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Wi-Fi / MESH Networking

A Hands-on Workshop



Santa Clara County ARES®/RACES

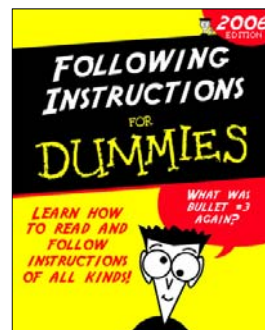
18 June 2016

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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
2. Download and install the program Angry IP Scanner
<http://angryip.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.



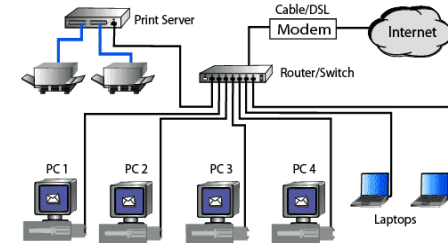
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Local Area Networks

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.



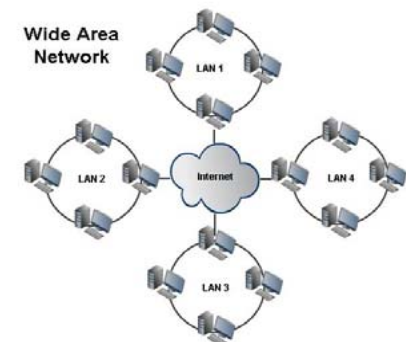
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Wide Area Networks

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 3.4×10³⁸ (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-05-05-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!*

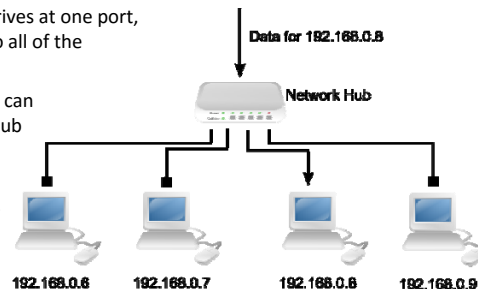
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Hubs

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



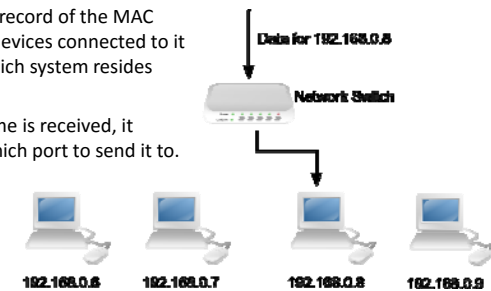
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Switches

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.



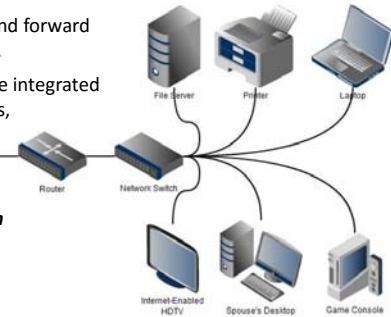
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Routers

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.

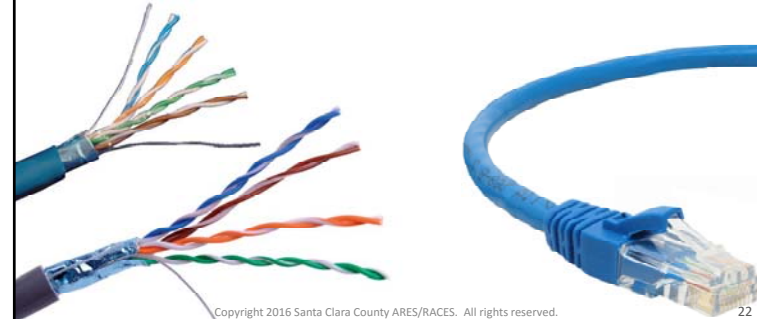


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Ethernet Cables

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 UTP¹.
 - **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 STP².
 - **Cat7: Even Faster still, but...;** even stricter specs; thicker, more bulky, harder to bend, cable type is SSTP³.

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

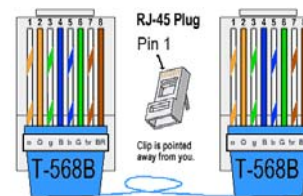
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Ethernet Cables

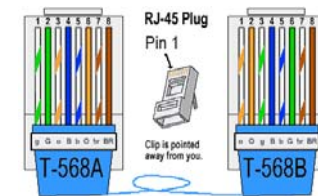
2. Basic Network Equipment

- **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!*

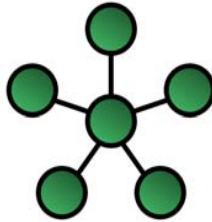
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Network Topology

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).



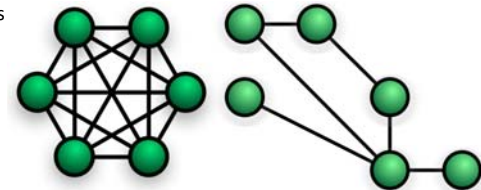
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Mesh Network Topology

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

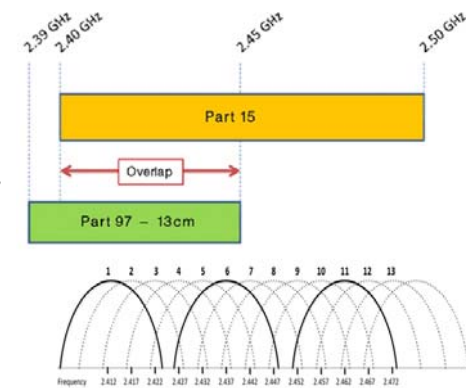
3. A look at Mesh Networking

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>
- AREDN: Find and download the firmware
<http://www.aredn.org/content/software>
- Raspberry Pi: See the details here...
<https://github.com/urlgrey/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.

What we use in SCC RACES... today

←

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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 Outpost/Telnet connectivity to BBS

WiFi / Mesh Participant Stations

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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



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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!*

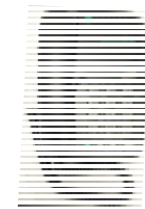
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Getting started with VoIP Telephony

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.



Zully's ZIP2 VoIP Phone



Polycom IP Sound Point



iPhone, Android and the media5-phone app

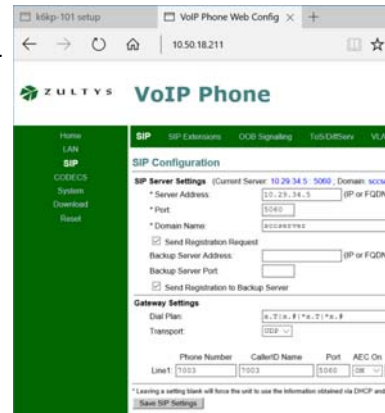
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Configuring your VoIP Phone

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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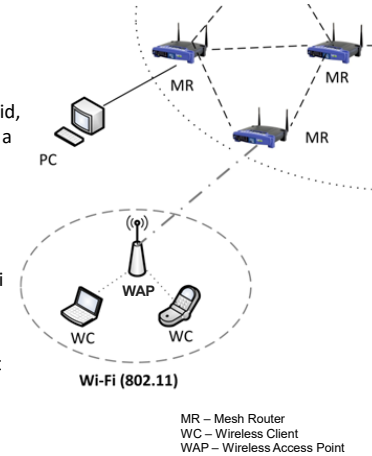
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Wireless Clients & VoIP Phones

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 (Zulty'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 our 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

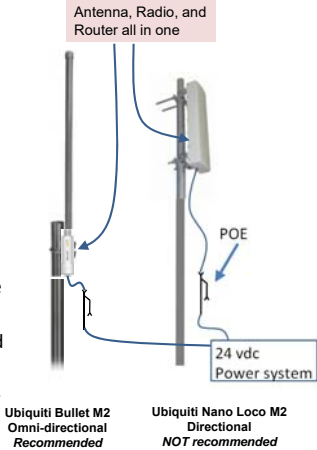


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Example #2 – Outdoor Mesh Node, Ubiquiti

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.



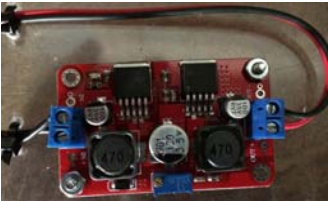
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Its all about the power


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 – 5 vdc

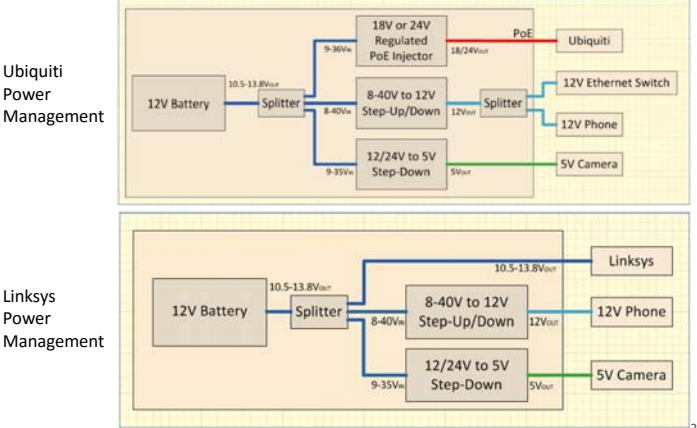


DC-DC Converter, 12vdc – 24vdc

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Its all about the power

5. Building your own System



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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
- Basic Outdoor Wi-Fi Planning
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@yahogroups.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