Broadband Mesh Networking and Amateur Radio

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Presentation to
High Desert Amateur Radio Club
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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

<table>
<thead>
<tr>
<th>Channel</th>
<th>Center Frequency</th>
<th>FCC Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.402 GHz</td>
<td>Part 97</td>
</tr>
<tr>
<td>0</td>
<td>2.407 GHz</td>
<td>Part 97</td>
</tr>
<tr>
<td>1</td>
<td>2.412 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>2</td>
<td>2.417 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>3</td>
<td>2.422 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>4</td>
<td>2.427 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>5</td>
<td>2.432 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>6</td>
<td>2.437 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>7</td>
<td>2.442GHz</td>
<td>Part 15</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>2.462GHz</td>
<td>Part 15</td>
</tr>
</tbody>
</table>

9cm

Amateur Radio 9cm band

Licensed Users

AMSAT

Part 15 - 802.11b/g

Broadband Hamnet
### IEEE 802.11a & 5.8 GHz Ham

<table>
<thead>
<tr>
<th>Channel</th>
<th>Center Frequency</th>
<th>FCC Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>132</td>
<td>5.660 GHz</td>
<td>Part 97</td>
</tr>
<tr>
<td>136</td>
<td>5.680 GHz</td>
<td>Part 97</td>
</tr>
<tr>
<td>140</td>
<td>5.700 GHz</td>
<td>Part 97</td>
</tr>
<tr>
<td>149</td>
<td>5.745 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>153</td>
<td>5.765 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>157</td>
<td>5.785 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>161</td>
<td>5.805 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>165</td>
<td>5.825 GHz</td>
<td>Part 97 &amp; Part 15</td>
</tr>
<tr>
<td>169</td>
<td>5.845 GHz</td>
<td>Part 97</td>
</tr>
<tr>
<td>173</td>
<td>5.865 GHz</td>
<td>Part 97</td>
</tr>
<tr>
<td>177</td>
<td>5.885 GHz</td>
<td>Part 97</td>
</tr>
<tr>
<td>180</td>
<td>5.905 GHz</td>
<td>Part 97</td>
</tr>
</tbody>
</table>

#### Amateur Radio 5cm band

- **Part 15 - 802.11a**
- **Radar**
- **Part 15 - 802.11a**
- **ISM**
- **Broadband Hamnet**
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

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

[GitHub link](https://github.com/urlgrey/hsmm-pi)
[Google Community link](https://plus.google.com/communitie/HSMM-PI)
HSMM-Pi Status Page

![HSMM-Pi Status Page](image)

### Status

**KA8JMW-120**

<table>
<thead>
<tr>
<th>Neighboring Mesh Nodes</th>
<th>Mesh Services</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hostname</strong></td>
<td><strong>IP Address</strong></td>
</tr>
<tr>
<td>KA8JMW-230.local.mesh</td>
<td>10.20.139.230</td>
</tr>
<tr>
<td>KA8JMW-30.local.mesh</td>
<td>10.94.10.30</td>
</tr>
</tbody>
</table>
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 use 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

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.

TP-Link
15dBi omni
$50 ebay
More Antennas

- **Phased Array**
  - 19 dBi gain

- **Parabolic Dish**
  - 18 dBi and up

- **Parabolic Dish/Grid**
  - 24 dBi gain

- **Yagi**
  - 14 – 25 dBi
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)
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

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Rocky Mountain Ham Radio

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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/](http://groups.yahoo.com/neo/groups/nm-mesh/)
Who wants to come out and play?

Join the NM-MESH email listserv

Questions/Discussion
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
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