Broadband Mesh Networking and Amateur Radio

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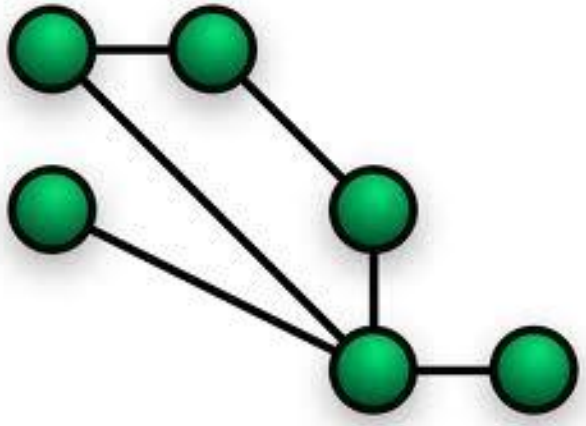


Presentation to
High Desert Amateur Radio Club
January 18, 2014

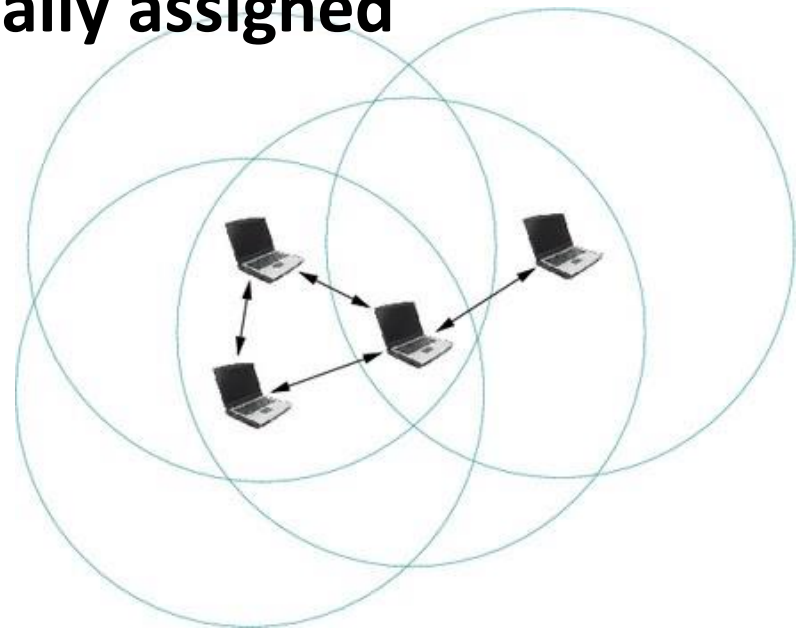
ARRL 100 YEARS

Presentation Outline

- What is a network?
- 802.11g part 15 vs. part 97
- Broadband-Hamnet™ (BBHN)
  - Overview
  - Hardware
  - Antennas
  - Range
  - Uses
  - Comparison to Packet Radio

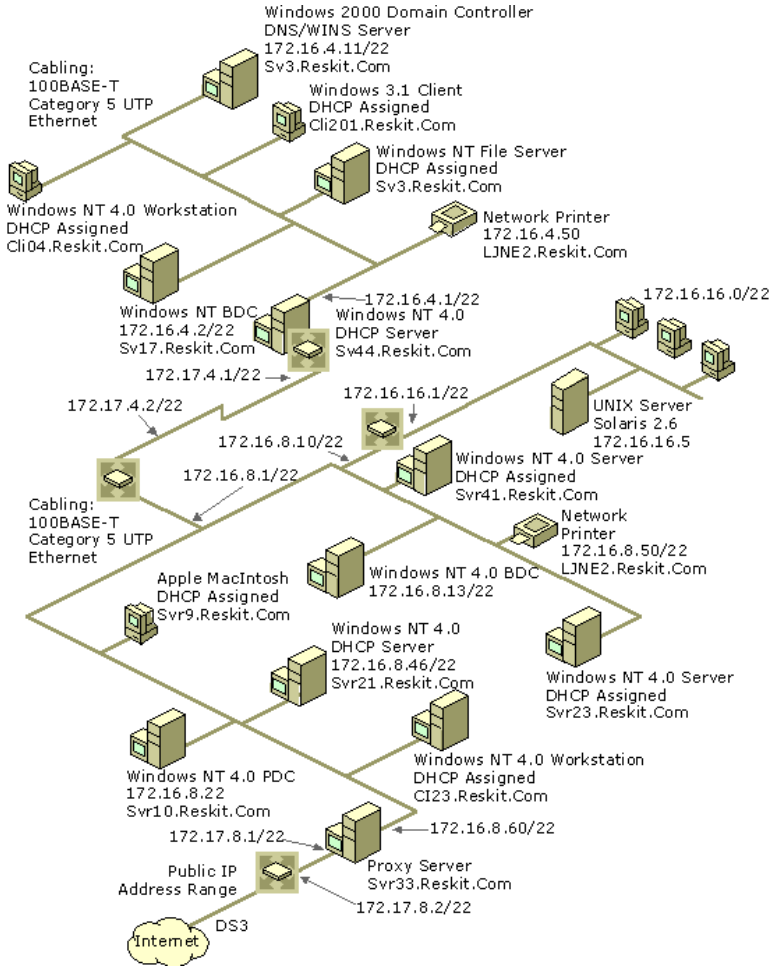
What is a “network”?

- A network is two or more computers (nodes) connected to each other
- ‘Ad Hoc’ or ‘Peer to Peer’ network
  - Allows for point-to-point communication between nodes
  - Node addresses are manually assigned
  - Local by nature
  - Typically very simple



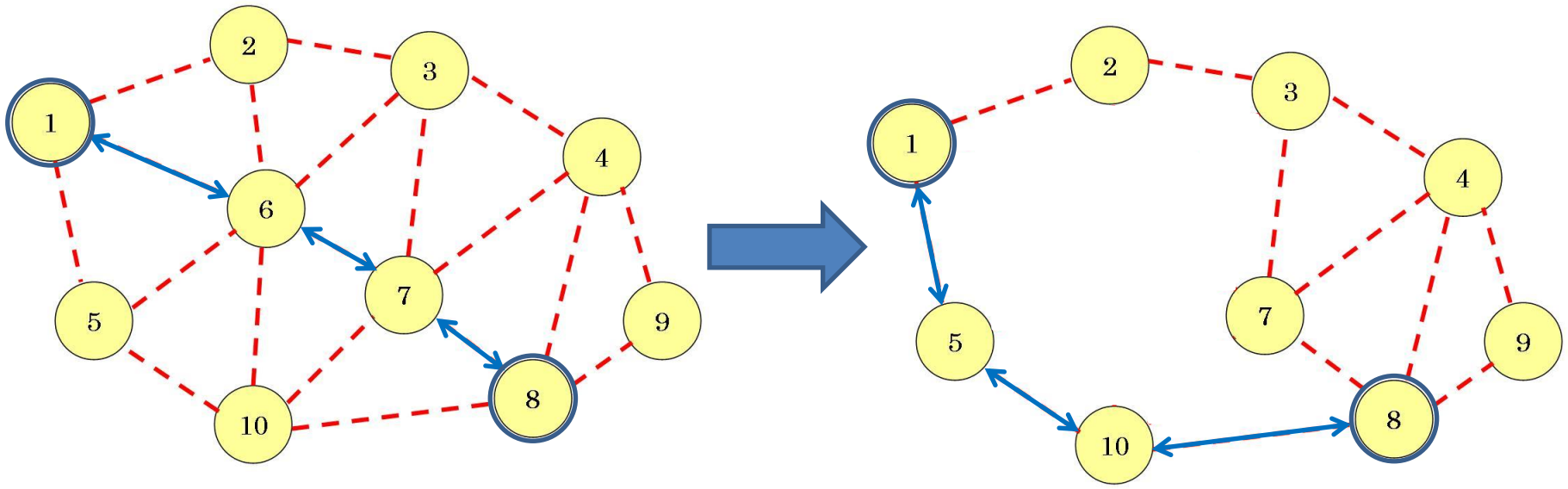
What is a “network”?

- **Infrastructure network**
  - **Can utilize a variety of topologies (ring, star, bus, tree, mesh)**
  - **Nodes join and drop off the network**
  - **Specialized routers, servers and access points control many service functions like assigning addresses and directing traffic**
  - **Can be very complex**
  - **Can be difficult to setup and maintain**



What is a Mesh Network?

- "Infrastructure-less" collection of "overlapping" RF nodes in a mesh topology
  - Each node can route traffic via adjacent nodes
- Self discovering, Self configuring
  - Mesh forms automatically
- Dynamically adjusts to changing resources
  - Automatically reconfigures the network as nodes join or leave the mesh; fault tolerant



Nodes in a Mesh Network

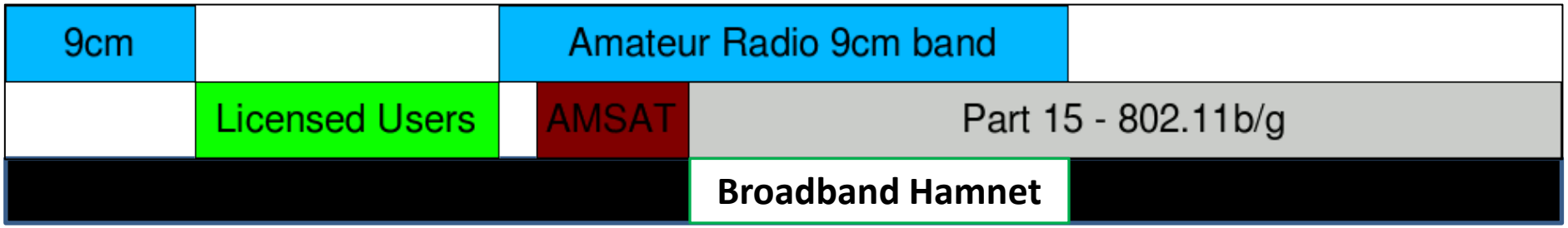
In a mesh network, each node…

- **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 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**

IEEE 802.11b/g vs. 2.4 GHz Ham

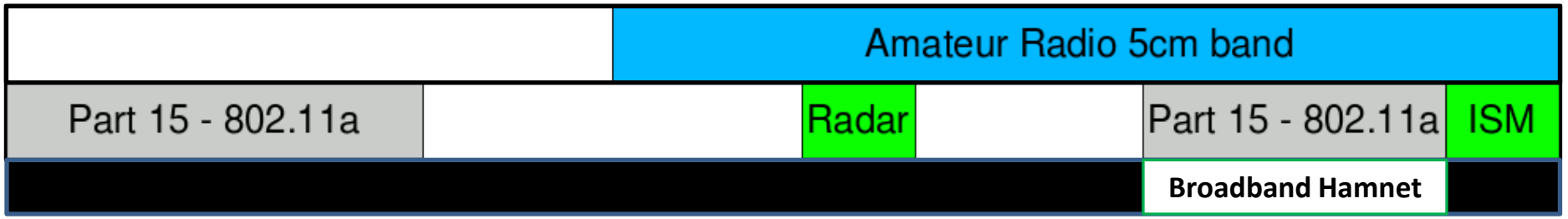
802.11b/g (13 cm)

Channel	Center Frequency	FCC Regulations
−1	2.402 GHz	Part 97
0	2.407 GHz	Part 97
1	2.412 GHz	Part 97 & Part 15
2	2.417 GHz	Part 97 & Part 15
3	2.422 GHz	Part 97 & Part 15
4	2.427 GHz	Part 97 & Part 15
5	2.432 GHz	Part 97 & Part 15
6	2.437 GHz	Part 97 & Part 15
7	2.442GHz	Part 15
…		
11	2.462GHz	Part 15



IEEE 802.11a & 5.8 GHz Ham

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



Power Limits: Part 15 vs Part 97

Part 15 regulations

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

Part 97 regulations

- **Maximum allowable transmitter power output ranges from 10 watts (+40) to 1500 watts (~+62 dBm) depending on the flavor of 802.11 used.**
- **No EIRP limit**

What is Broadband–Hamnet™ (BBHN)?

- Amateur radio utilization of mesh networking
- 802.11g bandwidth performance on amateur radio frequencies
- Champions the use of “commercial off the shelf” (COTS) equipment
  - Linksys WRT54GL
  - Raspberry Pi
  - Ubiquiti
  - …
- Initial experimentation began in 2004

http://hsmm-mesh.org

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)

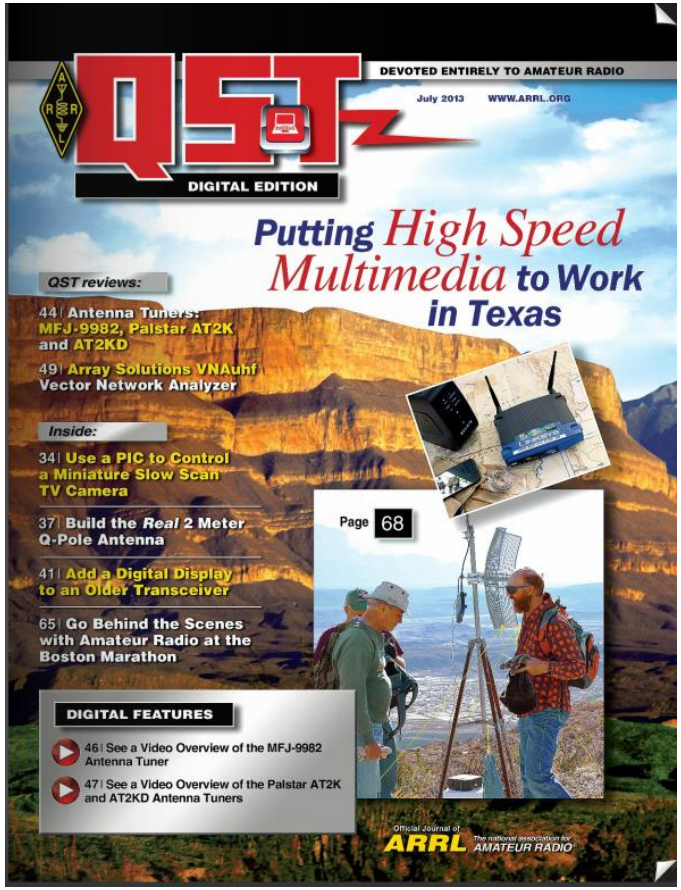
BBHN vs. Packet Radio

	Broadband-Hamnet	Packet Radio
Data Rate	Up to 54 Mbps	Most commonly 0.0012 Mbps
Setup and Use	Requires special (common) knowledge	Requires special (not so common) knowledge
Software and Applications	Commonplace	Limited, special software required
Traffic routing	Simple, flexible, robust	Generally not flexible
Equipment	Very common	Generally common
Cost	Ranges from very inexpensive to expensive	Ranges from very inexpensive to expensive
Spectrum	2.4 GHz and above	Typically used from HF to UHF

Linksys WRT54GL

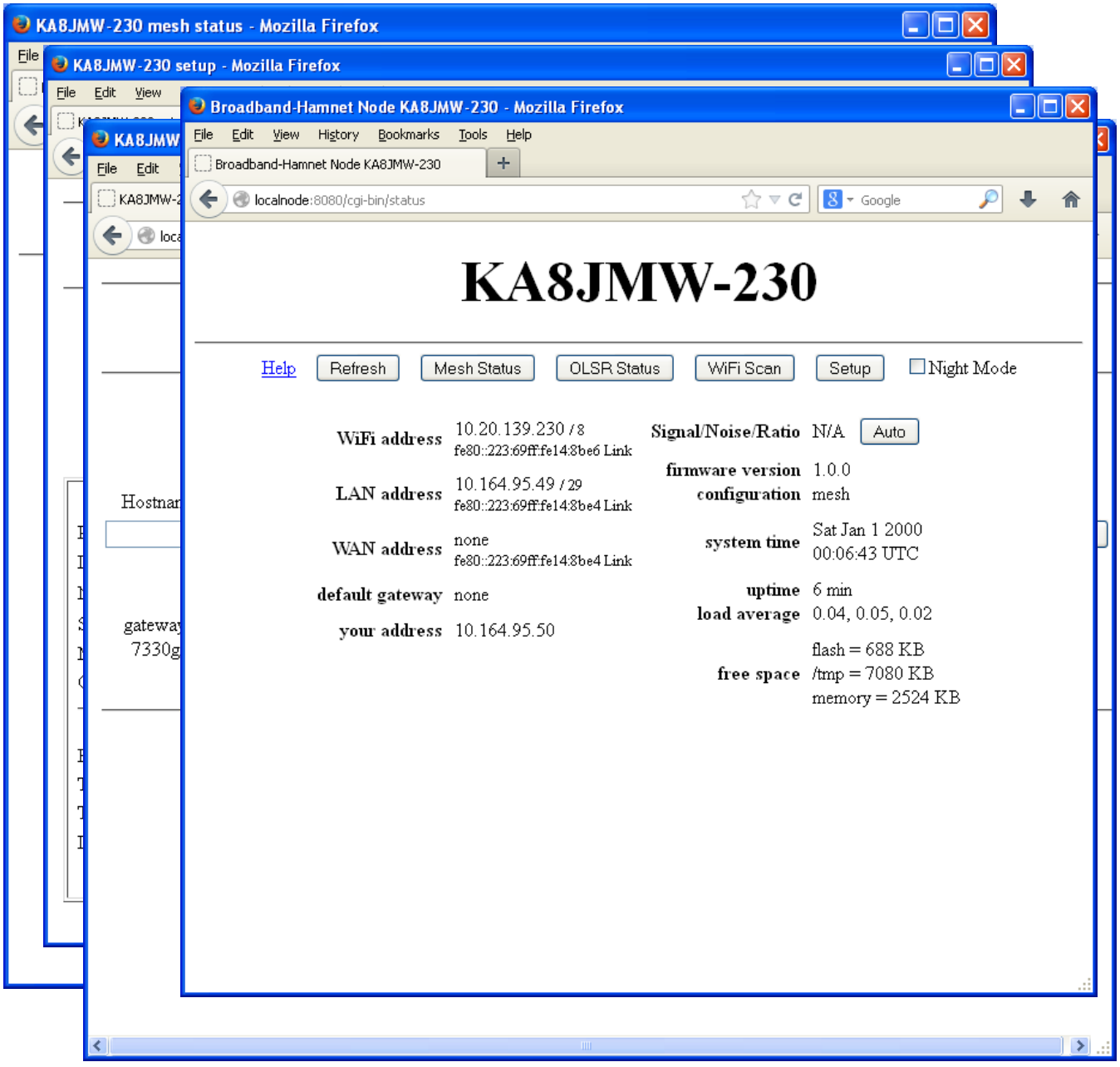
- Repurposed home router
- Inexpensive (~**$25 on Ebay**) and readily available
- “Stock” RF Power (**75 mW-250 mW**)
- 12VDC Power
- Modified Firmware
  - **BBHN**
  - OpenWRT
  - DD-WRT

July 2013 QST



BBHN Status Page

BBHN software has a robust, Browser based user interface to setup and manage the MESH node.



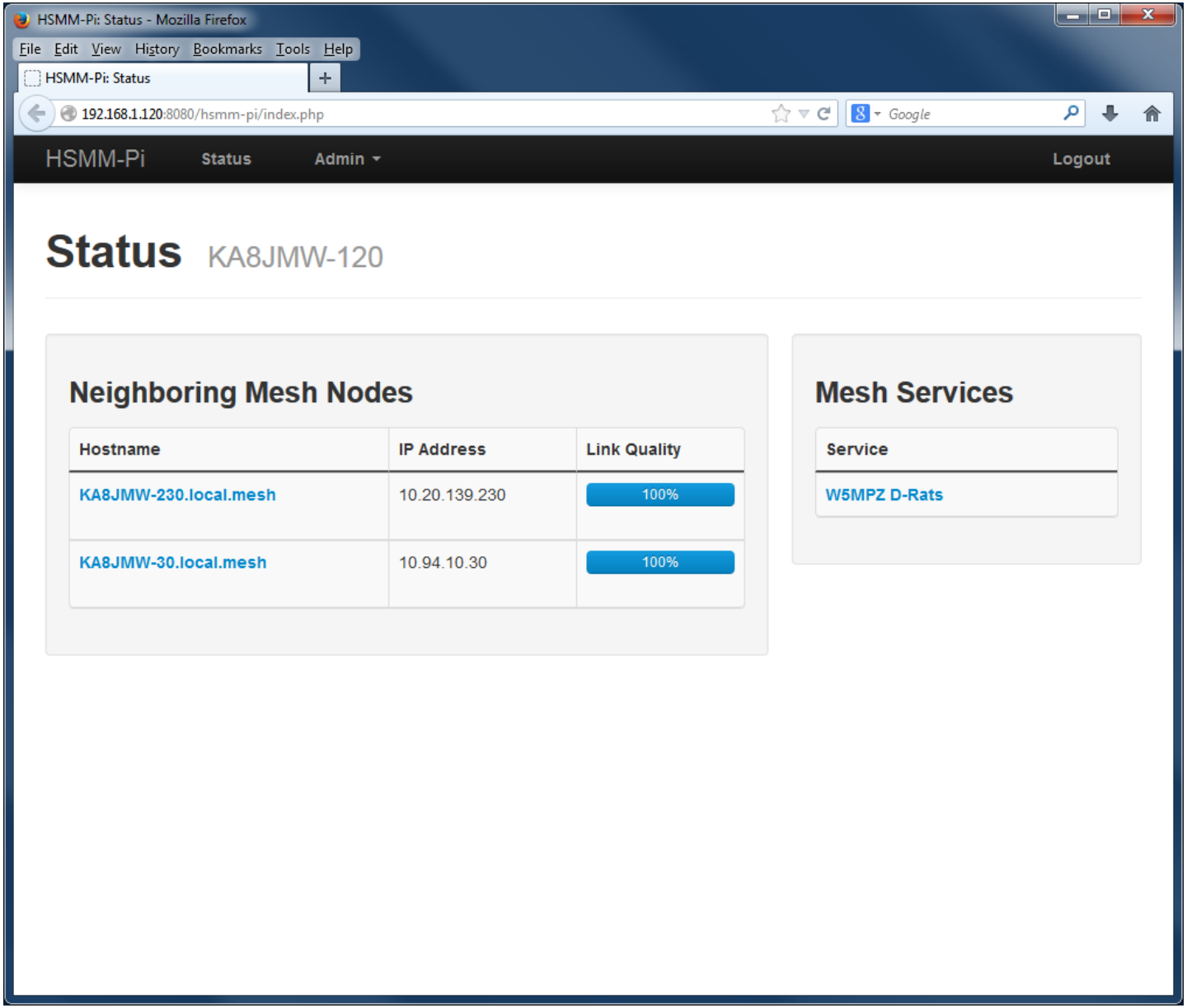
MESH Networking on the Raspberry Pi

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

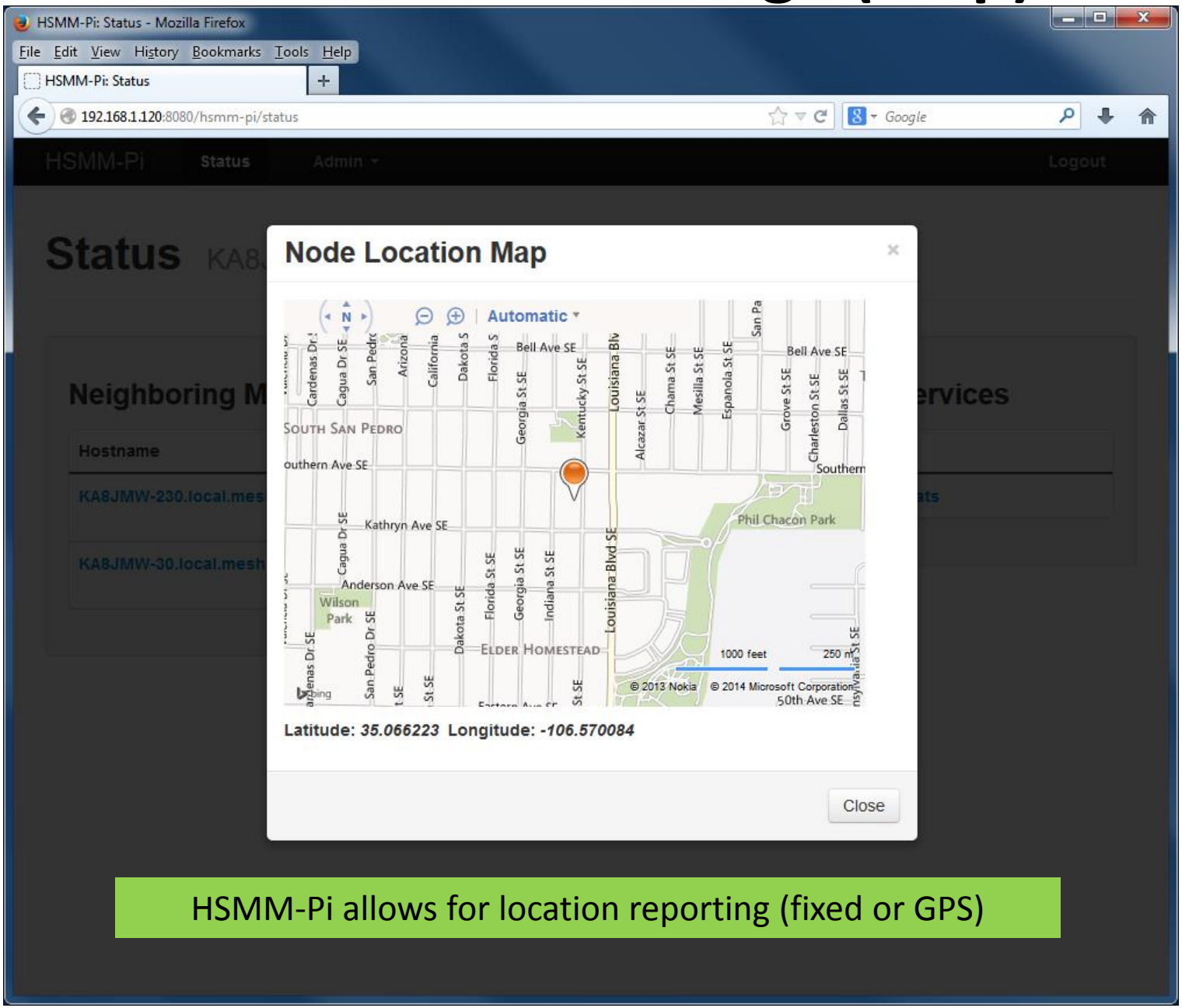
- Can be simultaneously used for other applications since this is an actual computer, not just a router

https://github.com/urlgrey/hsmm-pi
https://plus.google.com/communitie/HSMM-PI

HSMM-Pi Status Page



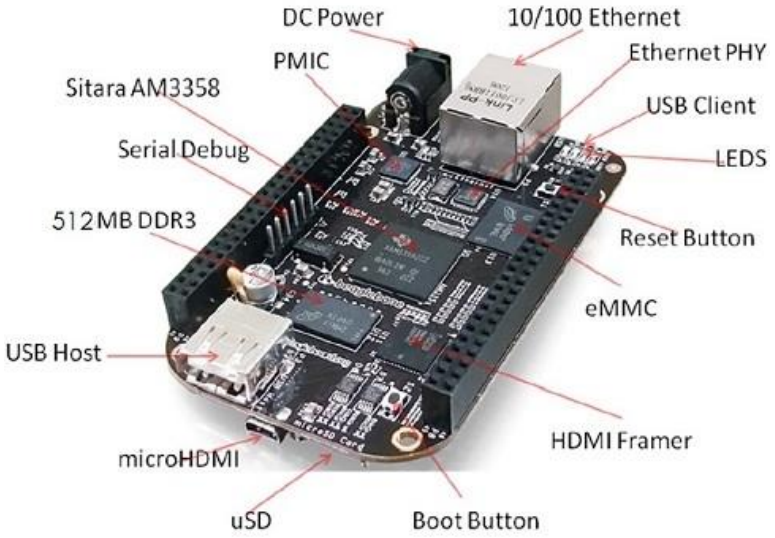
HSMM-Pi Status Page (map)



HSMM-Pi allows for location reporting (fixed or GPS)

Other Platforms
Now Capable of running BBHN Compatible Software

BeagleBone Black
Single board computer
Running Linux



Laptop computer running Ubuntu can used simultaneously both as mesh node and workstation

Newly Supported BBHN Devices

- **Ubiquiti 2.4GHz**
  - **Bullet M2 HP, $73 + antenna**
  - **AirGrid M2 HP, $59**
  - **NanoStation Loco M2, $79**
  - **Rocket M2, $79 + antenna**
- **Beta testing complete**
  - **2/1/2014 software release**
- **Evaluating M3 & M5 devices.**

Prices Jan 2014, Baltic networks www.balticnetworks.com

Linksys WRT1900AC

- Dual-Band (2.4 and 5 GHz)
  - 600Mbps on 2.4Ghz
  - 1.3Gbps on 5GHz
- 4 antennas
- Beam forming Technology
  - Focuses signal to the device for optimal performance
- USB Port
- eSata Port
  - Add external storage or other devices to share across your network
- 4 Gigabit Ethernet Ports
- 1.2GHz Dual-core ARM Processor
  - 128MB Flash memory
  - 256MB DDR3 RAM
- Open Source Firmware

Debuted at CES, Jan 2014

http://www.linksys.com/wrt1900AC

Extending Your Range

2.4 GHz bi-directional amplifier

TX: 24 dB typical

RX: 15 dB typical

TP-Link
15dBi omni
$50 ebay

NOTE: Beware of questionable, inexpensive amps peddled on eBay and elsewhere. Wi-Fi modulation requires linear amplification, which implies amplifier will generate heat in operation. If amp doesn't have a heat-sink to dissipate heat produced by PA, it may be an unreliable knock-off.

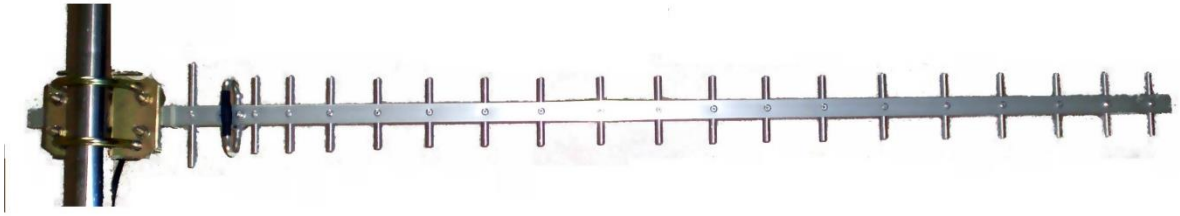
More Antennas

Phased Array
19 dBi gain

Parabolic Dish
18dBi and up

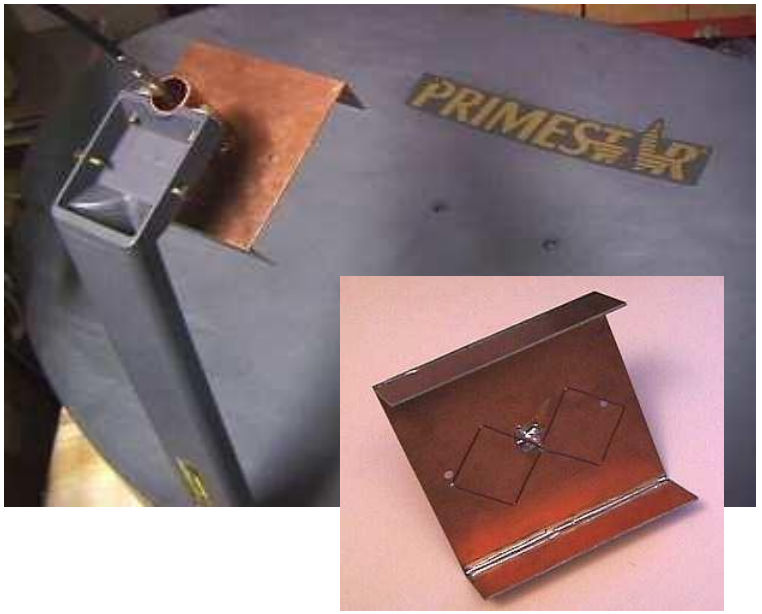
Parabolic Dish/Grid
24 dBi gain

Yagi 14 – 25dBi



Homebrew Antennas

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



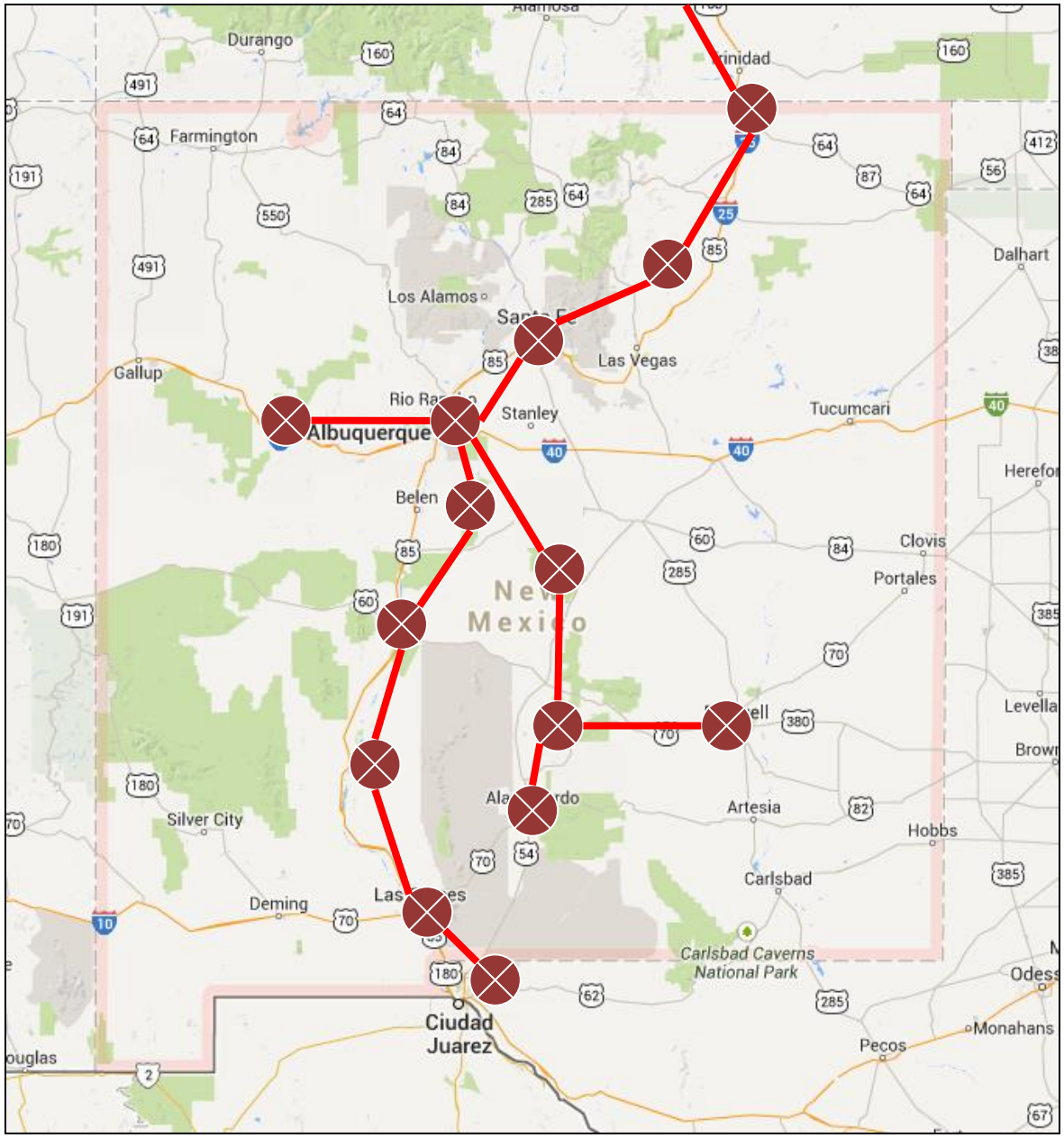
Bi-quad attached to DSS dish
~27-31 dBi gain

Reported 2.4 GHz Broadband Range Tests

- **134 miles across open ocean in Italy**
- **79 miles in the California Coastal Mountains**
- **34 miles per leg in the Shenandoah valley**
- **18 miles to the edge of space (BLT-26, Aug 2010)**
- **10 miles across Austin, TX**

A WRT54GL with stock antenna and firmware typically operates out to approximately 300 feet

An Exciting Project in the Works…

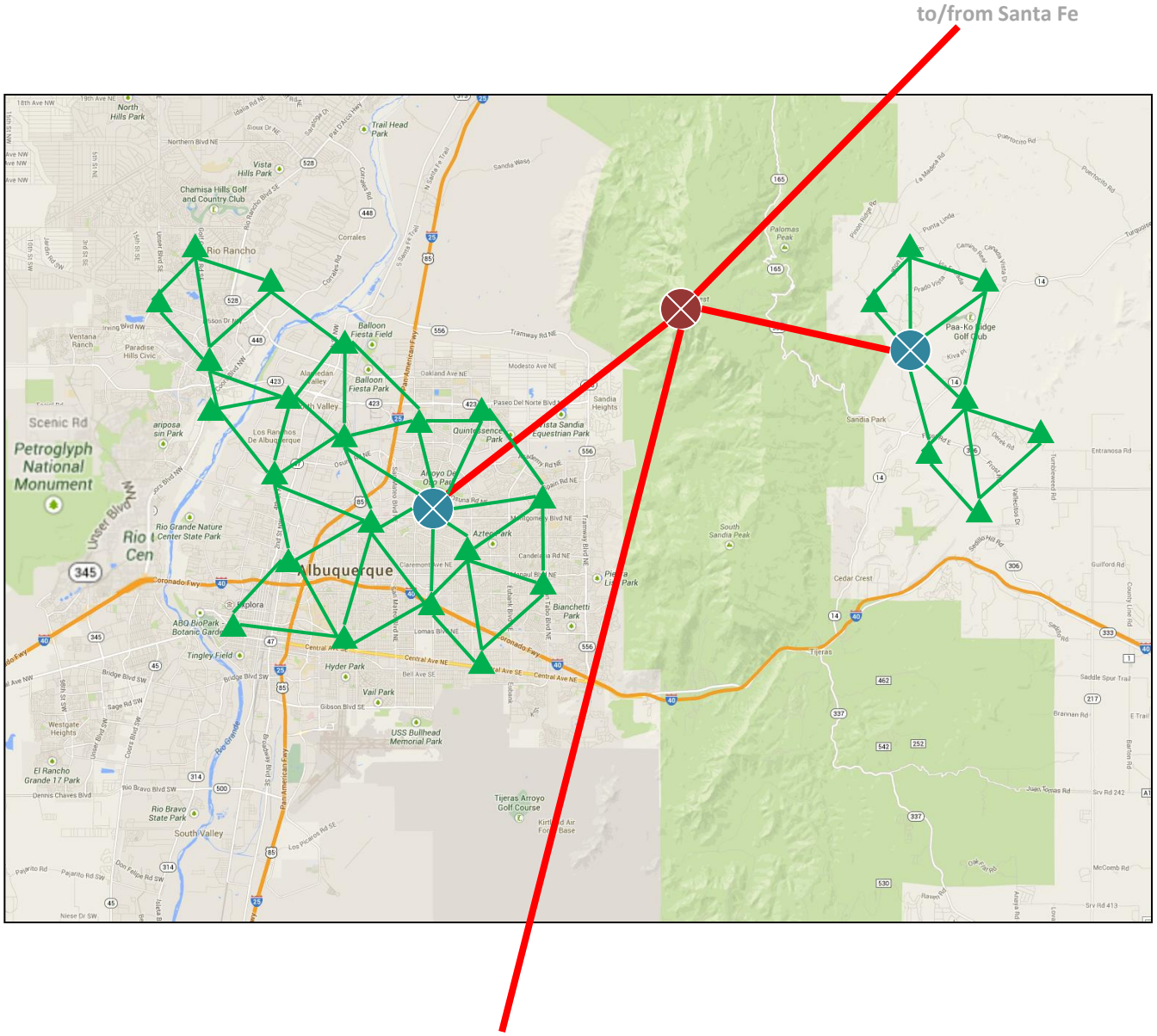


-- Announced at Socorro hamfest
-- Site planning and link analysis in progress
-- All equipment for proof of concept platform and first backbone span purchased, currently being bench tested
-- Installation of first span expected Feb/Mar

= Ubiquiti/Mikrotik 100-Mbit/sec point-to-point microwave system (COTS)

Rocky Mountain Ham Radio

An Exciting Project in the Works…



= Ubiquiti/Mikrotik 100 Mbit/sec P2P backbone (COTS)

= 2.4 GHz 5+ Mbit/sec MESH-PI, HSMM-MESH nodes

= Local mesh to backbone gateway/server

To Learn More

NM-MESH email listserve

- **A state-wide resource for collaboration, experimentation, Q&A, etc.**
- **Growing number of subscribed members across New Mexico and west Texas**
  - **Prospective and curious mesh users**
  - **Current mesh users**
  - **Experimenters**

Visit http://groups.yahoo.com/neo/groups/nm-mesh/

Who wants to come out and play?

Join the NM-MESH email listserve

Questions/Discussion

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 29 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 can be reached via email at ka8jmw@arrl.net

ARRL 100 YEARS

Speaker Bio

Brian Mileshosky N5ZGT was first licensed at the age of 12 in 1992. Twenty one 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