc.) which are needed to demonstrate the network to prospective EMCOMM clients. It may also be difficult to justify the expense of acquiring strategic high-ground properties necessary to connect the mesh-islands.



The interim solution AREDN has provided is based on Internet tunneling. This involves setting up an encrypted tunnel between one tunnel server-node and one node in each of the other mesh-islands. This has the effect of connecting all participating mesh-islands together in the same network. In doing so, you can gain the benefits of having completed the network and, at the same time justify the build-out of IP-based services for the users and demonstrate the utility to prospective customers.

While tunneling is an effective way to gain that critical mass, it is a poor strategy for EMCOMM / AUXCOM deployment and should only be used as a temporary means of achieving a specific goal. Tunnels will likely not be functional in a real disaster.

Conclusion

There are a variety of mesh network systems today. AREDN is unique in that it operates under Part 97 under the authorizations inherent in our Amateur license grant. It is easy to configure and is deployable by typical hams to served agencies without any knowledge of data networking or the design of the mesh to which a node is being connected. It can be used to provide a variety of IP-based services or to restore failed intranet-based agency services.

The AREDN Project team provides support via its website at www.aredn.org to Emcomm/AUXCOM groups wishing to deploy this technology.

Footnotes:

(1) From the proceedings of the ARRL and TAPR 34th Digital Communications Conference 2015, http://www.tapr.org/pdf/DCC2015-AREDN-Project-K6AH.pdf

The AREDN Project Team

The Software development team is comprised of:

- Conrad, KG6JEI
- Joe, AE6XE
- Darryl, K5DLQ
- Randy, WU2S
- Trevor, K7FPV
- Andre, K6AH (the author)

The team was honored by the ARRL in 2014 by receiving their Microwave Development Award. You can meet them and discuss your AREDN implementation project on the AREDN Forums at http://www.aredn.org/forum

Writer's Bio

Andre Hansen, K6AH, has been a ham for forty-six years and is a frequent speaker at Southern California radio clubs. He holds an Extra Class license and is a member of the ARRL. He currently works as an IT Regulatory Compliance Consultant for Abbott Laboratories. He is also the project manager for the AREDN Project development team. Having managed information systems and IT infrastructure projects for much of his career, he finds the AREDN project a nice blend of his professional experience and Ham Radio hobby. Andre spends much of his spare time working on this project, but also enjoys VHF & HF mobile, as well as contesting. In 2013, Andre took First-Place Overall, Rover, in the ARRL June VHF contest.

You can learn more about the author at http://www.aredn.org/bio/K6AH