Development of Alachua County Initial Microwave MESH Network Linked to Packet Repeater Network

by Gordon Gibby

Alachua County ARES (qsl.net/nf4rc/) volunteers are slowly but steadily rolling out a 2.397GHz (ham band) microwave MESH network, in conjunction with the Gator Amateur Radio Club (www.gatorradio.org). We now have one residential station (high in a tree at a house on high ground) and one station on the top of 164-foot Beatty Tower dormitory at the University of Florida Campus.

At the present time, we are only using AREDN type software with Ubiquiti type hardware. HAMWAN looks interesting and we may investigate it also. In order to be an EMERGENCY network, and to meet requirements from our sites on the University of Florida campus, at this point (and for the foreseeable future) we are NOT connected to the main "internet" although I have (for the moment) a block of AMPRnet numbers to test.

This is a fledgling and growing area of ham radio, so the knowledge base is scattered and jumbled. Here are some baseline sites of interest:

- Suggestions for starting out an AREDN mesh network: https://www.aredn.org/content/mesh-

network-guidelines; based on Ubiquiti hardware
- Alternate technology (hamwan) https://hamwan.org/ based on Microtik hardware.

Ubiquiti hardware is easily purchaseable off Amazon. There are two basic hardware:

- **Nanostation** has a built-in 10dbi antenna system and requires only the external power (POE power over ethernet) that comes with it for function (Avoid the lower powered "loco" version.)

- **Bullet** has a male N connector and needs an external antenna in addition to the external POE power supply

(Microtik hardware is also available, but see cautions on hamwan site to ensure not frequency-limited. Suggest to contact the Tampa bay group with expertise on this system: http://flscg.org/)

Ubiquiti / AREDN hardware

Both Nanostation & Bullet come in models for 2, 3 and 5 GHz, although the 3 GHz models are very hard to find and more expensive. We are working with the 2 GHz models for the moment to get slightly better penetration through all our trees; we may add a 5Ghz network where many more "ham-only" frequencies are available.

At microwave frequencies, transmission line loss can be huge, so the general idea is you mount the Ubiquiti bullet transceiver right at the antenna, and then all that connects back to you is shielded ethernet providing power and passing network signals, not RF.

As sold for consumer usage, these devices appear like a home router, run a DHCP server (and pass out IP numbers to clients on their wired ethernet network), position themselves as the "default route" and will interconnect with other such devices nicely. For ham radio usage, the software is replaced with AREDN proprietary software which adds ham radio call signs, can screen out (illegal) encrypted transmissions, and otherwise functions very much like a home router that complies with ham radio identification and other requirements.

Information on how to do the firmware changes, including the various "gotchas" is well covered on the AREDN web site (read this first: https://www.aredn.org/content/software and compare to the instructions here: https://www.aredn.org/content/uploading-firmware-ubiquiti) and also in a text that I've written and is available on Amazon.

With the AREDN implementation of a mesh net you gain all the "internet-style" TCP/IP based capabilities ---which include among others

- You can operate voice over IP and configure a ham radio voice telephone system. (We've tested this with Grandstream voip phones and it works great. https://www.amazon.com/Grandstream-GXP1625-Medium-Business-Device/dp/B00VNMWRFK/ref=sr_1_6?s=electronics&ie=UTF8&qid=1518007990&sr=1-6&keywords=grandstream&dpID=41qIzmk7crL&preST=_SX300_QL70_&dpSrc=srch $45)
- You can create your own web servers (with content that is ham-legal) and operate them over the

mesh network; servers can be computers of any type, any operating system, or can even be Raspberry Pi's.

- You can operate a file server.
- You can operate a WINLINK gateway server (RMS_RELAY) with email services, which then connects to an external HF or VHF network to pass traffic in /out of your area

Advantages

The primary ADVANTAGE of a microwave mesh network is its high speed. Using 5MHz bandwidth you can get multi-megabit per second performance, blindingly fast compared to normal ham radio analog or digital or packet.

Disadvantages

The primary DISADVANTAGE of a microwave mesh network is that microwaves act like microwaves!! They dont penetrate very well at all. In free space, the paltry 600 mW output signal of a Ubiquity device can go miles and miles --- and you can use antennas of 10, 21 or 24 dBi gain as you please as a ham --- but the old saying is "10 miles or ONE TREE!" is your range --- Every wall, every tree exacts a toll, so unlike 2 meters, you have to really pay attention to your intended path, the Fresnel zone etc in creating an initial setting. Once you have a boatload of mesh stations, they will work around this limitation, but in the beginning, it is good to have HIGH stations whose signals only have to pierce the vegetation layer at a steep angle to reach a station, rather than skimming THROUGH the trees for hundreds to thousands of yards....with resultant enormous signal loss.

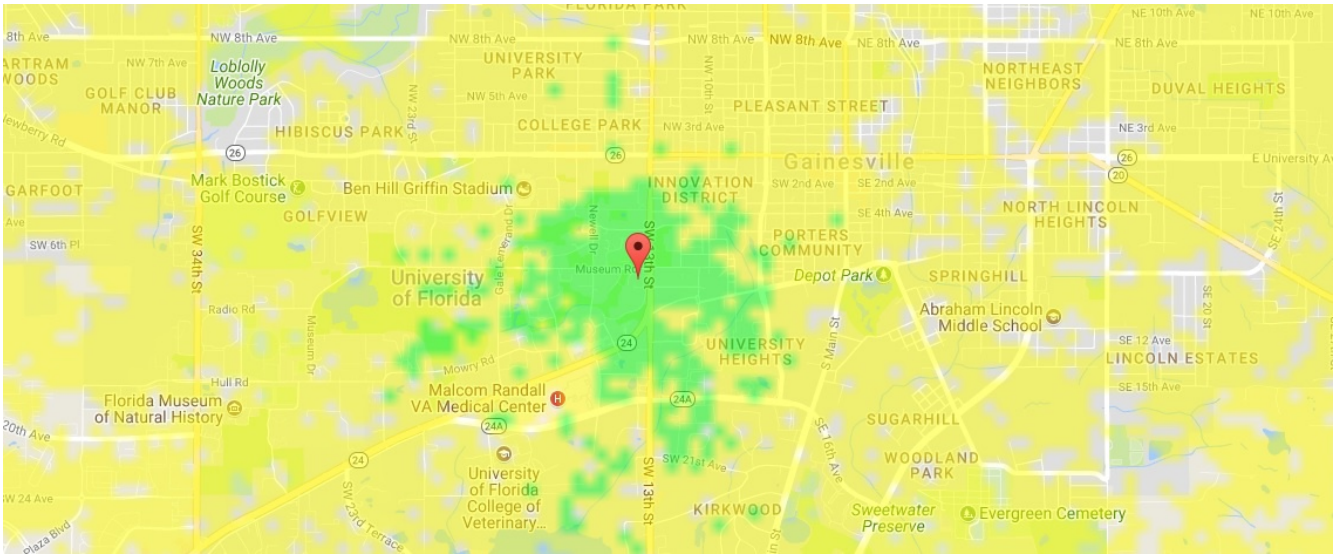
In order to begin to create a mesh network, it is helpful to understand **LINK BUDGETS**. You start with +28 dBm out of the transceiver, may use an antenna to create an effective +38 dBm or more, and your receivers need to see -80 dBm or so in order to have a reasonable throughput. You would think with allowable losses of up to 120 dBm your range would be nearly infinite--- and if in free space, it truly would be, but we were quite happy to execute a 4-mile link in a test where we had to dive through some trees to reach a 15 dBi vertical collinear antenna hoisted up as high as we could in a higher part of town--- and ended up with a 14dB S/N ratio. These systems are incredibly popular out WEST where they put the repeater on the side of a mountain and it insonates an entire tree-less western desert city --- those of us who live in "Tree Town" USA have a much bigger problem.

Free space loss is related only to spreading out of the waves; the frequency component has more to do with the fact that higher frequency antennas of 0 dBi are SMALLER and have lower aperture. See HTTP://en.wikipedia.org/wiki/Free-space_path_loss for more explanation

> Free space loss calculator: https://www.pasternack.com/t-calculator-fspl.aspx
> 2400 MHz, 0.6 Watt, 10 dBi antenna on each end: 1 mile = 104 dB loss; 20 miles = 130 dB loss; 40 miles = 136 dB loss;

When building a mesh network, ALWAYS remember to add in the "lightning arrester" system from Ubiquiti and use shielded ethernet (class 5e) from the transceiver back to the lightning arrestor – this will help protect your gear from "nearby" strikes. (https://www.amazon.com/Ubiquiti-Networks-ETH-SP-External-Suppressor/dp/B00R20OIAY/ref=sr_1_3?ie=UTF8&qid=1517930436&sr=8-3&keywords=ubiquiti+lightning+protector&dpID=31s6hLW2hlL&preST=_SY300_QL70_&dpSrc=srch $11) Nothing is likely to protect it from a direct hit. Likewise, I have no information on their protection from EMP. The Ubiquiti arrestor has multiple gas discharge tubes to clip high voltage spikes, probably around 60 V.

Radio Mobile Online (http://www.ve2dbe.com/english1.html) allows free simulations of coverage – but this requires a bit of experience to make work well. To allow for the 5 MHz bandwidth, receiver signal strength has to be set for 4 microvolts. Use 2310 as the frequency. Using settings of: 9 dbi transmitter omni, 10 dbi receiver gain, 0.6 watt transmitter, receiving antenna at 20 feet, transmitting antenna on top of Beatty Towers (50 meters AGL), 95% accurate (yellow) signal, STRONG signal (green) set for 20 dB above that, one gets the coverage map below – which shows all the "holes" caused by terrain/buildings. To make microwave systems work in a tree / building city, one needs multiple mesh stations!



Radio Mobile also allows for point-to-point simulations, with nice graphical displays of the Fresnel zone and objects impinging on it. The difference between a 146MHz fresnel zone and a 2310 MHz fresnel zone is impressive. https://en.wikipedia.org/wiki/Fresnel_zone

Since this node just went up on Feb 5th, our experience with its coverage is minimal. However, I was easily able to connect to it from a parking deck a half mile away with 30 dB S/N. Even more surprising, I was able to connect through the exterior concrete wall of the University of Florida Dental Tower from the W4DFU home station – and with 40 dB S/N. This gives the GARC HF & satellite station potential high speed (multi-megabit) access to the MESH system as well as to the packet system.

TAKING IT A STEP FARTHER: Connecting to AX.25

The interesting part is that BPQ software is able to package AX.25 packets inside UDP-type internet packets. Indeed there are many ham radio BPQ nodes all over the world that communicate to each other over the internet for some of their links, sending AX.25 packets this way. The BPQ software (which may run on a Windows computer or on a linux Raspberry Pi) can't tell that you have replaced its Internet connection with your local Mesh network! It is just all TCP/IP to it. This makes it possible "marry" longer-range VHF AX.25 networks (and potentially even HF links) to BPQ nodes on mesh

networks.

To the BPQ node, the microwave transceiver is merely another “port.” So in Gainesville, Florida, we are constructing a fledgling mesh network:

2.397 GHz
5 MHz bandwidth
Channel -2

and connecting it to an existing 2-meter packet AX.25 network covering 4000 square miles, by way of linbpq systems running on Raspberry Pi Version 3.

This makes it possible to use AX.25 to go from one node to another (possibly over microwave) and then to another (over 2 meters) and to another (perhaps back over microwave) --- seamlessly.

What isn't quite yet clear to me is exactly how best to leverage this ability for WINLINK type emergency communications, but we're working on that! Stay tuned for future developments!

IP CONNECTION

From a practical standpoint, since the Ubiquiti devices can provide DHCP support, the Raspberry Pi of the associated AX.25 station immediately acquires an IP number and is now accessible by tcp/ip over the MESH network. At present it has significant security installed for protection. However, now a connection can be easily made to that Raspberry using SSH (and in the future, potentially vnc) – allowing work on the Raspberry to be accomplished from the comfort any nearby location with signal, rather than having to obtain keys, and visit the uncomfortable mechanical room where the station is located. As the local mesh system develops and connections begin to occur, synergistic advantages like this are likely to increase.