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## Wi-Fi / MESH Networking

A Hands-on Workshop



Santa Clara County ARES®/RACES

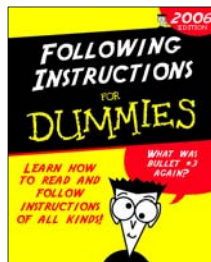
18 June 2016

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## Housekeeping

- Refreshments
- Pen/pencil & paper
- Cell phones & pagers
- Side conversations
- Questions
- Breaks
- Restrooms
- In case of emergency



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## Agenda

- 0900: Introductions, Logistics
- 0910: Network Basics
- 0925: *Hands-on Exercise #1* – Looking at your Network Configuration
- 0945: Basic Network equipment
- 0955: *Hands-on Exercise #2* – Cable Inspection
- 1010: A first look at Mesh Networking
- 1030: *Hands-on Exercise #3* – Checking out the Mesh Node configuration
- 1100: VoIP Telephony
- 1110: *Hands-on Exercise #4* – VoIP Phone Configuration
- 1140: Building your own Station
- 1200: Close

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## Opening Comments

- This class will not make Network Engineers out of you.
- Hope to spark an interest to enable you to take the next step.
- Mesh and Mesh Networking is a very compelling system.
- Most importantly, what are the opportunities for applying a Mesh Network Solution to a public service or emergency response?

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## Pre-work

1. Review the material titled "Introduction to Mesh Networks for Amateur Radio"  
[http://www.scc-ares-races.org/mesh/preso/Intro\\_To\\_Mesh\\_Ham\\_v150302.pdf](http://www.scc-ares-races.org/mesh/preso/Intro_To_Mesh_Ham_v150302.pdf)
2. Download and install the program Angry IP Scanner  
<http://angrrip.org/download/> (available for Linux, MAC, Windows)

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## 1. Network Basics

**Topics**


1. Types of networks
2. Network device addressing
3. *Hands on exercise!*

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## What is a network?

### 1. Network Basics

- A **computer network** consists of two or more computing devices that are connected in order to share resources and the information you store there.




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## Personal Area Networks

### 1. Network Basics

- A PAN is the smallest network which is personal to a user.
- may include Bluetooth enabled or infra-red enabled devices.
- has a connectivity range up to 10 meters.
- PANs may include wireless computer keyboard and mouse, Bluetooth enabled headphones, wireless printers, & TV remotes.

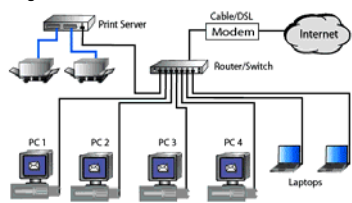


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## Local Area Networks

### 1. Network Basics

- Usually confined to a limited geographic area, such as a single building or a college campus.
- The number of systems connected in LAN may vary from as few as two to as many as 16 million.
- A LAN provides a way of sharing resources between end users.
- LANs are made up of inexpensive networking and routing equipment.
- A LAN can be wired, wireless, or a mix of both.
- LANs mostly operate on private IP addresses.

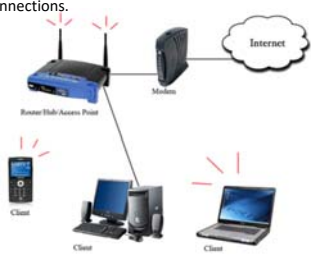


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## Wireless Local Area Networks

### 1. Network Basics

- Wireless LANs, use radio frequency (RF) technology to transmit and receive data over the air.
- Minimizes the need for wired connections.
- Wireless LANs give users mobility without having to be physically connected by a cable.

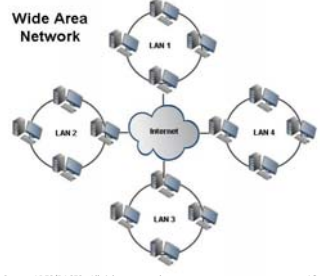


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## Wide Area Networks

### 1. Network Basics

- Combine multiple LANs that are geographically separate.
- Connects several LANs with fiber optic or dedicated leased lines such as, T3, by dial-up phone lines, by satellite links or by data packet carrier services.
- Since they are equipped with a very high speed backbone, WANs use very expensive network equipment.



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## The Internetwork

### 1. Network Basics

- A network of networks is called an *Internetwork*, or the **Internet** for short... the largest network in existence.
- The internet connects all WANs, and can have connections to LANs and Home networks.
- The Internet uses the TCP/IP protocol suite and uses IP as its addressing protocol.
- What is IP?

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## Network Addressing

### 1. Network Basics

**Address:** what every networkable device needs. There are 2 address attributes of which you should be aware...

1. **IP address** – Internet Protocol address, a unique numerical label assigned to each device on a network.
  - IPv4: Format is like 192.168.1.055, range to ~4.3b (32 bits)
  - IPv6: Format is like 2001:db8:0:1234:0:567:8:1, range to  $3.4 \times 10^{38}$  (128 bits)

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## Network Addressing

### 1. Network Basics

2. **MAC Address** – a.k.a. *Hardware Address* or *Physical Address*. Every Network Interface Card (NIC) has a hardware address that's known as a MAC (Media Access Control) address.
  - A MAC address is a unique identifier assigned to a network interface when it is manufactured. It is stored in the NIC's hardware, such as the card's read-only memory or other firmware.
  - The ARP (Address Resolution Protocol) maps an IP address to a MAC address.
  - MAC Address formats look something like 00:0a:95:9d:68:16.

Manufacturer's 6 digit code  
Unique 6 digit number

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## Network Addressing

### 1. Network Basics

#### Addressing take-away's

- 2 address attributes to remember:
  - IP Address: 192.168.1.73
  - MAC address: 24-BE-05-BB-E1
- **Why do I need to know this?**
  - Each mesh node is essentially its own LAN with its own Local IP Addressing scheme.
  - Servers typically get static IP addresses assigned so they are **easy to find**. Being able to find a device's IP address from its physical MAC address will help you do that.
  - Clients (user PCs) usually get dynamic addresses so they are **easy to configure**. Your PC may be assigned a different IP address depending on which node you plug in to.

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## Hands On! Exercise #1

A look at addressing

#### What you need:

1. PC running Windows
2. Can join on a wireless network
3. The program "Angry IP Scanner" loaded on your PC

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## 2. Basic Network Equipment

#### Topics

1. Hubs, Switches, and Routers
2. Ethernet Cables
3. *Hands on exercise!*

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### Hubs

#### 2. Basic Network Equipment

- **Hubs:** Hubs are commonly used to connect segments of a LAN. A hub contains multiple ports.
  - Hubs are multi-port repeaters that repeat everything they hear.
  - When a packet arrives at one port, it is "broadcast" to all of the ports on this hub.
  - Only one machine can talk through the Hub at a time.
  - Hubs are not very common anymore

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### Switches

#### 2. Basic Network Equipment

- **Switches:** Switches are commonly used to connect segments of a LAN and contains multiple ports.
  - Multiple machines can talk through a switch at the same time.
  - Switches keep a record of the MAC addresses of all devices connected to it and identifies which system resides on which port.
  - When a data frame is received, it knows exactly which port to send it to.

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### Routers

#### 2. Basic Network Equipment

- **Routers:** Routers are completely different devices and are used to tie multiple networks together.
  - Routers make forwarding decisions based on the network address
  - Routers connect networks and forward data packets between them.
  - A wide variety of services are integrated into most broadband routers, such as DHCP.
  - Many routers also include multiple connect ports, essentially acting as a *switch* for local devices as well.

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### Ethernet Cables

#### 2. Basic Network Equipment

- **Ethernet Cables:** the standard cables used to connect network equipment (switches, routers, computers, printers, etc.) together.
- The cable is typically a 8 conductor twisted pair, with an RJ-45 connector on each end.

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### Ethernet Cables

#### 2. Basic Network Equipment

- Ethernet cables have different specs for interference shielding, data transmission speed, and bandwidth.
- With each successive category, there has been an increase in data transmission speed and bandwidth.
  - **Cat5:** A little older and slower; support speeds up to 100Mbps. Cable type is UTP<sup>1</sup>.
  - **Cat5e:** Faster with less interference; speeds up to 1000 Mbps "gigabit", cuts down on crosstalk, cable type is UTP.
  - **Cat6:** Even Faster; stricter interference specifications, speeds up to 10-Gigabit, cable type is UTP or STP<sup>2</sup>.
  - **Cat7:** Even Faster still, but...; even stricter specs; thicker, more bulky, harder to bend, cable type is SSTP<sup>3</sup>.

1. UTP = Unshielded Twisted Pair
2. STP = Shielded Twisted Pair
3. SSTP = Fully Shielded Twisted Pair

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### Ethernet Cables

#### 2. Basic Network Equipment

- **Typical CATEGORY Cables:** 4 pairs of twisted wires for carrying signals; used in structured cabling for computer networks such as Ethernet.

**Patch (straight-thru) Cable.** These cables have the same type of connector standard at both ends and are the standard cable used for almost all purposes.

**Crossover Cables.** These cables are used to connect similar devices together, like a computer to a computer, or a switch to a switch.

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## Ethernet Cables

### 2. Basic Network Equipment

#### What cable do I have?

- On most cables, you should be able to find the label printed on the outside surface of the cable.



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## Ethernet Cables

### 2. Basic Network Equipment

#### Cable take-away's

- You need a CAT cable with all 4 pairs for Power over Ethernet (PoE) to work.
- If you already have a CAT5 with 4 pairs, that will work.
- If you are buying new, CAT5e or CAT6 will work fine.
- A higher performance cable will not result in more throughput.
- Network performance will be gated by the slowest device in your data path (PC -> cable -> switch/router -> <medium> -> server).
- CAT5 cables will easily support Mesh Node data rates.

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## Hands On! Exercise #2

#### What you need:

- Ethernet cable

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## 3. A Look at Mesh Networking

#### Topics

- Network Topology
- Introduction to Mesh Networking
- Rules and Limitations of Mesh
- WiFi Channels
- Hardware
- Software
- Who's using Mesh Networking
- Hands on exercise!*

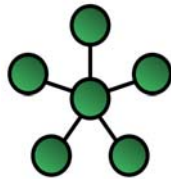
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## Network Topology

### 3. A Look at Mesh Networking

- Topology** describes how the various members (nodes) of a network are connected together.
  - Most small networks (your office, your home) use a *star topology*, with a central node (a switch/router) connected to a bunch of clients (your laptop, smartphone, Xbox, etc.).
  - The star topology implies that if one client wants to talk to another, the data must go through the central point (the router).



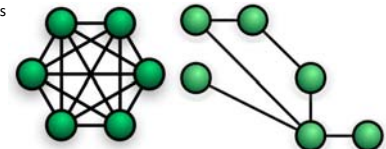
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## Mesh Network Topology

### 3. A Look at Mesh Networking

- Mesh Network Topology**
  - A mesh is when multiple nodes are connected to multiple other nodes.
  - Full-mesh is when every node connects to every other node.
  - Partial mesh is something less than that, but more than something else.
- If a node goes down, there are other paths that can move the message along.



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### Broadband-Hamnet™

3. A look at Mesh Networking

**Introduction**

- **Amateur radio mesh data network:** Built using re-purposed commercial hardware flashed with amateur radio-specific firmware (Linksys WRT54 series, Ubiquiti, Raspberry Pi).
- **Regular Ham bands:** Wireless links can be established in the 900 Mhz, 2.4GHz and 5.8GHz bands.
- **High-speed:** 54Mbps digital data network using the IEEE 802.11g standard on 2.4GHz.

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### Broadband-Hamnet™

3. A look at Mesh Networking

**Introduction (continued)**

- The BBHN mesh network is...
  - **Self discovering:** It automatically discovers its neighbors.
  - **Self configuring:** It automatically determines which neighbors it can reach directly vs. which neighbors are reached with one or more hops.
  - **Self healing:** If one node goes down, traffic is automatically re-routed through a different path.

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### Broadband-Hamnet™

3. A look at Mesh Networking

**Introduction (continued)**

- Rules and limitations
  - **Falls under Amateur Radio Service:** With limitations set by the service, like high power!
  - **No Encryption:** Communications cannot be encrypted, as is the case for all amateur radio communications.
  - **Risk of hackers:** From those who understand mesh networks and OLSR (Optimized Link State Routing).
    - !! As a Precaution !!**
      1. Do not connect your mesh network directly to your home network!
      2. Make sure your PC anti-virus and firewall are working correctly.

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### Overlaying the Ham Bands

3. A look at Mesh Networking

Picture is an approximation of channels and frequencies

- 2.4GHz WiFi Band, Channel 1 is the BBHN Standard

Also,

- 5.8GHz Wi-Fi Band, Channels 132-165
- 900MHz; Full Band

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### BBHN Hardware

3. A look at Mesh Networking

**Linksys, WRT54G**

- Repurposed home router - 2.4GHz (13 cm band)
- Its just a small Linux computer with router and Wi-Fi built in
- Inexpensive – around \$25 on eBay and readily available
- But! You CANNOT buy the ones that we need new.
- 12 VDC Power

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### BBHN Hardware

3. A look at Mesh Networking

**Ubiquiti**

- Multiple models supported
  - Rocket M2
  - BulletM2
  - AirGrid M2
  - NanoStation Loco M2
  - NanoStation M2
- Moderate cost; readily available
- 24 VDC Power
- higher power, outdoor ready, and readily available from multiple vendors

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### Network Software

3. A look at Mesh Networking

**Sorting out the software**

- BBHN: Find and download the firmware <http://www.broadband-hamnet.org/software-download.html> ← What we use in SCC RACES... today
- AREDN: Find and download the firmware <http://www.aredn.org/content/software>
- Raspberry Pi: See the details here... <https://github.com/ur1grey/hsmm-pi>

**Whatever you decide...**

- Understand any compatibility issues with your local organization
- Be very careful to pick the correct download. Installing the wrong firmware may *BRICK* your device.

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### Who is using Broadband Hamnet?

Santa Clara County RACES Exercise, April 2015

No Commercial Power Anywhere

**Participant Tasks:**

- 1) Deploy station in the field (no commercial power)
- 2) Establish WiFi /Mesh connectivity
- 3) Establish VoIP (telephone) connectivity
- 4) Establish WWW connectivity
- 5) Establish Video connectivity
- 6) Establish Online Chat connectivity
- 7) Establish FTP connectivity
- 8) Establish File Sharing connectivity
- 9) Establish Output/Telnet connectivity to BBS

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### Who is using Broadband Hamnet?

BBQ Festival, Milpitas, May 2015

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### Who is using Broadband Hamnet?

Sheriffs Heroes Fun Run, Cupertino, November 2015

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### Who is using Broadband Hamnet?

Austin Texas

[www.BBHN.org](http://www.BBHN.org)

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### Hands On! Exercise #3

Getting to know your Linksys router

**What you need:**

1. PC that can get on a network
2. Ethernet cable
3. A mesh node with power

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## Getting started with VoIP Telephony

### 4. VoIP Phone

**Topics**

- Introduction to VoIP Phones
- Configuring your phone
- Wireless Clients & VoIP apps
- *Hands on exercise!*

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## Getting started with VoIP Telephony

### 4. VoIP Phone

- All VoIP phones basically operate the same once connected to a phone system.
- VoIP phones do 2 things after power is applied to them:
  - Register with the router to get an IP address... gets you the dial tone.
  - Register with the PBX... now you can make a call.






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## Configuring your VoIP Phone

### 4. VoIP Phone

- VoIP Phones are Internet Devices.
- VoIP Phones connect to a router.
- Most VoIP phones have an embedded web server as the user interface for configuring the phone.
- To get to the VoIP phone's user interface, you need to know it's... **IP Address!**



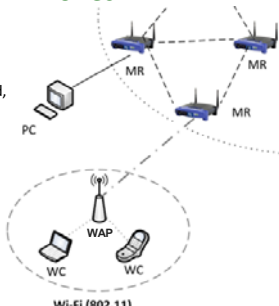
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## Wireless Clients & VoIP Phones

### 4. VoIP Phone

**Final thoughts on wireless clients**

- Wireless devices (such as an Android, iPhone) do not connect directly to a mesh network.
- Wireless devices access the mesh network through a Wireless Access Point (WAP).
- The Mesh network operate on WiFi Channel 1.
- A WAP will find a different Wi-Fi channel (6 or 11) for wireless client access.



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## Hands On! Exercise #4

### Setting up your VoIP Phone

**What you need:**

1. PC that can get on a network
2. Ethernet cable
3. A mesh node with power
4. VoIP Phone (Zully's)
5. Optional: iPhone or Android with the app *media5-fone*

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## Where do we go from here?

### 5. Building your own System

**Topics**

1. **Indoor, Outdoor deployment**
2. **Power management**
3. **Deployments in terms of users**

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### Example #1 – Indoor Mesh Node, Linksys

#### 5. Building your own System

- Mesh in a box
- Ideal for close-proximity multiple workstations where network end-user phone support is needed
- Allows additional router ports for laptops, IP cameras, WAPs, or other network devices.

1. Ethernet cables
2. Router, VoIP Phone
3. Power: batteries, power cables

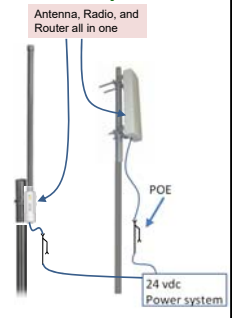


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### Example #2 – Outdoor Mesh Node, Ubiquiti

#### 5. Building your own System

- Ubiquiti devices offer a weather proof package, no or minimal RF cable loss, and relatively easy mounting.
- These devices are available in 2.4 GHz (M2), 3.4 GHz (M3), 5 GHz (M5), and 900 MHz (M900) frequencies.
- They all use Power-Over-Ethernet (POE) via a CAT 5 data cable.
- **Omni-Antennas:** best choice to avoid the hidden transmitter problem.
- **Directional Antennas:** not recommended for mesh **UNLESS** you are certain that you're at the edge of your operating area.



Antenna, Radio, and Router all in one

Ubiquiti Bullet M2 Omni-directional Recommended

Ubiquiti Nano Loco M2 Directional NOT recommended


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### Its all about the power


#### 5. Building your own System

#### Power considerations

- Battery = 11.0v - 13.8v  
7 Ah works, 18Ah is better
- Ubiquiti = 24.0v
- Linksys router = 11.0v - 13.8 v
- Zultys Zip2 = 11.0v - 13.8 v
- Zultys Zip2+ = 7.0v
- WebCam = 5.0v



DC-DC Converter, 12vdc - variable

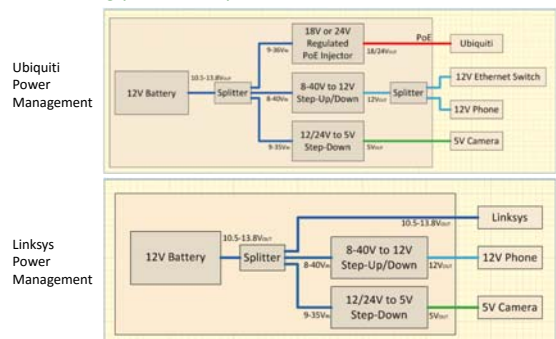


DC-DC Converter, 12vdc - 24vdc

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### Its all about the power

#### 5. Building your own System



Ubiquiti Power Management

Linksys Power Management

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### Need more details?

#### 5. Building your own System

- Power Options for Field Deployment.  
[http://www.scc-ares-races.org/mesh/doc/Power\\_Options\\_for\\_Field\\_WiFi\\_v150604.pdf](http://www.scc-ares-races.org/mesh/doc/Power_Options_for_Field_WiFi_v150604.pdf)
- Basic Outdoor Wi-Fi Planning  
[http://www.scc-ares-races.org/mesh/preso/Basic\\_WiFi\\_Net\\_Planning\\_v140516.pdf](http://www.scc-ares-races.org/mesh/preso/Basic_WiFi_Net_Planning_v140516.pdf)

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### What's next?

- Build a station that is ready to go!
- Look at how your local emergency responders (public safety, CERT, RACES) get work done. What do they need? What capabilities are missing?
- How would a mesh field deployment fill the gaps?
- Work within your local RACES organization on a field test, and then look for a low key event to try mesh out.
- Join the [scc-mesh@yahoogroups.com](mailto:scc-mesh@yahoogroups.com) to keep tabs on what's going on.
  - Specifically, watch for any discussion (and decisions) on using BBHN versus AREDN.

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Thank you... questions?



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Broadband-Hamnet™  
HSMM-MESH™

- Original developers of firmware for Linksys devices.
- Stated they will maintain software for the Linksys devices.
- No development effort noted on web site since early 2015.



- Ported firmware to Ubiquity M2 devices.
- Split off from BBHN group in early 2015 to form AREDN.
- Has added firmware for other Ubiquity devices M3, M900, M5.
- Stated they will not maintain firmware for Linksys devices due to use of old technology/lack of memory.
- Takes advantage of Ubiquiti MIMO for faster data rates.
- Access to Ham only channels with no Part 15 interference.  
2 channels on 2.4 GHz, 24 channels on 3.4 GHz, 7 channels on 5.8 GHz