High Speed Mesh Networking and Amateur Radio

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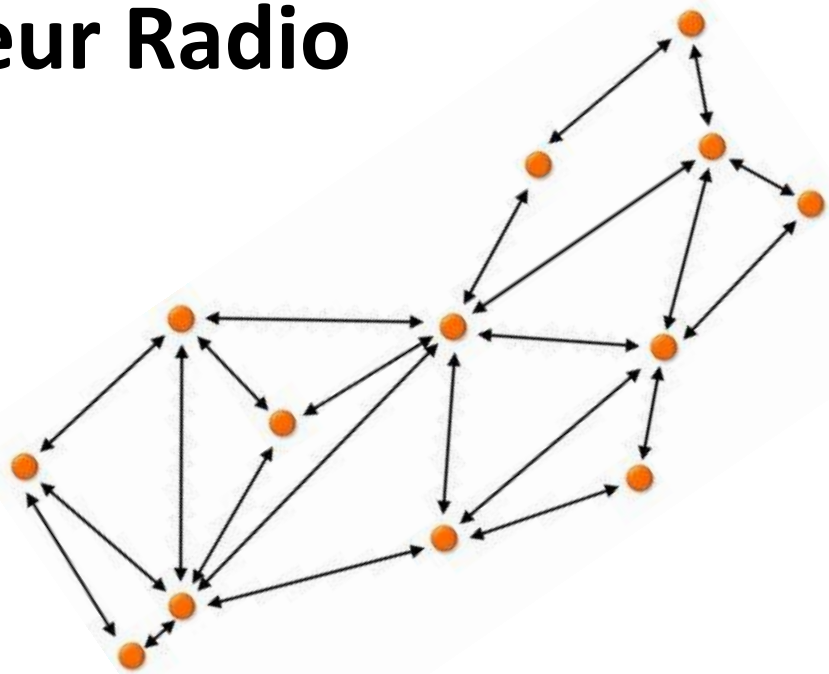


Presentation to
285 TechConnect Radio Club TechFest
November 1, 2014

ARRL 100 YEARS

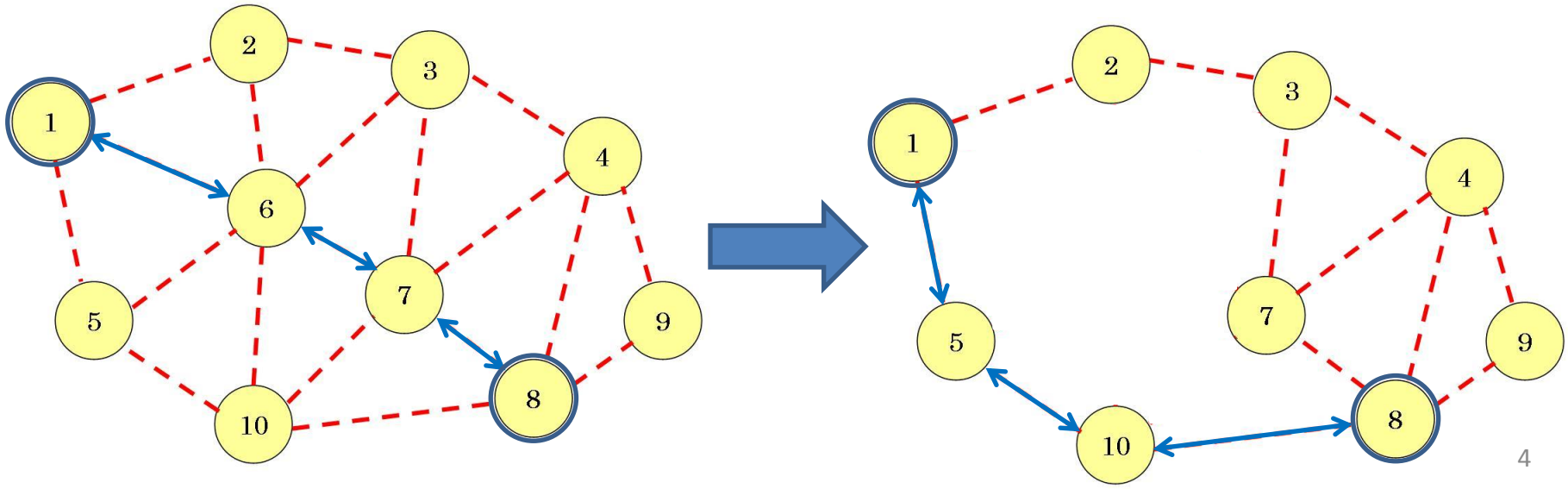
What's Ahead…

- Overview of mesh networks
- 802.11: Part 15 vs. Part 97
- Mesh networking in amateur radio
  - Practical applications
  - Hardware
  - Firmware
  - Antennas
  - Systems engineering considerations
  - For more information…
  - Questions / Collaboration

Overview of Mesh Networks

What is a Mesh Network?

- Collection of overlapping nodes in a mesh topology
  - Each node can route traffic via adjacent nodes
- Self-discovering, self-configuring, self-healing
  - Mesh forms and adapts automatically
- Dynamically adjusts to changing resources
  - Routing protocols enable automatic reconfiguration as nodes join or leave the mesh



Nodes in a Wireless Mesh Network

In a wireless mesh network, each node…

- Links to any other node it can hear on the network
- Builds a routing table to track which nodes are currently connected to the mesh (and how) to enable routing messages through the mesh
- Can connect to a resource (internet, video camera, server, etc.) allowing all nodes to have access to the same asset

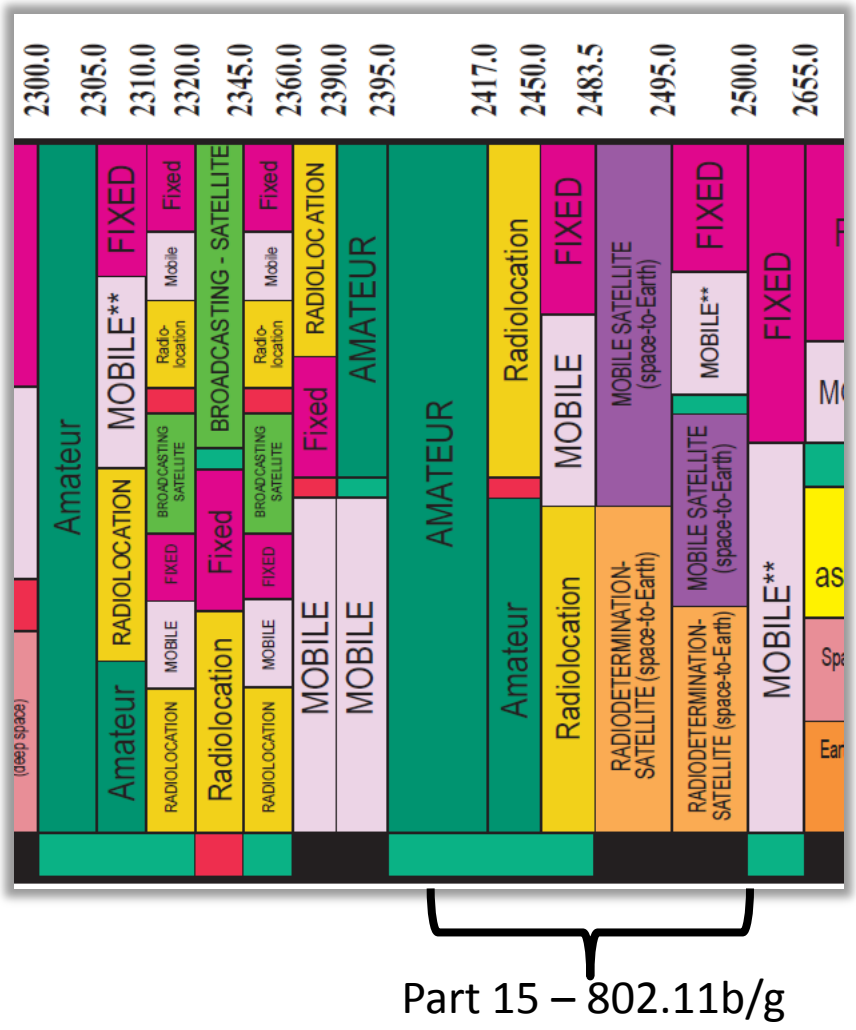
802.11: Part 15 vs Part 97

IEEE 802.11b/g vs. 2.4 GHz Spectrum

802.11b/g (13 cm)

Channel	Center Frequency	FCC Regulations
−1	2402 MHz	Part 97
0	2407 MHz	Part 97
1	2412 MHz	Part 97 & 15
2	2417 MHz	Part 97 & 15
3	2422 MHz	Part 97 & 15
4	2427 MHz	Part 97 & 15
5	2432 MHz	Part 97 & 15
6	2437 MHz	Part 97 & 15
…		
14	2484 MHz	Part 15

http://en.wikipedia.org/wiki/High-speed_multimedia_radio

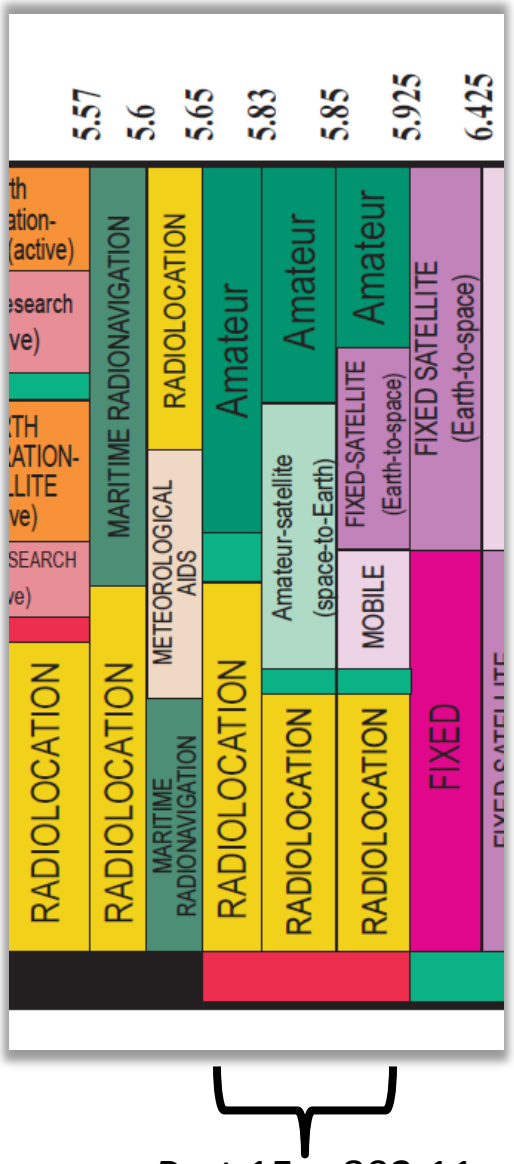


802.11b – DSSS – 22 MHz BW – 11 MB/sec
802.11g/n – OFDM – 20 MHz BW – 54 MB/sec

IEEE 802.11a vs. 5.8 GHz Spectrum

Channel	Center Frequency	FCC Regulations
132	5.660 GHz	Part 97
136	5.680 GHz	Part 97
140	5.700 GHz	Part 97
149	5.745 GHz	Part 97 & Part 15
153	5.765 GHz	Part 97 & Part 15
157	5.785 GHz	Part 97 & Part 15
161	5.805 GHz	Part 97 & Part 15
165	5.825 GHz	Part 97 & Part 15
169	5.845 GHz	Part 97
173	5.865 GHz	Part 97
177	5.885 GHz	Part 97
180	5.905 GHz	Part 97

http://en.wikipedia.org/wiki/High-speed_multimedia_radio



802.11a – OFDM – 20 MHz BW – 54 MB/sec

Power Limits: Part 15 vs Part 97

Part 15 regulations

- Maximum allowable transmitter power output: 1 watt (+30 dBm)
- Maximum allowable EIRP: 4 watts (+36 dBm) for Point to Multipoint

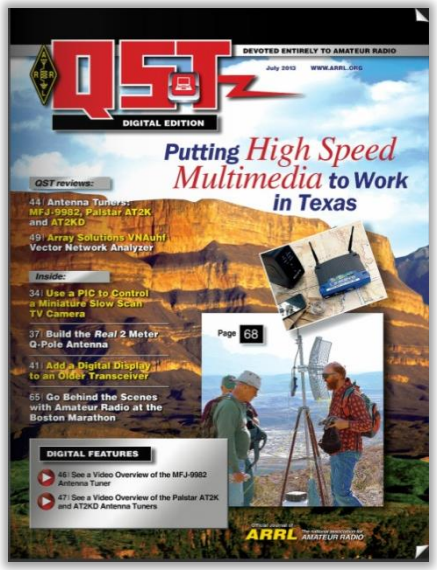
Part 97 regulations

- Maximum allowable transmitter power output ranges from 10 watts/+40 dBm (802.11b DSSS) to 1500 watts/~+62 dBm (802.11a/g/n OFDM)
- No EIRP limit

Mesh Networking in Amateur Radio

What is it All About?

- Amateur radio utilization of mesh networking
- 802.11a/g/b/n performance on amateur radio frequencies
- Extensive range of practical applications that can be brought to bear in experimental, public service, or fun settings
- Champions the use of “commercial off the shelf” (COTS) equipment
  - Linksys WRT54GL
  - Raspberry Pi
  - Ubiquiti access points
  - Others



July 2013 QST

Practical Applications

Amateur Radio Applications

Numerous potential applications would be enabled within our very own Amateur Radio spectrum, including:

- Email
- Keyboard chatting
- File transfers
- Streaming video
- Voice over IP (VoIP)
- Web applications
- Improved public service/ARES communications
  - D-RATS functionality (chatting, form transmission, file transfer, etc.)
- Repeater control, linking, and administration
- Experimentation and technology development

Anything you might do via your home computer on your home network (within the bounds of FCC Part 97 regulations, since this is being done via ham radio spectrum)

Hardware

Linksys WRT54GL

- Repurposed home router
- Inexpensive (~**$25 on Ebay**) and readily available
- “Stock” RF Power (**75 mW-250 mW**)
- 12VDC Power
- Modified Firmware
  - Broadband-Hamnet™
  - NW-MESH
  - OpenWRT
  - DD-WRT

Raspberry Pi

- Inexpensive
  - $35 Raspberry Pi computer
  - $10 Wifi adapter
- Power (**25 mW and up**) depending on WiFi adapter
- MESH network software options
  - HSMM-Pi
  - OpenWRT
  - DD-WRT
  - OSLR

- Can be simultaneously used for other applications since this is an actual computer, not just a router

Ubiquiti Bullet and Nano station

- $75 and up
- “Stock” Power (**250 mW and up**)
- Modified Firmware
  - Broadband-Hamnet™
  - NW-MESH
  - OpenWRT
  - DD-WRT
  - OSLR
- 2.4, 3.3, 5 GHz amateur bands

Laptop running Ubuntu Linux

- Modified Software
  - HSMM-PI
- 2.4, 3.3, 5 GHz amateur bands
- Mesh node *and* work station

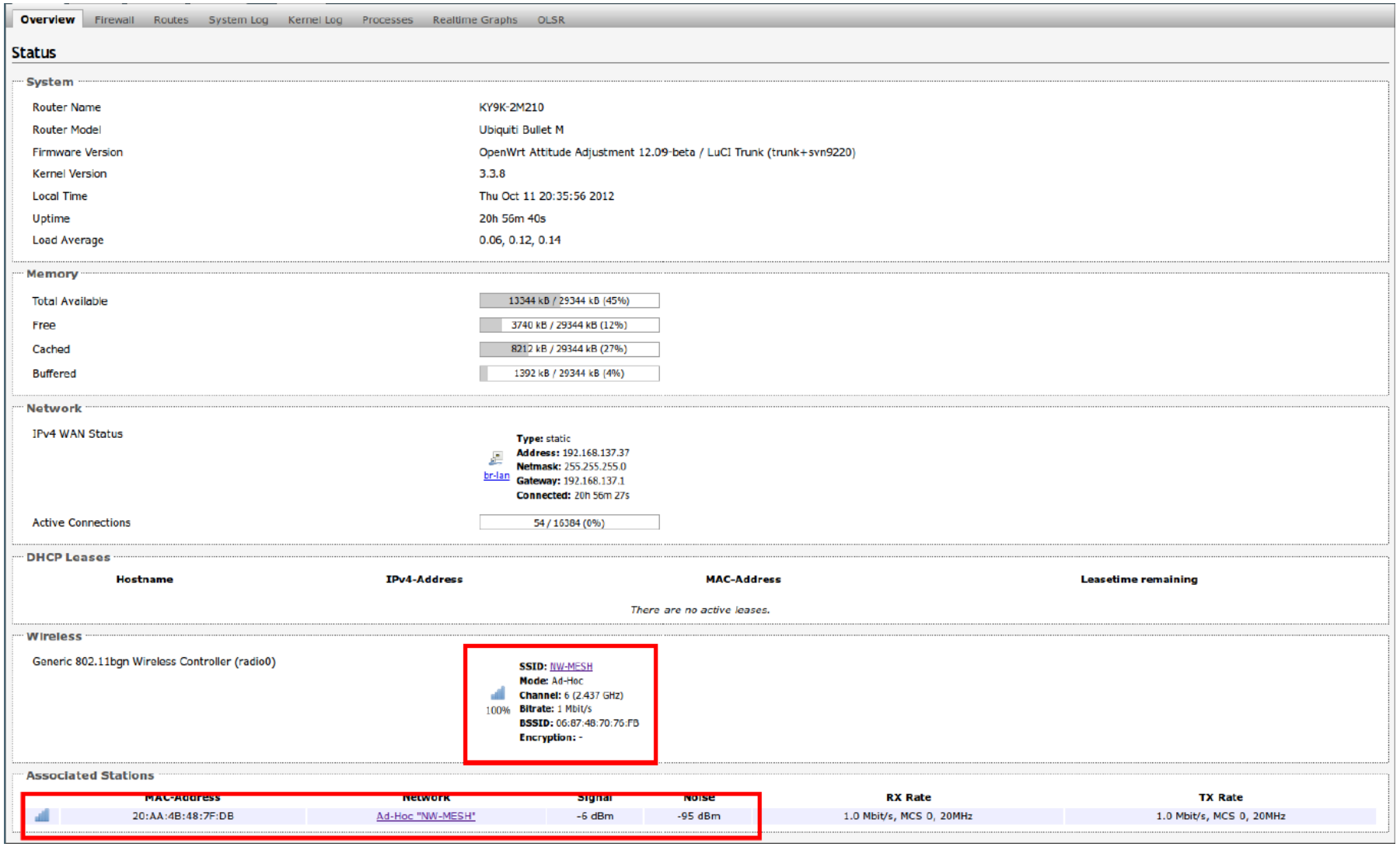
Firmware Types

NW-MESH

NW-MESH: Overview

- Originated 2012 in South King County, Washington
- Ad-hoc group – no centralized leadership
- Developed to fill gap of interoperability with a variety of access point hardware
- Current focus on deploying the latest OpenWRT firmware on multiple platforms such as Ubiquiti, TP-Link, RaspberryPi, MikroTik, and similar devices
  - Everything supported by OpenWRT
  - http://wiki.openwrt.org/toh/start
  - Hundreds of devices including boards which allow running multiple radios on multiple bands
- CHANGEME builds
  - Requires changing 4-5 parameters labeled “CHANGEME” to have a fully functioning mesh node
  - Ubiquiti BulletM2HP, WRT54G (Backfire), others

NW-MESH Screenshot



NW-MESH: The Future

- Platform for development, new ideas, and experimentation
  - What will YOU do with it?
- Already Demonstrated
  - Adding new applications
  - Point-to-Point links on multiple bands
  - VLAN support for moving over served-agency L2 network
  - Routerboards (Mikrotik) brought up to support multiband and other development
- Under Consideration
  - Babel – a much more bandwidth conservative routing protocol. Important for constrained links (56K+)
  - Multicast content distribution (likely NORM based)
  - USENET news network

Firmware Types

Broadband HamNet™

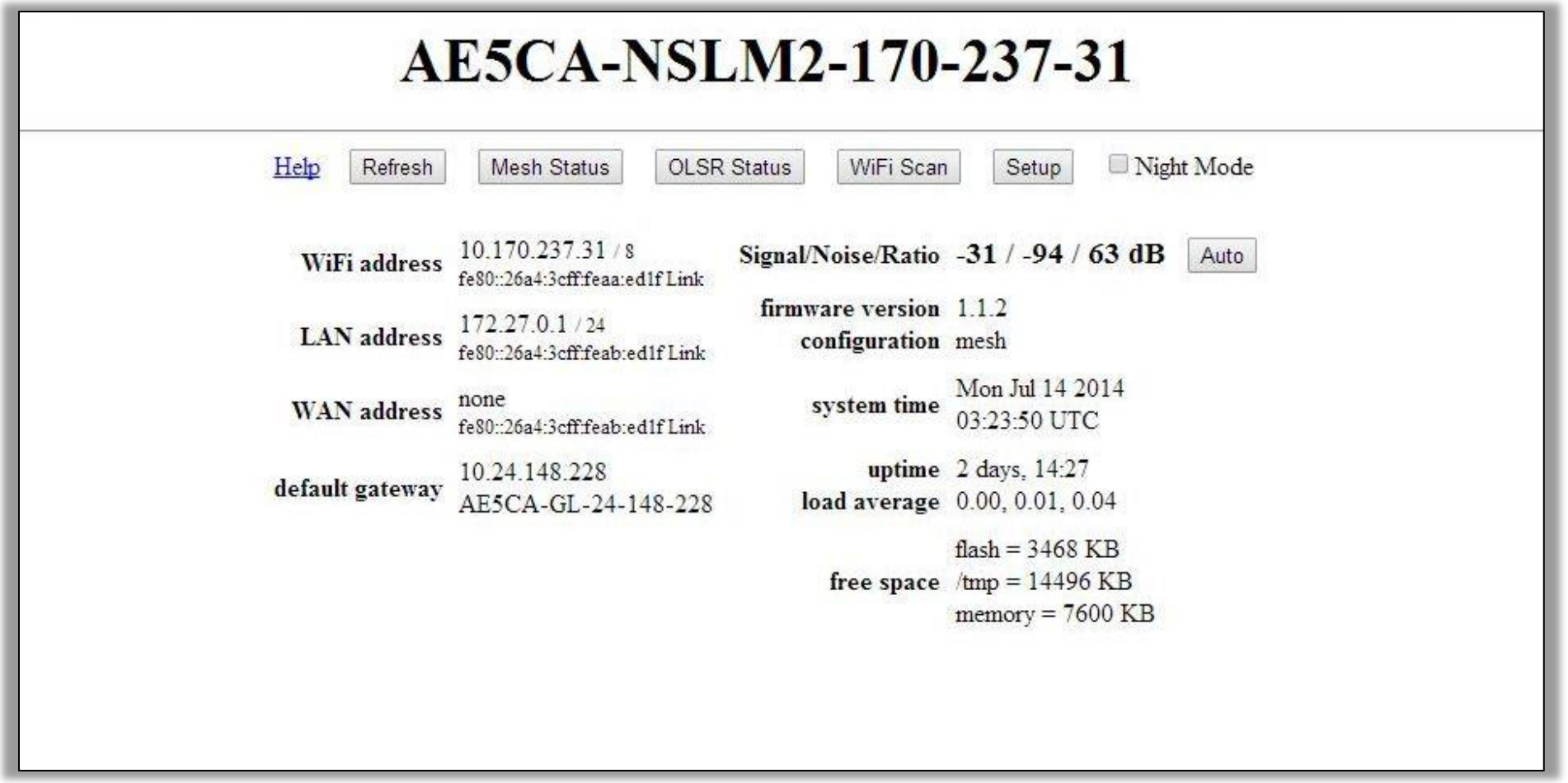
Broadband Hamnet™: Overview

- Widely used world wide
- Self discovering, configuring, advertising, fault tolerant
- Fully supported on the web and by users
- All users on current firmware are interoperable
- Click navigation reaches a network devices or service
- Built in configuration and aiming tools
- Internal system status pages
- Automatic IP address assignment throughout
- Nothing to load on computer, web browser runs it
- Back to back LAN connection joins and routes multiple bands
- 2.4 and 5.8 GHz active now, 3.4 GHz and 900MHz in beta

Broadband Hamnet™: Hardware

- Linksys WRT54G (hardware versions 1 through 4)
- Linksys WRT54GL (all hardware versions)
- Rocket M2
- Bullet M2 HP
- AirGrid M2 HP
- NanoStation Loco M2 (NSL-M2)
- NanoStation M2 (NS-M2)
- Other makes/models as noted on BBHN website

Broadband Hamnet™ status page



Broadband Hamnet™: The Future

- Full support for current hardware on 2.4, 3.4, 5.8 GHz and 900 MHz
- Extend supported device list in these bands
- More configuration screens to create common services
- Click and configure to create VPN tunnel host/client
- More FAQ content and downloadable reference docs
- More YouTube videos for training
- Webinars on using Broadband-Hamnet with served agencies

Firmware Types

HSMM-Pi

HSMM-Pi: Overview

- Mesh networking with the Ubuntu 12.04 Linux distribution
- Targeted at the low-cost Raspberry Pi single-board computer powered by 5V @ 1 Amp
- The Raspberry Pi is equipped with a 700 MHz ARM processor and 512 MB of RAM, creating many possible applications for a single HSMM-Pi board beyond just mesh networking.
- The HSMM-Pi project consists of the following:
  - Installation script that installs the software packages necessary to run a mesh node
  - PHP-based web application for configuration & monitoring

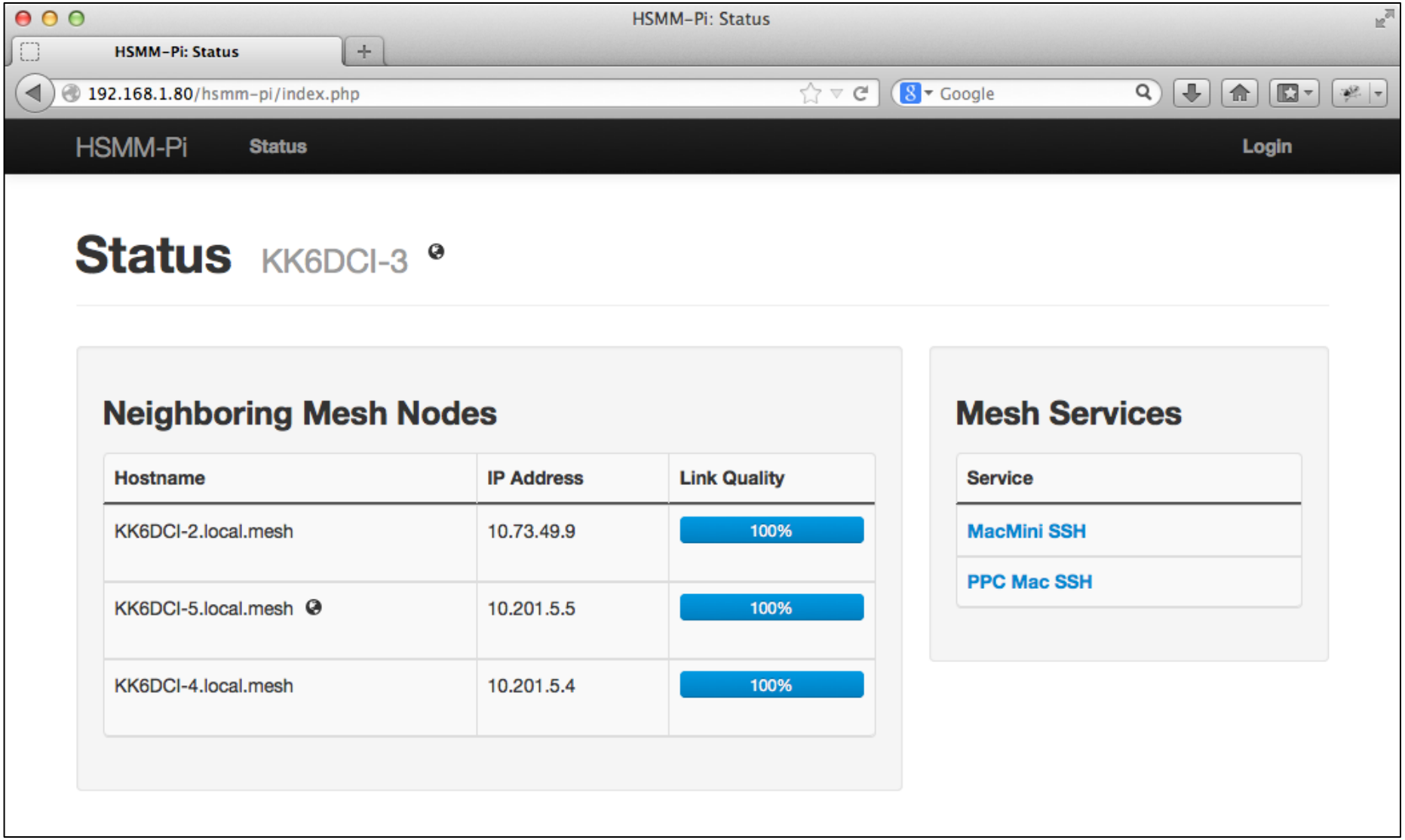
HSMM-Pi: Hardware

- Raspberry Pi Models A or B (recommended, has 10/100 Ethernet port) ($35)
- 4GB SD card ($5)
- USB WiFi Adapter (see website for model recommendations) (~$12)
- Extras:
  - Simple housing
  - Ethernet Cable and Switch to connect other computers to the mesh

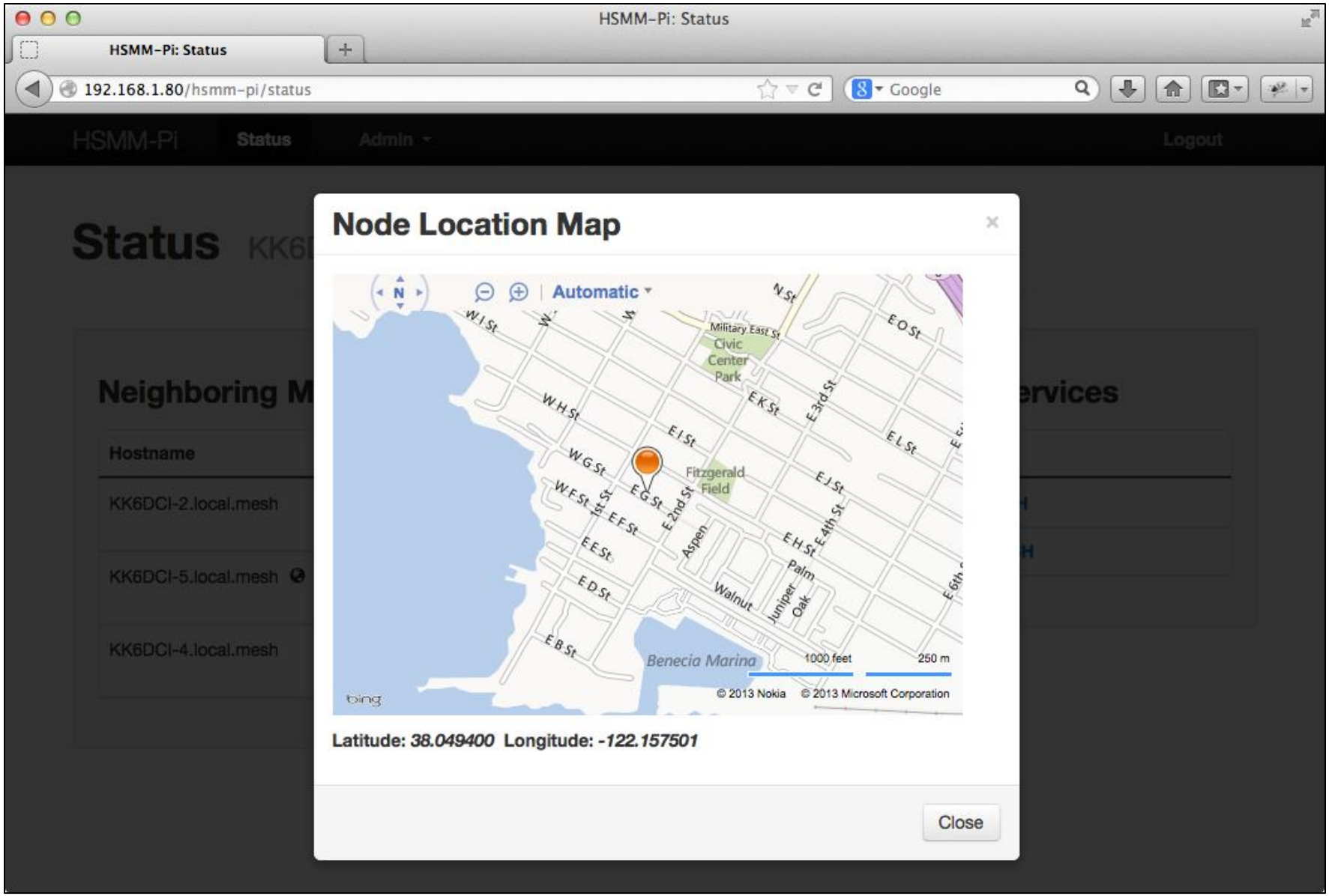
HSMM-Pi: Features

- Runs on low-cost, open-source hardware and software
- Interoperable with some versions of Broadband Hamnet mesh networking platform
- Supports port-forwarding to hosts behind the mesh node
- WiFi site-survey shows neighboring wireless networks, allowing for optimal channel selection
- Supports USB GPS receivers compatible with the Linux ‘gpsd’ service
- GPS signal can be used as a time source for the mesh node, and the node lat/lon are broadcast through the mesh network periodically
- Allows for near-realtime tracking of mesh node positions on an annotated Bing Maps display (requires internet connection)
- Some USB WiFi adapters support removable antennas, which provides the opportunity to use high-gain antennas and amplifiers.

HSMM-Pi web status page



HSMM-Pi web status page



HSMM-Pi: The Future

- Support for USB Network-Attached Storage (NAS) file-shares
- An embedded IRC chat server (would be useful for EOC communication)
- Support multiple radios on separate channels on a single Raspberry Pi node (one radio for mesh, another for a local WiFi network at the edge)
- Add annotations to GPS map view indicating which mesh nodes are in range and signal strength

Antennas

Antennas

The most important component of any communication system.

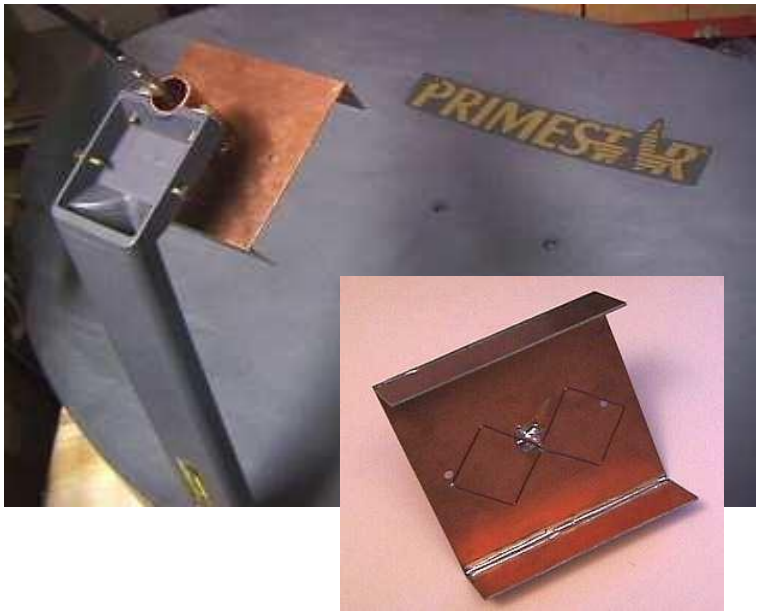
Yagi antenna
TL-ANT2409B
14 dBi gain

Parabolic antenna
TPLink TL-ANT2424B
24 dBi gain

Vertical antenna
TPLink TL-ANT2415D
15 dBi gain

Homebrew Antennas

Pringles Cantenna
~7 dBi gain
(Spicy Cajun model required)



Bi-quad feed and DSS dish
~27-31 dBi gain

Systems Engineering Considerations

Systems Engineering Considerations

- Band of operation
  - Ambient RF noise level
  - Path loss
- Distance between links and obstructions
  - Online link analysis tool: Radio Mobile Online (http://www.cplus.org/rmw/rmonline.html)
- Antenna polarization
- Link margin
- Bandwidth limitations
- Number of node hops
- Hardware reliability

For More Information…

For More Information…

- Firmware specific
  - NW-MESH
    - https://groups.yahoo.com/neo/groups/NW-MESH/info
  - Broadband Hamnet™
    - http://www.broadband-hamnet.org
  - HSMM-Pi
    - https://www.github.com/urlgrey/hsmm-pi
- General inquiries
  - Google “mesh networking amateur radio”
  - Or feel free to contact us…
    - Brian Mileshosky N5ZGT n5zgt@arrl.net
    - Ed James KA8JMW ka8jmw@arrl.net

Questions?

Speaker Bio

Brian Mileshosky N5ZGT was first licensed at the age of 12 in 1992. Nearly 25 years later, ham radio is just as exciting now as it was when that highly anticipated envelope from the FCC with his ticket arrived in the mail. Brian is active on the air between 80 meters and 10 GHz, chasing DX, contesting, experimenting with novel technologies, assisting with public service communications, and mentoring new hams who seek the thrill of ham radio. Brian has served in numerous club and ham convention leadership positions and has sat on ARRL's Board since 2005, currently serving League members as Director of the Rocky Mountain Division (composed of the Colorado, New Mexico, Utah and Wyoming sections). Professionally, Brian is an RF/microwave engineer engaged in research, development, and fielding of RF systems and applications from UHF through 30 GHz. Brian can be reached via email n5zgt@arrl.net

Speaker Bio

Ed James, KA8JMW of Albuquerque, NM is originally from Canton, OH where he was licensed over thirty five years ago. Since then, Ed has savored from the broad palette that amateur radio offers. Activities have included the design and fabrication of various projects from DC to daylight, QRP, net operations, traffic handling, rag chewing, contesting, DX, transmitter hunting, Search and Rescue, public service, satellites, EME and as an elmer to many a new ham. The thrill of that first QSO hasn't diminished. He has over 30 years of service as an electrical engineer leading space based and defense projects at Sandia National Laboratories. Ed, his wife Carol and their five daughters are all active amateur radio operators. Ed is an Assistant Section Manager for the ARRL New Mexico Section and Assistant Director of ARRL's Rocky Mountain Division and can be reached via email at ka8jmw@arrl.net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