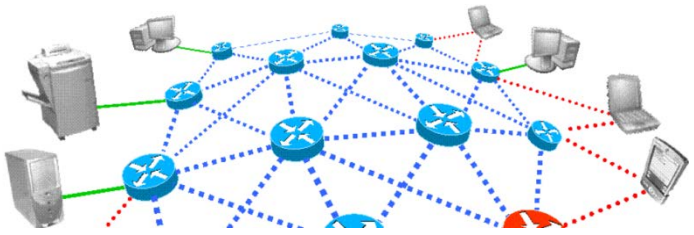
Hands-on MESH Network Workshop

Cupertino ARES/RACES

Date: **23 July 2015**
Version: **1.4**



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0. Pre-study

Before arriving at the workshop, please review the following material:
http://www.scc-ares-races.org/mesh/preso/Intro_To_Mesh_Ham_v150302.pdf

On arrival at the workshop, please do the following:

1. Boot up your PC
2. Enable your wireless networking.
3. Find and connect to the SSID named “Mesh_Workshop”

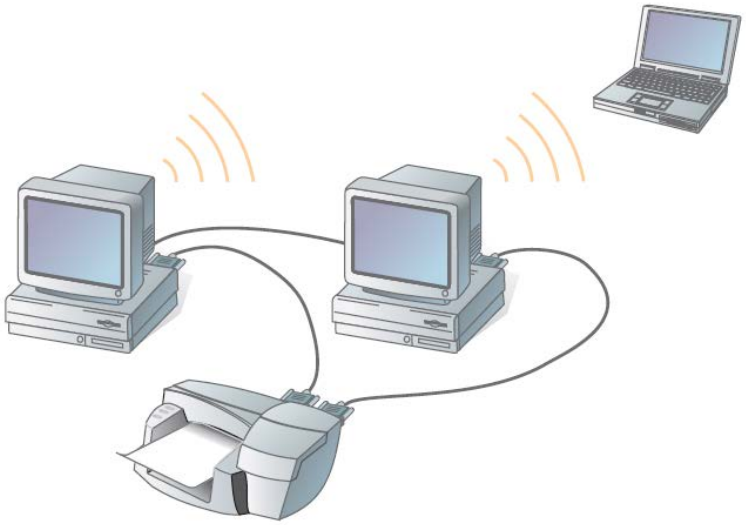
1. Network Basics

What we will cover

1. The definitions of the 6 key address parameters
2. How to determine your IP address, Subnet Mask, Network Address

1.1 What is a network

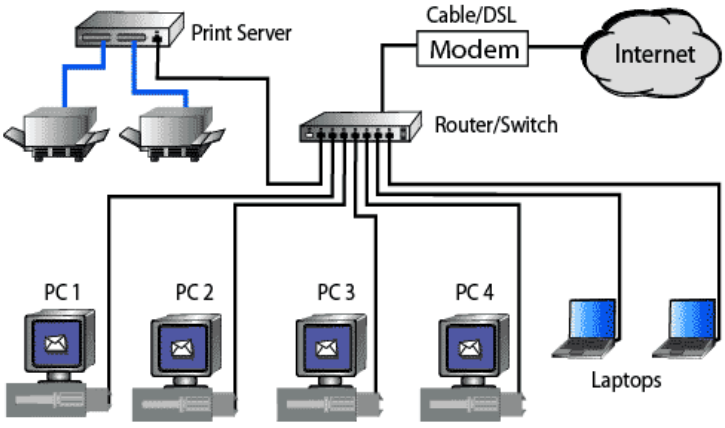
A **computer network** consists of two or more computing devices that are connected in order to share resources and the information you store there.



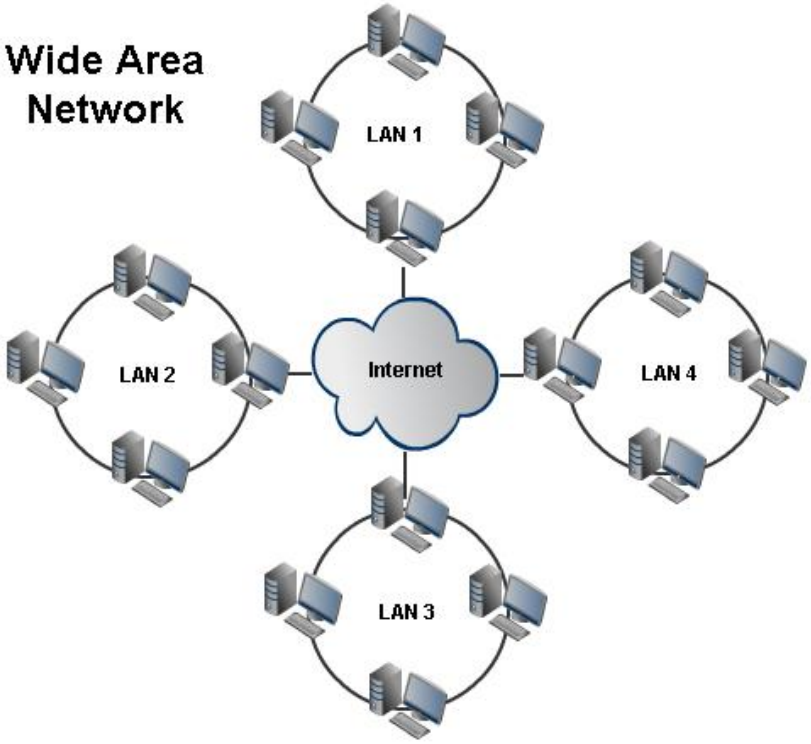
The most basic computer network (which consists of just two connected computers) can expand and become more usable when additional computers join and add their resources to those being shared.

1.2 Types of Networks

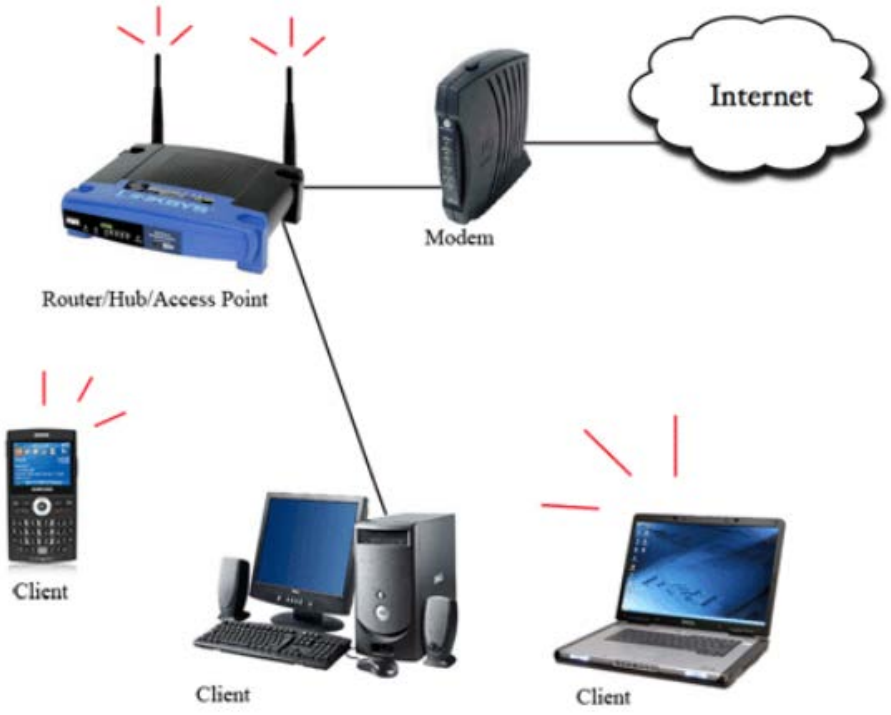
LANs: Local Area Networks are usually confined to a limited geographic area, such as a single building or a college campus. LANs can range from small, linking as few as three computers, to large where they link hundreds of computers used by thousands of people.



WANs: Wide Area Networks combine multiple LANs that are geographically separate. This is accomplished by connecting the several LANs with dedicated leased lines such as a T1 or a T3, by dial-up phone lines (both synchronous and asynchronous), by satellite links and by data packet carrier services.



WLANs: Wireless LANs, or WLANs, use radio frequency (RF) technology to transmit and receive data over the air. This minimizes the need for wired connections. WLANs give users mobility as they allow connection to a local area network without having to be physically connected by a cable.



1.3 Network Addressing

Cell Phone Analogy. You need phone numbers for your phone to connect to another phone. Without phone numbers, your cellphone is essentially a brick.

Addressing: what every networkable device has.

1. IP address – Internet Protocol address, a unique numerical label assigned to each device on a network.
    a. IPv4: Format is like 172.16.254.1, range to ~4.3b (32 bits)
    b. Loopback: for testing. 127.0.0.1 also known as "localhost"
    c. IPv6: Format is like 2001:db8:0:1234:0:567:8:1, range to 3.403×10^{38} (128 bits)
    d. *How to Determine:* Use Windows "ipconfig" command to find it

6. MAC Address – Every NIC (NIC = Network Interface Card) has a hardware address that's known as a MAC, for Media Access Control. MAC address is given to a network adapter when it is manufactured. It is hardwired or hard-coded onto your computer's network interface card (NIC) and is unique to it. Something called the ARP (Address Resolution Protocol) translates an IP address into a MAC address. ARP takes data from an IP address to an actual piece of computer hardware.

    a. Format is like 00:0a:95:9d:68:16.

7. Where do IP Addresses come from?
    a. Static IP address – you pick and set the device's IP address. If you need to always know what your IP address is, then you need a Static IP address because it is constant. Useful for:
        i. Useful for Servers accessible by other clients, like VoIP
        ii. Clients are configured with the above 4 IP address parameters.

    b. DHCP address – Once set up, Routers assigns each computer attached to the router an IP address automatically. Clients are configured to ask for an IP Address.

8. **Addressing Take-Aways:** 2 address characteristics to know:
    a. IP Address: 192.168.1.73
    f. MAC address: 24-BE-05-05-BB-E1

HANDS ON! Exercise #1: Looking at your Network Configuration

This exercise will help you answer 4 questions:

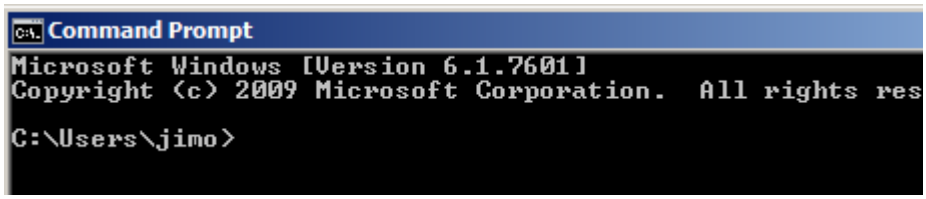
1. Who am I? (network speaking)
2. What's my name?
3. Is my network working?
4. Who else is out there?

NOTE: Make sure you are connected to the wireless network named "Mesh_Workshop"

Step 1 — Run the Program: *cmd*

1. The **cmd** program brings up the Windows Command Line prompt
2. To run cmd, go to Windows Start. Enter **cmd** in the run field or in the "Search programs or files" field.

3. ***Verify*** the Command Prompt window opens, and you are presented with a Prompt (your login followed by a ">").



Step 2 — *WHO AM I?...* Running the Program: *ipconfig*

1. **ipconfig** displays the IP address, subnet mask, and default gateway for all network interfaces you have installed.
2. **Run ipconfig from the cmd prompt. Try these command strings:**
   a. `ipconfig ?` (shows help for ipconfig)
   b. `ipconfig` (displays your network Configuration)

```
C:\Users\jimo>ipconfig

Windows IP Configuration


Ethernet adapter Bluetooth Network Connection:

   Media State . . . . . . . . . . . : Media disconnected
   Connection-specific DNS Suffix  . :

Ethernet adapter Local Area Connection:

   Connection-specific DNS Suffix  . : attlocal.net
   IPv6 Address. . . . . . . . . . . : 2602:306:3970:90d0:d62:5b89:45
   Temporary IPv6 Address. . . . . . : 2602:306:3970:90d0:fd05:bcd9:2
   Link-local IPv6 Address . . . . . : fe80::d62:5b89:451a:1212%13
   IPv4 Address. . . . . . . . . . . : 192.168.1.82
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : fe80::221:7cff:fea8:13c1%13
                                       192.168.1.254
```

(Example; partial listing shown here, your listing will be different)

Step 3

1. After running ipconfig, Review the listing, and…
    a. Find your IP Address (IPv4 version) _____

Step 4

1. Run **ipconfig** from the cmd prompt. Try these command strings:
    a. `ipconfig /all` (displays a lot of network info)

2. After running ipconfig, from your listing,
    b. Find your PC's Physical Address (MAC)
        Ethernet Adaptor _____
        Wireless LAN Adaptor _____

Step 5 ***WHAT'S MY NAME?...*** Running the Program: ***hostname***

1. This program displays the name of your computer.

2. Run **hostname** from the cmd prompt.
    a. `hostname` (returns the computer name)

```
C:\Users\jimo>
C:\Users\jimo>hostname
den7

C:\Users\jimo>
```

3. After running hostname, from your listing,
    c. Find you're your computer name _____

Step 6 **IS MY NETWORK WORKING?** Running the Program: ***ping***

1. This program is used to test the "reachability" of a host on an IP network and to measure the round-trip time for messages sent from the originating host (you) to a destination computer.

2. Run **ping** from the cmd prompt, these 4 options.
    a. `ping` (returns help for this command)
    b. `ping 127.0.0.1` (ping yourself)
    c. `ping localhost` (ping yourself)
    d. `ping <computer name>` (ping yourself)

```
C:\Users\jimob>ping 127.0.0.1

Pinging 127.0.0.1 with 32 bytes of data:
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128
Reply from 127.0.0.1: bytes=32 time<1ms TTL=128

Ping statistics for 127.0.0.1:
    Packets: Sent = 4, Received = 4, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 0ms, Maximum = 0ms, Average = 0ms

C:\Users\jimob>_
```

What were the results of the 4 ping runs?

Step 7 ***WHO ELSE IS OUT THERE? …*** Running the Program: ***arp***

1. This program displays (or modifies) the IP Address to physical address (MAC) translation table used by the Address Resolution Protocol (ARP).

NOTE: Do not make any changes to the ARP translation table.

2. First, run the Ping command as follows:
   a. `ping <broadcast address>` (ping the network with the broadcast address)

3. Next, run **arp** from the cmd prompt.
   b. `arp –a` list all devices on the network

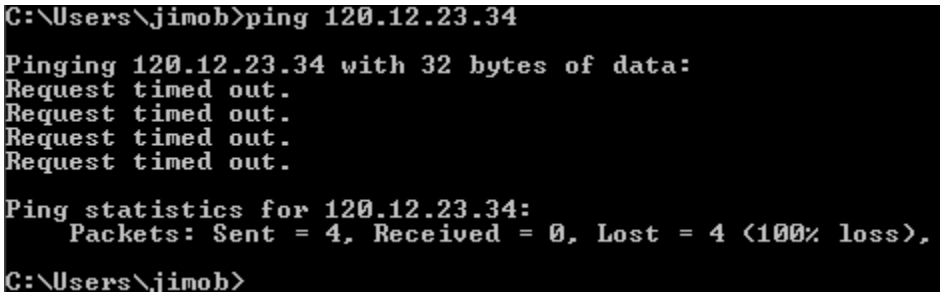
```
C:\Users\jimo>arp -a

Interface: 192.168.1.82 --- 0xd
  Internet Address      Physical Address      Type
  192.168.1.68          00-0a-3c-13-b6-c0     dynamic
  192.168.1.69          18-55-0f-d8-0c-8c     dynamic
  192.168.1.73          3c-a9-f4-5d-85-34     dynamic
  192.168.1.85          a0-48-1c-5a-1a-01     dynamic
  192.168.1.94          68-ee-96-16-7f-08     dynamic
  192.168.1.95          24-76-7d-e4-d7-ff     dynamic
  192.168.1.99          b8-3e-59-50-fc-e1     dynamic
  192.168.1.254         00-21-7c-a8-13-c1     dynamic
  192.168.1.255         ff-ff-ff-ff-ff-ff     static
  224.0.0.22            01-00-5e-00-00-16     static
  224.0.0.251           01-00-5e-00-00-fb     static
  224.0.0.252           01-00-5e-00-00-fc     static
  224.0.0.253           01-00-5e-00-00-fd     static
```

4. Your own PC's IP address and associated MAC Address will not be included in the listing.

5. From this list pick other IP addresses on your network, and ping them.

Step 8 **What happens if the device is not there?**

1. Run **ping** from the cmd prompt for a device that does not exist (make up an IP address)
   c. `ping 234.12.23.345`



NOTE: This is an important troubleshooting tip to know that a device is connected and available on the network.

Step 9 **When done,**

1. **DISCONECT** from the wireless network "Mesh_Workshop", and
2. **DISABLE** your wireless adaptor.

HOW TO… ***Nice to Know…*** **Converting Decimal to Binary**

Conversion of binary to decimal (base-2 to base-10) numbers and back is an important concept to understand as the binary numbering system forms the basis for all computer and digital systems.

Binary numbering system

1. Decimal numbering system (base 10) has 10 digits (0 through 9)
2. (Base 2) has 2 digits (0 and 1)
3. In the binary numbering system, a binary number, such as "01 100 101" (spaces are inserted for readability), is expressed with a string of "1's" and "0's" with each digit along the string from right to left having a value twice that of the previous digit.
4. The left-most bit is called the Most Significant Bit (MSB).
5. The right-most bit is called the Least Significant Bit (LSB).

MSB	**Binary Digit**						**LSB**
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

6. An easy method of converting decimal to binary number equivalents is to write down the decimal number and to continually divide-by-2 (two) to give a result and a remainder of either a "1" or a "0" until the final result equals zero.
7. Suppose we want to convert 254 to binary.

Do the math	Result	Remainder	
254 / 2 =	127	0	…**Least Significant Bit**
127 / 2 =	63	1	
63 / 2 =	31	1	
31 / 2 =	15	1	
15 / 2 =	7	1	
7 / 2 =	3	1	
3/2 =	1	1	
1/2	0	1	…**Most Significant Bit**

Decimal Digit Value	128	64	32	16	8	4	2	1
Binary Digit Value	1	1	1	1	1	1	1	0

8. So, Decimal 254 equals Binary 11 111 110.

HOW TO… ***Nice to Know…*** **Converting Binary to Decimal**

1. How do we convert Binary to Decimal? Recall this table?

MSB	**Binary Digit**						**LSB**
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
128	64	32	16	8	4	2	1

2. In the binary number system, the weight of each digit increases by a factor of 2 as shown. So, the first digit (LSB) has a weight of $\boldsymbol{2^0}$, the second digit has a weight of $\boldsymbol{2^1}$, the third a weight of $\boldsymbol{2^2}$, the fourth a weight of $\boldsymbol{2^3}$ and so on.
3. For example, converting the Binary number **11 100 101** to a Decimal number would be:

Decimal Digit Value	128	64	32	16	8	4	2	1
Binary Digit Value	**1**	**1**	**1**	**0**	**0**	**1**	**0**	**1**

4. By adding together ALL the decimal number values together from left to right at the positions that are represented by a "1" gives us:

   (128) + (64) + (32) + (4) + (1) = 229 as a decimal number.

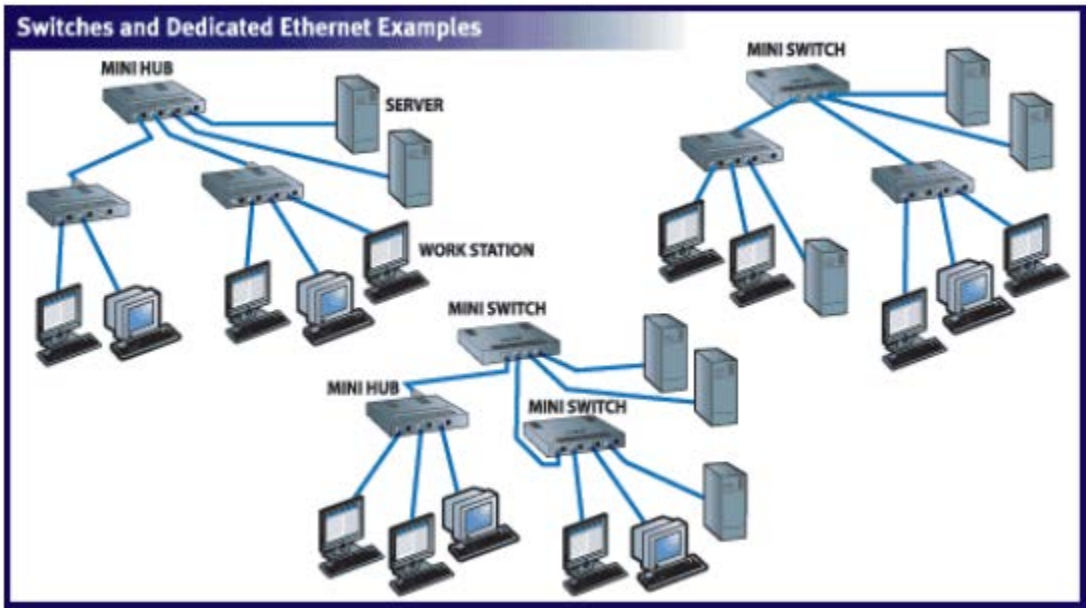
5. So, Binary **11 100 101** equals Decimal **229.**

2. Basic Network Equipment

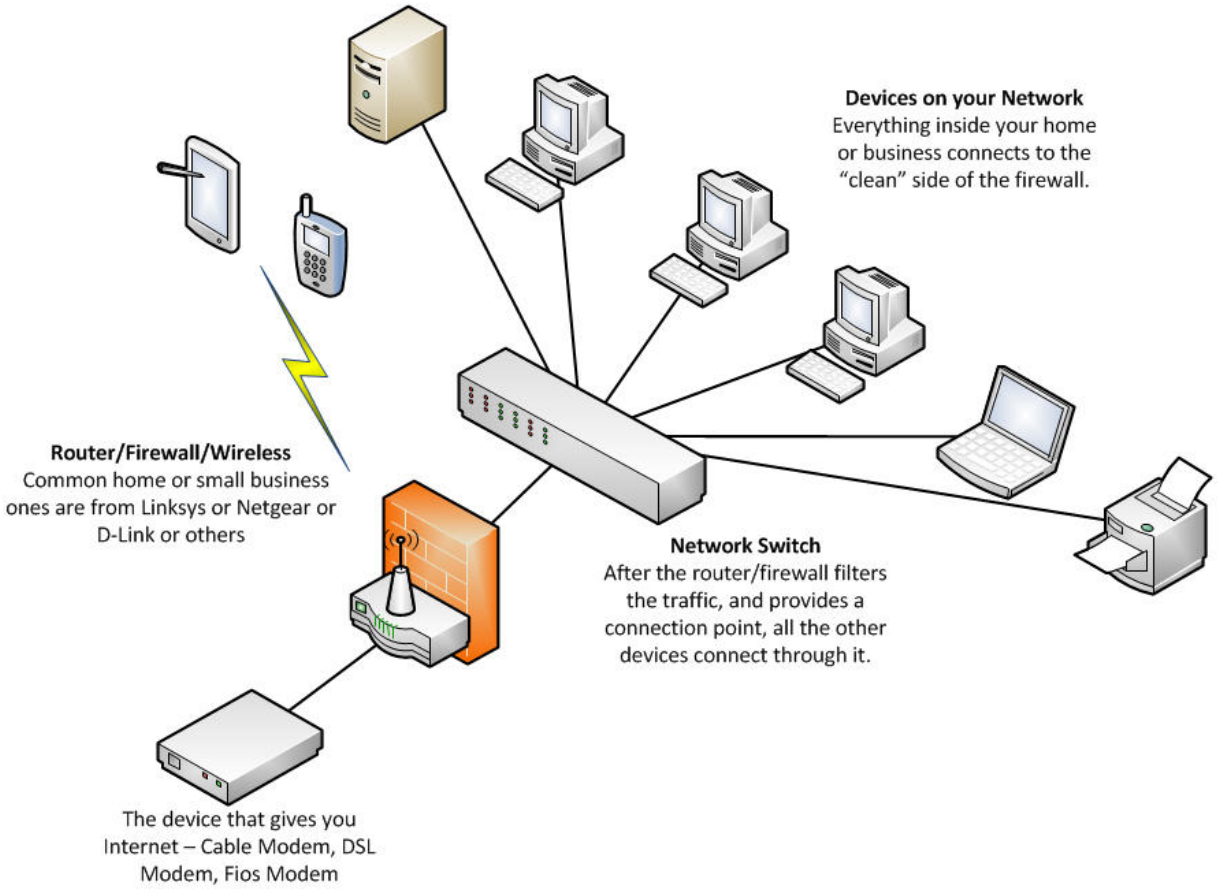
2.1 HUBs, Switches, Routers, and Cables

1. **Hubs:** Hubs are commonly used to connect segments of a LAN. A hub contains multiple ports.
    a. Hubs are just multi-port repeaters. They simply repeat everything they hear.
    b. Hubs operate at the physical layer (layer 1) of the OSI model.
    c. When a packet arrives at one port, it is "broadcast" to all of the ports on this hub.
    d. It doesn't matter that the frame is only destined for one port.
    e. The hub has no way of distinguishing to which port a frame should be sent.
    f. Passing it along to every port ensures that it will reach its intended destination.

2. **Switches:** Switches are commonly used to connect segments of a LAN and contains multiple ports.
    a. Switches (which are just multi-port bridges) make forwarding decisions based on the MAC address.
    b. Switches operate at the Data Link Layer (layer 2).
    c. Unlike a Hub, switches keep a record of the MAC addresses of all devices connected to it.
    d. With this information, a switch can identify which system is sitting on which port.
    e. So when a frame is received, it knows exactly which port to send it to.



3. **Routers:** Routers are completely different devices. They are used to tie multiple networks together.
    a. Routers make forwarding decisions based on the network address
    b. They operate at the network layer (layer 3).
    c. A router routes packets to other networks until that packet ultimately reaches its destination.
    d. A router is typically connected to at least two networks, commonly two Local Area Networks (LAN) or Wide Area Networks (WAN), or a LAN and its ISP's network.
    e. Routers are located at gateways, the places where two or more networks connect.
    f. Using headers and forwarding tables, routers determine the best path for forwarding the packets.
    g. Today, a wide variety of services are integrated into most broadband routers.
        1. A router will typically include a 4 - 8 port Ethernet switch (or hub) and a Network Address Translator (NAT).
        2. They usually include a Dynamic Host Configuration Protocol (DHCP) server, Domain Name Service (DNS) proxy server, and a hardware firewall to protect the LAN from malicious intrusion from the Internet.



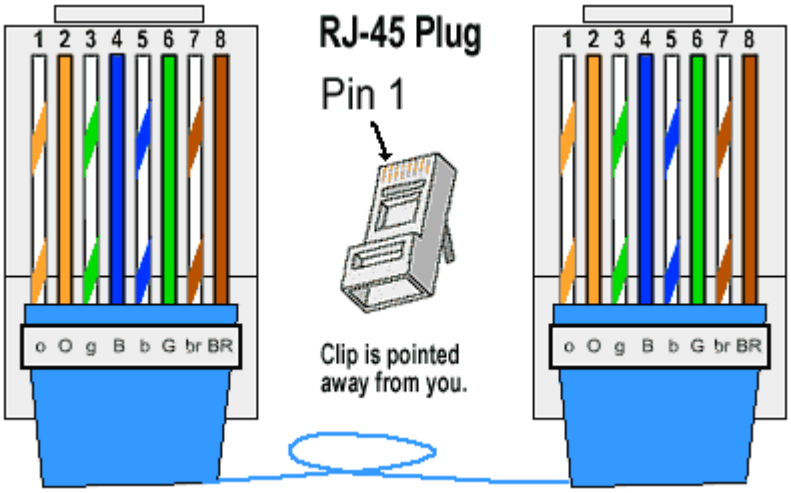
4. **CAT5 Cables:** 4 pairs of twisted wires for carrying signals. This type of **cable** is used in structured cabling for computer networks such as Ethernet.

   a. Cable standards

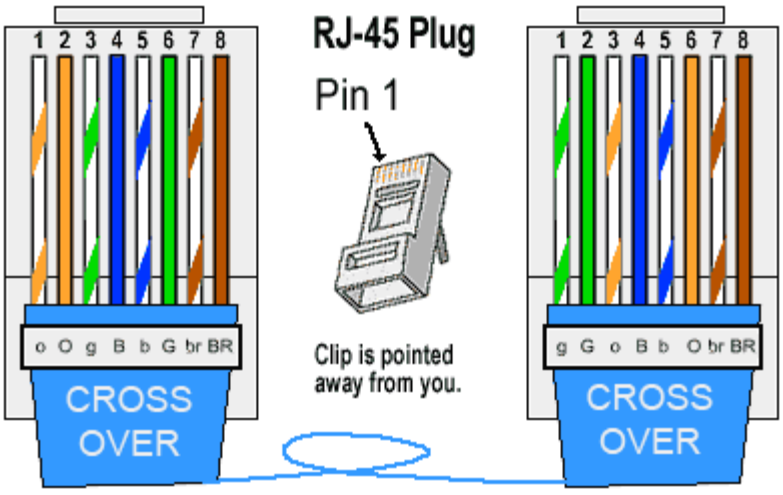
Ethernet Type	Bandwidth	# Pairs	Cable Type	Max Distance
10Base-T	10 Mbps	2	Cat3/Cat5	100m
100Base-TX	100 Mbps	2	Cat5	100m
1000Base-T	1 Gbps	4	Cat5e/Cat6	100m
10GBase-T	10 Gbps	4	Cat6a	100m

   b. Types of Cables

      1. **Straight Through Cable.** These cables are the standard cable used for almost all purposes.



      2. **Crossover Cable.** These cables directly connect one computer to another computer (or device) without going through a router, switch or hub.



   c. Bottom Line

      1. You know it is a straight through if both sides of the connectors match.

HANDS ON! Exercise #2: Cable Inspection

This exercise gives you a chance to get to know your Ethernet Cable:

Step 1 1. Take a look at your Ethernet Cable. Note the pin-outs

Pin	Color
1	
2	
3	
4	
5	
6	
7	
8	

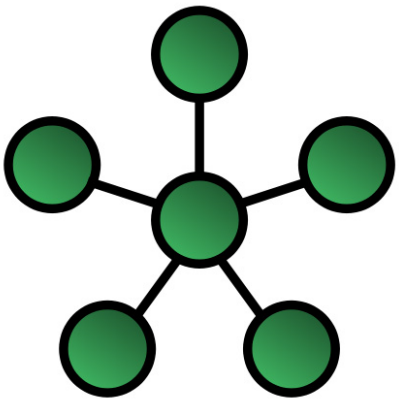
Pin	Color
1	
2	
3	
4	
5	
6	
7	
8	

Type of Cable: _____

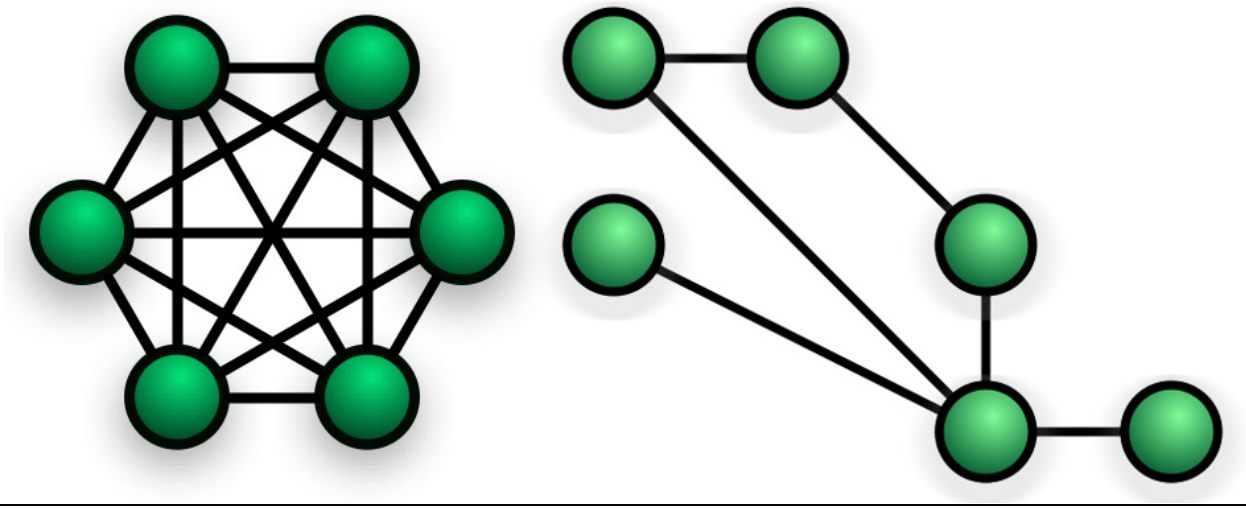
3. A First look at Mesh Networking

3.1 Topography

1. Typical Network Topology
    a. Topology describes how the various members (nodes) of a network are connected together.
    b. 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.).
    c. The star topology dictates that if one client wants to talk to another (say, you want to send a photo from your laptop to your Xbox), the data must go through the central point (the router).



2. Mesh Network Topology
    a. A mesh is when multiple sites/nodes are connected to multiple other sites/nodes.
    b. Full-mesh is when every node connects to every other node (picture at left).
    c. Partial mesh is something less than that, but more than something else (like star topology).
    d. If a node goes down, there are other paths that can move the message along.

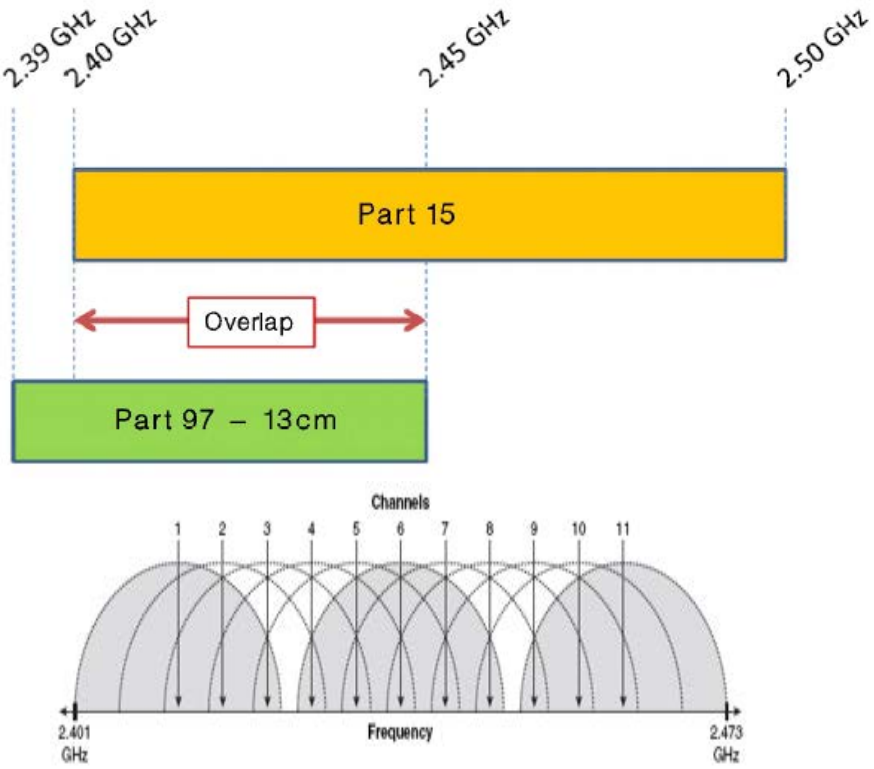


Is Mesh Networking for Real?
Mesh is happening all around us ***NOW!*** With IOS.7, my iPad now rings when my cell phone rings, as long as both are on the same WLAN. That's Mesh in your face (FaceTime setting, that is).

3.2 Broadband-Hamnet™

1. The BBHN software creates a high speed, self-discovering, self-configuring, fault tolerant, wireless computer network.
2. It automatically discovers its neighbors.
3. It automatically determines which neighbors it can reach directly vs. which neighbors must be reached through another neighbor.
4. However, (the bad part) it does all of this on a shared frequency instead of collection of separate links.
5. So, that makes it easy, but also means it is not as robust or as scalable as other mesh topologies. But for moderate traffic, it's "good enough".
6. Operates on the Ham Bands.

802.11g Wireless Band



Wi-Fi Channels, Channel 1 is the BBHN Standard
Wi-Fi, 20Mhz channel bandwidth

7. The channels used for Wi-Fi are separated by 5 MHz in most cases but have a bandwidth of 22 MHz.
8. As a result, channels overlap and it can be seen that it is possible to find a maximum of three non-overlapping channels.
9. Often Wi-Fi routers are set to channel 6 as the default, and therefore the set of channels 1, 6 and 11 is possibly the most widely used.
10. Broadband-Hamnet defaults to **Channel 1**.

3.3 Hardware

1. Linksys, WRT54G, WRT54GL, WRT54GS specific versions

   a. Repurposed home router - 2.4Ghz (13 cm band)
   b. Just a small Linux computer with router and Wi-Fi built in
   c. Inexpensive – around $25 on eBay and readily available;
      NOTE: You CANNOT buy new the ones we need.
   d. 12 VDC Power

2. Linksys Shopping Guide

Model	Version	Comments
WRT54GS	1.0 – 3.0	Most memory (32/8) MB
WRT54GS	4.0	16/4 Mb
WRT54G	1.1 – 4.0	16/4 Mb
WRT54GL	1.0 – 1.1	16/4 Mb
WRT54G	1.0	16/4 MB 5V DC power Warning - uses different supply voltage from all other models.

3. Ubiquiti, Rocket M2, BulletM2, AirGrid M2, NanoStation Loco M2, NanoStation M2, PicoStation M2

3.4 BBHN Software

1. Find and download the firmware
   http://www.broadband-hamnet.org/software-download.html

> ***NOTE:*** be very careful to pick the correct download. Installing the wrong firmware may BRICK your device.

Software Download

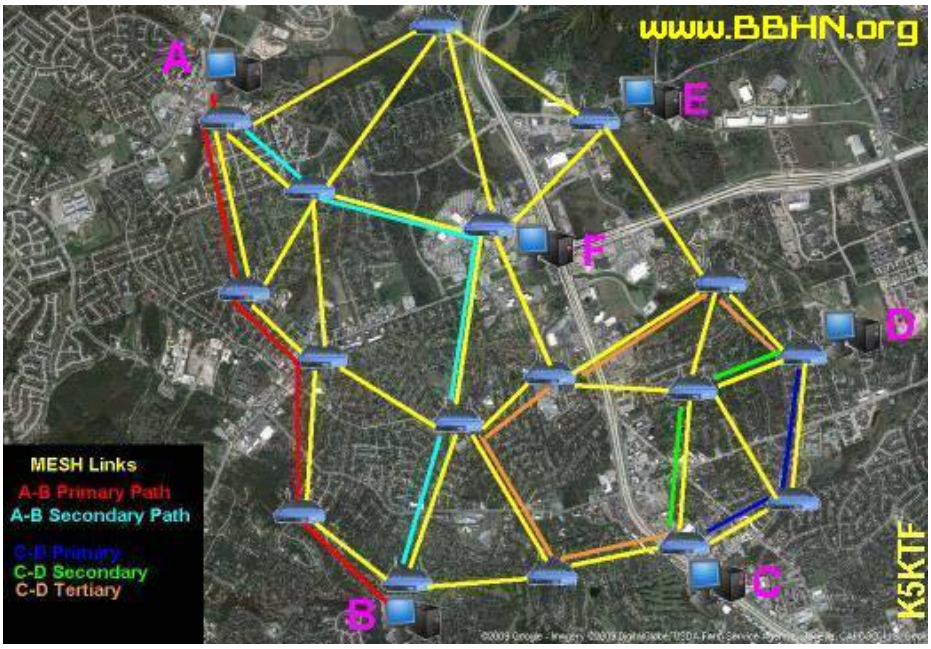
Broadband Hamnet Software Download
Linksys Firmware
Ubiquiti Firmware

a. The Linksys Firmware choices

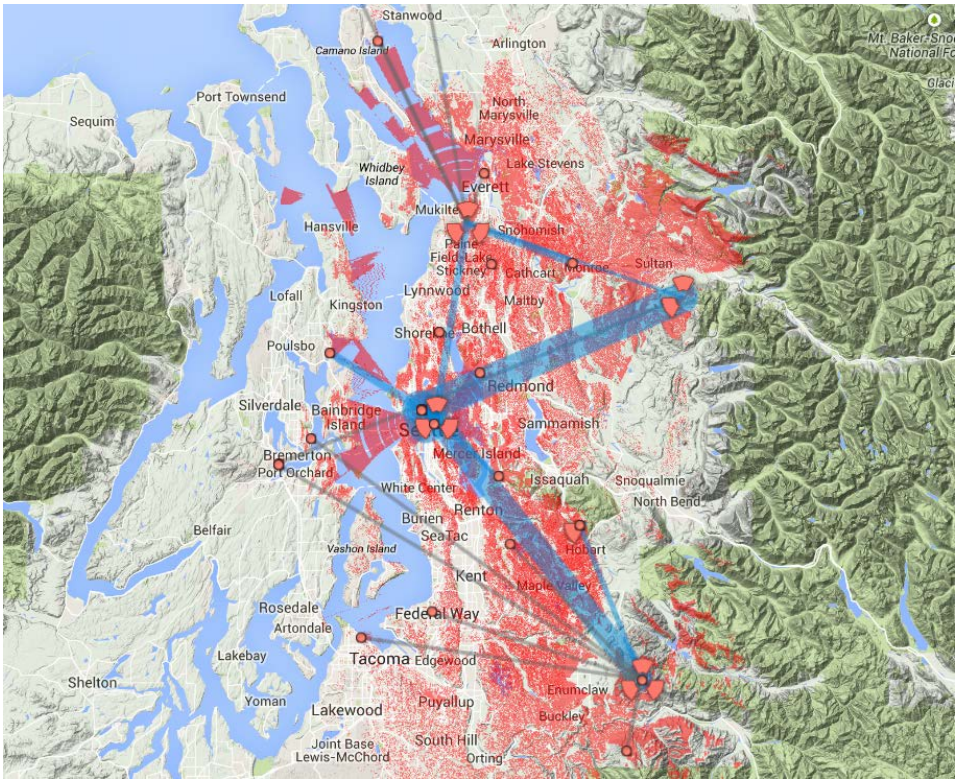
Please read this note about Linksys firmware support ending April 30th, 2015		
Broadband Hamnet firmware		
Release Notes		Release Notes for this build. Please read as this document contains detailed information about this release.
bbhn-3.0.0-brcm-2.4-squashfs.trx	2.9M	upgrade an existing mesh node md5sum: cce4619a7380287b6d464082d33ee077
bbhn-3.0.0-usr5461-squashfs.bin	2.9M	firmware for a non-mesh usr5461 md5sum: 3da0c4df3ba19811b076edf78dcc09e4
bbhn-3.0.0-wrt300n_v1-2.4-squashfs.bin	2.9M	md5sum: c4a2e1a5ed8379d3c675ea6deb423079
bbhn-3.0.0-wrt54g-2.4-squashfs.bin	2.9M	firmware for a non-mesh WRT54G and GL md5sum: ef84b833bedf4f04404b6540432ab194
bbhn-3.0.0-wrt54g3g-2.4-squashfs.bin	2.9M	firmware for a non-mesh wrt54g3g md5sum: 8a94fb9bd437c4a54153f37be1fbf9b2
bbhn-3.0.0-wrt54gs-2.4-squashfs.bin	2.9M	firmware for a non-mesh wrt54gs md5sum: 123f6c834288d0583eb09c855da337d6
bbhn-3.0.0-wrt54gs_v4-2.4-squashfs.bin	2.9M	firmware for a non-mesh wrt54gs_v4 md5sum: cc6fed5aba61e82dba755c109384e455
bbhn-3.0.0-wrtsl54gs-2.4-squashfs.bin	2.9M	firmware for a non-mesh wrtsl54gs md5sum: 8836e686f0523f5445cf230c1d30fbc3

b. Follow the instructions for flashing your Router
   http://www.broadband-hamnet.org/documentation/68-firmware-installation-instructions.html

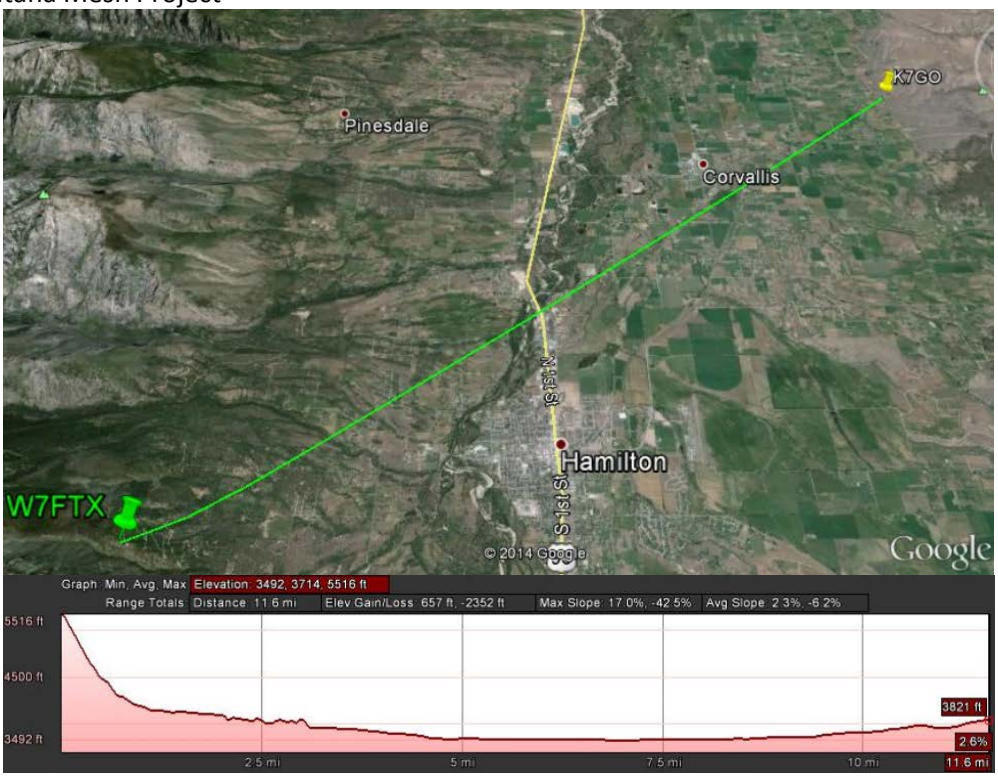
2. Where is Broadband Hamnet deployed?
   a. Austin Texas Area



   b. Greater Seattle WA (NW MESH Amateur Networking Project)
   HamWAN cells have been deployed to four sites. Each site is interconnected with 5.9 GHz modems and fully routed with OSPF. HamWAN provides routing to all existing AMPRNet systems.



c. Montana Mesh Project



HANDS ON! Exercise #3: Checking out the Mesh Node configuration

This exercise walks you through an initial inspection of the mesh node using BBHN's user Interface.

Step 1 **Plug into the Linksys Router**

NOTE! All nodes in the workshop are assumed to be already loaded with the MESH firmware

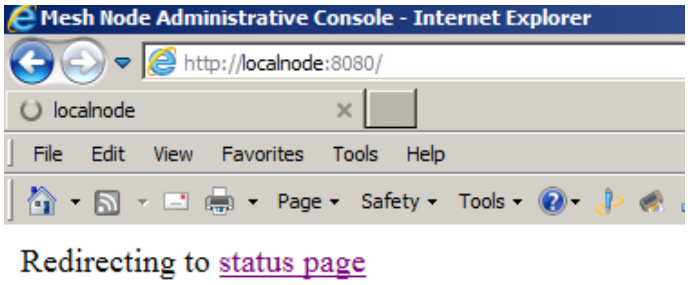
NOTE! **DISABLE** your wireless adaptor before proceeding. Wireless access to the Mesh Node from your PC is not supported.

1. Connect your PC/Laptop to the Linksys WRT54G Mesh Node with a CAT5/5e Cable.
2. Apply Power to the Linksys Node. The boot process will take about 1 minute. Once the DMZ LED goes out, the node is ready for use.
3. Run the **cmd** Program. Run the **ipconfig** program to view your IP address. Record it here.
    a. Find your IP Address _____

VERIFY that an IP address has been assigned AND is in the range **10.###.###.###**. If it is not, **STOP!** Do not proceed. Check your cable or Modem Power. Reboot your PC if necessary.

Step 2 **Accessing the Linksys / Mesh configuration**

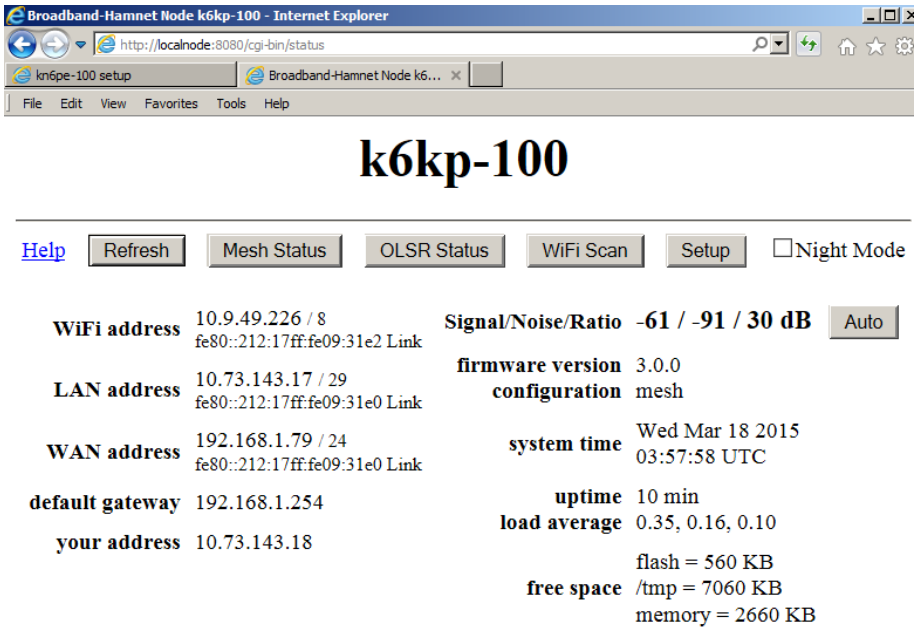
1. Start up your browser.
2. Enter the following in the URL field: http://localnode:8080
3. The first thing you will see is a redirect page:



Step 2 (continued)

Accessing the Linksys / Mesh configuration

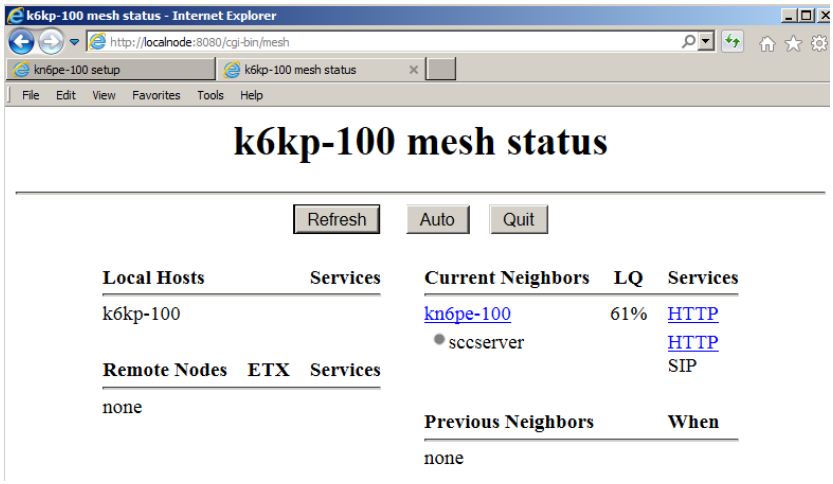
1. The Main Mesh Status Page is presented.



2. What is the name of this MESH Node? _____
3. What is the firmware version? _____
4. Notice the different IP addresses listed at this node. They are:
    a. Wi-Fi address: this is the address of the Port for this MESH node that talks to other MESH nodes.
    b. LAN address: this is the address of the Switch for the PCs plugged in to it.
    c. WAN address: this is the address of the Port if your node is connected to the internet
5. Notice your IP Address: does this match your answer from Step 1 above? _____

Step 3 **Looking at the Mesh Status**

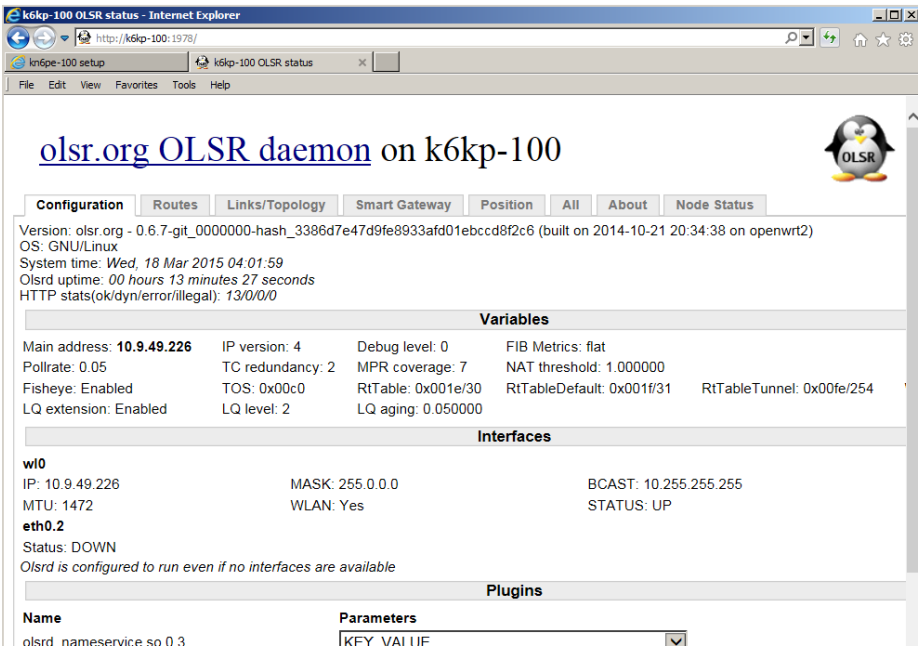
1. Press the ***Mesh Status*** button. This form reports the local Host name (your Mesh Node name) and the list of Mesh Node neighbors that you can hear.



2. Other controls on this page:
   a. Refresh: one-time refresh of the results on this page.
   b. Auto: automatically refreshes the results of this page about every 10 seconds.
   c. Quit: Exits this page and returns to the main status page.
3. Note the list of neighbors and any services they offer. In the above example, you see the following:
   a. Neighbor: **kn6pe-100**. Alias: **sccserver**
   b. Services: HTTP: This neighbor offers HTTP web services
      SIP: This neighbor offers SIP (PBX Phone) services
4. List the neighbors and their services that you see:
   1. Neighbor: _____, Services: _____
   2. Neighbor: _____, Services: _____
   3. Neighbor: _____, Services: _____
5. When done, press **Quit**.

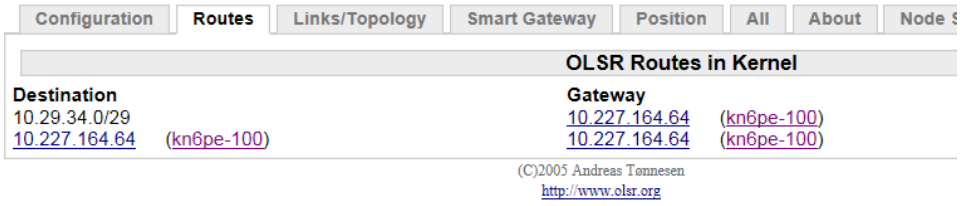
Step 4 **OLSR Status**

1. Back on the Mesh Node home page, press **OLSR Status**.



> ***What is OLSR?*** OLSR is an implementation of the Optimized Link State Routing protocol. Essentially, it allows **mesh routing** for any network equipment and manages the ad-hoc wireless mesh routing for your node.

2. This page has a lot of information about this node, its neighbors, and how to get around in the network. Let's do the following:
   a. Press **About**. This page shows a brief description about the other tabs.
   b. Press **Node Status**: ***if you get lost***, Node Status gets you back to the Main Mesh Status Page.
   c. Press **Routes**



      i. The first entry (10.29.34.0/29 in this example) refers to the network switch for the k6kp-100 MESH Node.
      ii. The second entry (10.227.164.64 in this example) is the Wi-Fi access port for the k6kp-100 MESH Node.

   d. For your system, what other destinations are present (Node Names only)?

      _____, _____, _____, _____

      Click on any one of the highlighted IP addresses or host names. What happens?

      _____

e. Note the Web address in your browser address line.

f. Go back to your own node (Hint: re-enter "http://localnode:8080" if you are not sure where you are).

g. Press **Links/Topography**. Can you determine which nodes are your immediate neighbors and which are 1 or 2 hops away?

_____

STEP 5 **Other Main Page tabs**

1. From your node's home page,
   a. Press **WiFi Scan**. This displays the list of all the Wi-Fi nodes that are within range of your node. Node the Signal Level in Column 1.

k6kp-100 WiFi scan

Refresh Auto Quit

Sig	Chan	Enc	SSID	MAC	Vendor
-52	8	*	2WIRE310	00217C:A813C1	2Wire
-64	3	*	cyclones	4C5E0C:67CCFB	
-65	1		BroadbandHamnet-20-v3	422AAF:B7F37A	Ad-Hoc
-79	3	*	LCARS	E4F4C6:149FFB	
-82	6	*	Sweet_Home	6C709F:EF3EF2	
-82	8	*	JodrellBank	881FA1:3873CA	
-83	11	*	Bletchley Park	000A95:F48DD1	Apple
-83	6	*	Welcome_Guest	7E709F:EF3EF2	
-85	3	*	freddythepup	14358B:113F24	
-85	9	*	ATTXxBX222	3C36E4:76BB50	
-88	11	*	ATT2G8x6c6	145BD1:E57ED0	

   b. Note all of the entries that are standard Wi-Fi routers that you might hear.

   c. Note the SSID that says BroadbandHamnet-20-v3. These are other BBHN Mesh Nodes that you can hear.

   d. What is the Channel Assignment for the BBHN nodes? _____

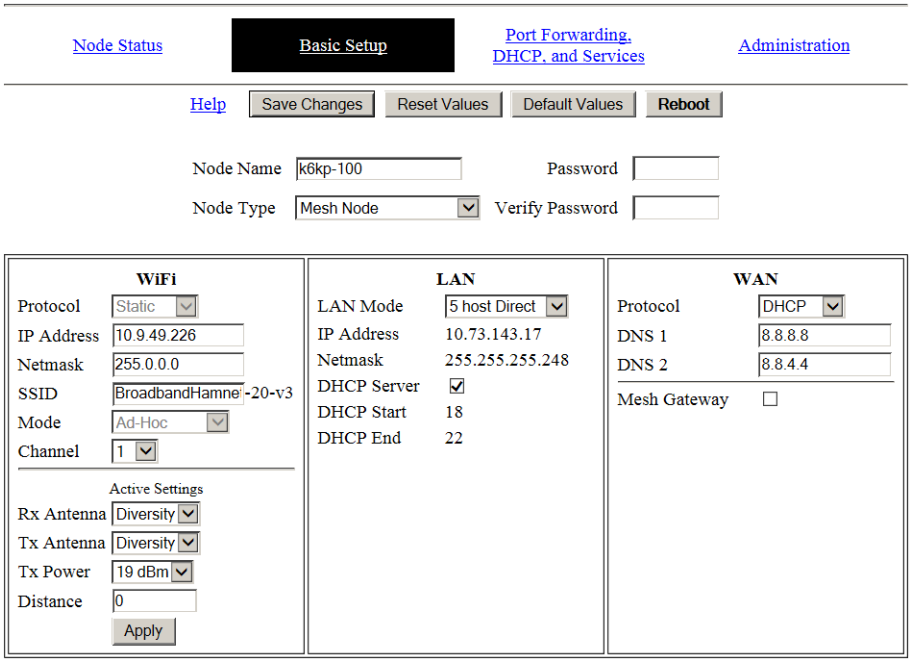
   e. If there is a "*****" in the **Enc** column, this means that the channel is encrypted. Note that the Broadband Hamnet nodes are not encrypted per Part 97 rules.

Step 6 **Setup/Basic Setup**

1. To access the Setup menu, you need to enter the mesh node logon and password:
   a. Logon: root
   b. Password: mesh

> ***NOTE:*** if you manage your own Mesh Node, ***DO NOT LOSE*** your password. The method for resetting it is non-trivial ☹.

2. After the logon form, the Settings page shows the basic setup for your node. Confirm these settings:
   a. Node Type: Set to Mesh Node.
   b. LAN Mode: Set to 5 Host Direct.
   c. WAN Protocol: Set to DHCP.



3. Under the LAN column, note that DHCP Server is checked and the Starting and Ending DHCP Addresses. Who on your node has these IP Addresses?

   a. IP addr _____ Owner: _____

   b. IP addr _____ Owner: _____

   c. IP addr _____ Owner: _____

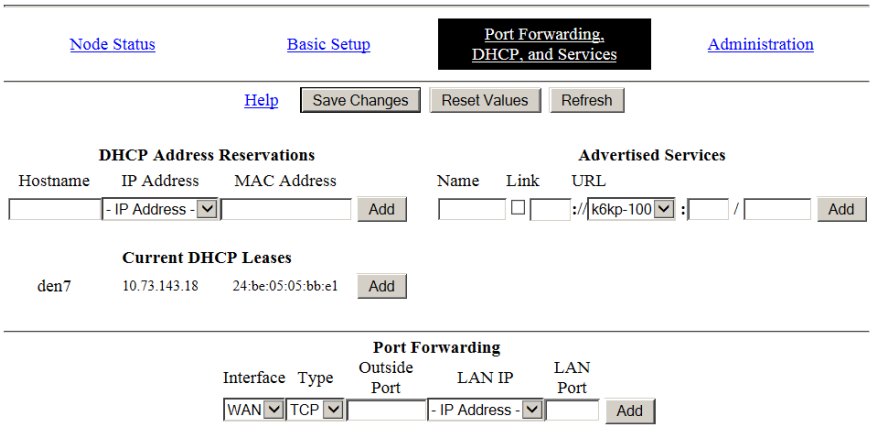
   d. IP addr _____ Owner: _____

   e. IP addr _____ Owner: _____

4. Change LAN Mode from 5 host Direct to another option like 13 Host Direct. What happened? Change it back when done.

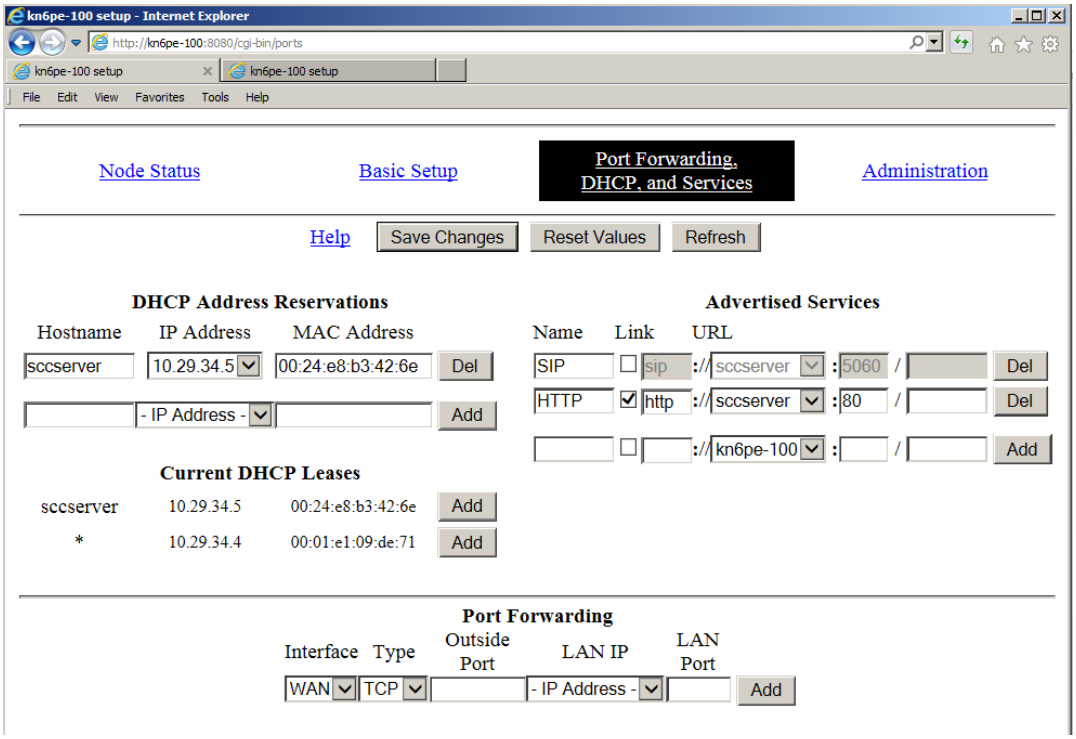
STEP 7 **Setup/Port Forwarding, DHCP, and Services**

1. This page shows the following:
    a. DHCP Reservations. Sometimes, it is important that a device's IP address does not change, such as a VoIP server (the phones need to know where it is). This is the way to "lock it in" to an IP Address regardless of when and where it is plugged into this Mesh Node.
    b. Current DHCP Leases. This shows what devices have been assigned an IP address by this Node. Note the associated MAC address. Hover over the **Add** button; this creates a DHCP reservation for the associated device
    c. Advertised Services. This lets the Mesh Node advertise an available network service to the network.
    d. Port Forwarding. If we are connected to the internet, this can add a port forwarding rule to the router portion of the node.



Step 8 **NICE TO KNOW: Looking at Advertised Services**

1. Let's take a look at a node with Advertised Services. Back on Step 3, you saw what neighbors you have and the services they offer. Here is how the services were set up on the **kn6pe-100** Mesh Node.



2. **Current DHCP Leases**. There are 2 devices connected to this mesh node:
   a. sccserver IP=10.29.34.5. This is a HTTP and SIP server.
   b. * IP=10.29.34.4. This is a Zulys ZIP2 VoIP Phone (no name)
3. **DHCP Address Reservations**. There is one device connected to this mesh node that is guaranteed a specific IP Address:
   a. sccserver IP=10.29.34.5. This is a Linux server.
4. **Advertised Services**. There are 2 services set up that reside on the **sccserver**:
   a. SIP: Tells other mesh node users that they can find the PBX VoIP phone server here.
   b. HTTP: Tells other mesh node users that they can find the website on this server.

STEP 9 **OPTIONAL: Setup/Administration**

1. Select the **Administration** Link.
2. There are 3 sections on this page.
    1. Firmware Update. As updates are released, you have the option of retrieving from the website the latest patch and updating your node.
    2. Package Management. The WRT54G is a Linux computer. As a result, it contains a Linux Operating System under the hood. This tab lets you manage system components. Unless you are into experimentation, DO NOT remove any packages from the node.
    3. Authorized SSH Keys. This is for loading secure keys to allow Secure Shell access to the Node.
3. In summary, we should never have to touch this page.

4. VoIP Phone

4.1 Introduction

1. Voice over IP (**VoIP**) is a group of technologies that allows phone calls to be made and received over an IP network (like the Internet) instead of using the traditional Public Switched Telephone Network (PSTN).
2. The components are:
    i. VoIP Phone sets
    ii. Server running a PBX (like Asterisk)
    iii. Configuration files to make the PBX work

4.2 VoIP Phones

1. All VoIP phones basically look and operate the same once they are connected to the phone system.
2. VoIP phones need to do 2 things after power is applied to them:
    a. Register with the router to get an IP address.
        i. Once an IP address is assigned, you will get a dial-tone, but cannot make a call
    b. Register with the PBX.
        i. Once the phone registers with the PBX, you can make a call.

Polycom
IP Sound Point

Guardian Telecom, Inc
Vandal Resistant Phone

Zulty's ZIP 2 IP phone

4.3 Configuring your VoIP Phone

1. Being an Internet Device, the VoIP phones are usually configured from its internal configuration screens accessible from the Internet.

HANDS ON! Exercise #4: VoIP Phone configuration

This exercise walks you through the setup of your VoIP phone. It assumes that the PBX configuration has been completed. The PBX (Asterisk) configuration is beyond the scope of this exercise.

Step 1 **Getting started**

NOTE: These instructions assume a Zultys ZIP2 VoIP phone. If you have some version of the ZIP phone brand, the forms and screens may look different.

NOTE: the phone must be set for DHCP before starting this installation.

1. Before plugging in the phone, turn it over and record the MAC Address. It will be a mix of HEX characters, 12 digits long.
   MAC Address : _____

Step 2 **Reset to Factory Defaults**

This step should be done whenever you are connecting your phone to a new network for the first time or if you are unsure of the phone settings last made (must be set to DHCP). Check with the MESH network administrator for assistance.

1. Perform a **Reset to Factory Defaults** for your Zultys ZIP2 phone:
   a. Ensure that there is no power connected to the ZIP2 (do not connect the power adapter).
   b. Pick up the handset.
   c. While pressing the '1' button, connect power to the phone. Do not release the '1' button until both the red and yellow LEDs stop flashing; this usually takes about 10 seconds.
   d. Disconnect power from the ZIP2 by removing the power adapter.

Step 3 **Normal Phone Power up procedure**

1. Once a phone has been configured into the network, the following is the normal Phone power up procedure.
   a. Connect the Phone to the Mesh router using an Ethernet cable.
   b. Connect power to the ZIP2.
   c. The phone quickly flashes twice the red LED above the keypad and the yellow LED below the keypad. Both LEDs turn off a few seconds after the power stabilizes.
2. Within a minute, check for a dial tone. If you hear one, this means:
   a. the phone has power, and
   b. the phone has been assigned an IP address by the Router.
3. If you did not hear a dial-tone,
   a. check the network cable between the phone and the router and power cycle the phone again.
   b. Perform a **Reset to Factory Defaults** to ensure the phone is configured for DHCP.

NOTE: If you do not have a Dial Tone at this point, do not proceed!

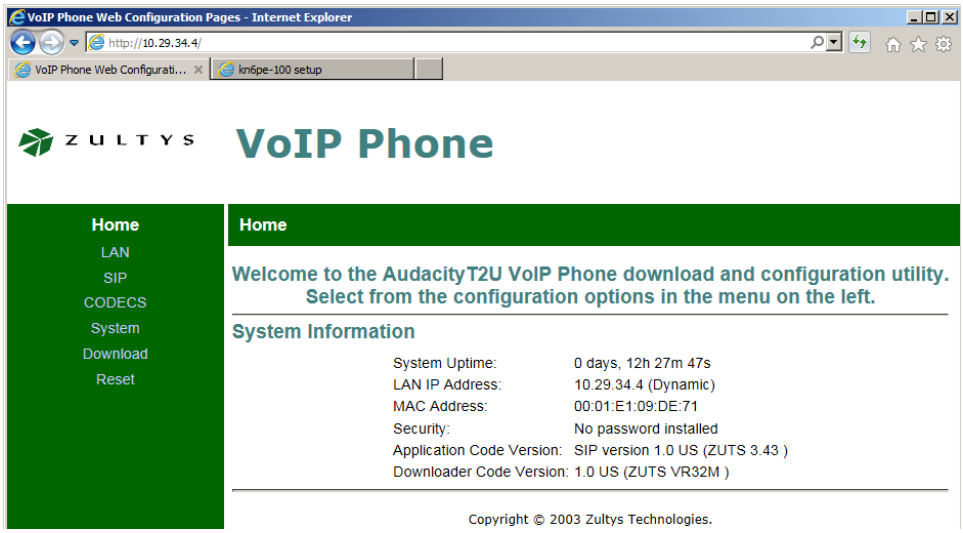
Step 4 **Determine the Phone's IP Address**

1. Before we can configure it, we need to find its IP Address.
3. From the Router
    a. From the browser, connect to your router http://localnode:8080
    b. Select the **Setup** link. Enter the router's logon and password.
    c. Select the **Port Forwarding, DHCP, and Services** link.
    d. Look under the **Current DHCP Leases** section.
    e. Find the entry that matches the phones' MAC address that you identified from Step 1 above. Record the corresponding IP Address below.
4. IP Address for this phone:

    _____

Step 5 **Accessing the Phone Interface**

1. There are typically 2 ways to configure this phone:
    a. Download a configuration file from a central server
    b. Manually enter the configuration from the phone's web interface.
2. We will be using the second method since this is more likely to be the method used in the field.
3. Open your browser and enter the phone's IP address in the URL address line. You are presented with the following form.



4. From the left menu, select **LAN**. Note the various network settings that the phone discovered. Note that "Dynamic IP Assignment" (DHCP) is set to YES.

Step 6 Get your unique configuration

STOP! Go to **the MESH network administrator** and request the following:

Server Address: _____

Port Number: _____

Domain Name: _____

Phone Number: _____

User Name: _____

Password: _____

Step 7 Configuring the Phone

1. Most of the phone general settings can be defaulted. The list of the standard settings that work are included in the appendix. However, we do need to make this phone unique on the network.
2. From the left menu, select **SIP**.

3. The following needs to be confirmed or entered for the phone to work.
    a. **SIP Server Settings**: Defines the location of the SIP server that manages all Telephone call processing. The 3 three fields that MUST be filled in are:
        i. Server Address _____ (from ***Step 6***)
        ii. Port Number: 5060_____
        iii. Domain Name: _____

b. **Gateway Settings**. This section uniquely identifies the phone on the Phone Network. On boot up, the phone connects to the SIP Server (above), and then registers with the phone's user name and password that you will enter here. Once registered, you can then make and receive phone calls. The fields are

   i. Phone Number: _____ (OK to leave blank)

   ii. Caller ID Name: _____ (OK to leave blank)

   iii. Port: 5060

   iv. AEC ON: [**ON**] (must be **ON**)

   v. User Name: _____ (from ***Step 6***)

   vi. Password: _____ (from ***Step 6***)

c. Press **Save SIP Settings**.

4. **Reset the phone.** All settings stored to the phone do not take effect until you power cycle or reset the phone. Do either of the following:

   a. To power cycle the phone, remove power from the phone for a few seconds and then reapply power.

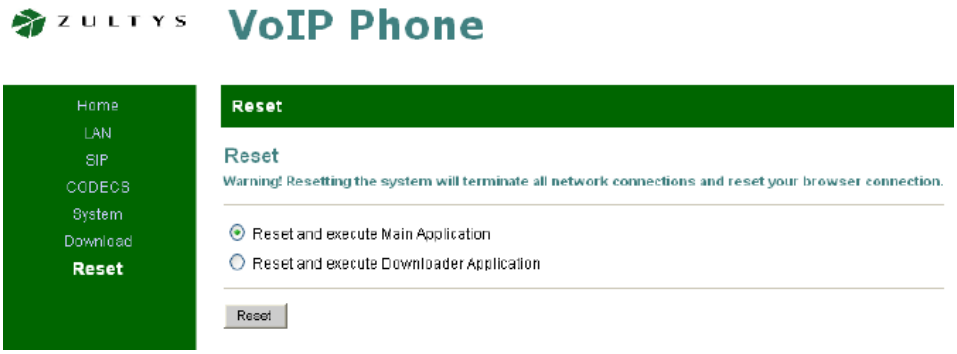
   b. To reset the phone,

      i. select **Reset** from the Left menu

      ii. select Reset and execute Main Application, and then

      iii. press the **Reset** button at the bottom of the phone.

5. The phone will restart as described in Step 3 of this exercise.



Step 8 **Test the phone**

1. Along with having all the phone numbers configured in, the SIP server for this workshop has 2 additional means for testing your phone's setup.
    a. Dial "100" This is a very basic phone-to-SIP Server test.
    b. Dial "200" play backs your extension number
    c. Dial "5000" This is an echo test. Listen to the description and follow the prompts.

NOTE: While the ZOLTYs ZIP2 phone has a Speaker button, it does have an external microphone. In short, this phone **IS NOT** a good candidate as a true speaker phone.

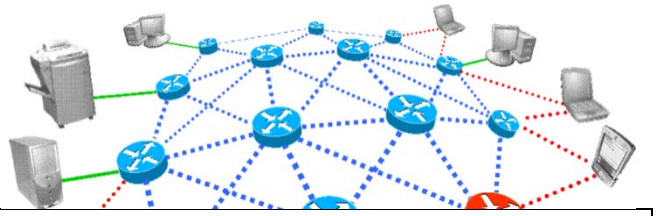
It works ☺… Now what?

2. If you hear the messages, your setup is correct!
3. Make your first phone call. Call Extension 7020, and report the following:
    a. Your first name, Call sign
    b. Names and Call signs of people at this extension
    c. Assigned Phone Number

It doesn't work ☹… Now what?

4. If you hear a rapid busy signal, your phone did not register with the SIP Server. Try the following:
    a. Check for a Dial Tone
    b. Check the LAN connection between the Phone and Mesh Router
    c. Check the power connection
    d. Check your settings: confirm …
        i. Server Name
        ii. Port Number
        iii. User Name
        iv. Password
    e. Power cycle or reset the phone
    f. Go back to Step 7.1 above and try again

MESH Workshop DIY



Indoor MESH Node (*Linksys hardware*)

Having a field-deployable MESH node already mounted, cabled, and configured ensures a speedy startup of the network and supporting apps.

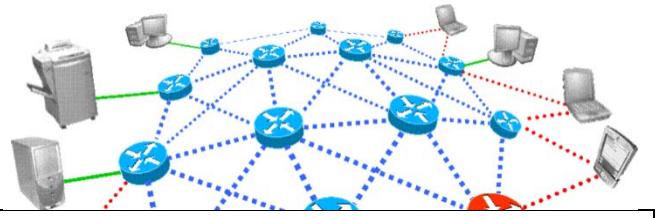
The MESH on a board (or in a box) approach is ideal for close-proximity multi-work station deployments where network phone support is needed while providing additional router network ports for laptops, IP cameras, WAPs, or other network devices.

This node could be connected to a PC configured as a server where FTP, network drives, and other network services could be provided.

Parts List

Item	Description	Source, Other Notes
Linksys WRT54G Router	Loaded with HSMM network software. Watch the model and version numbers	eBay, Flea Market, ~$10-$40
VoIP / SIP Phone	Configured for DHCP, SIP server address, and user login and password. Any VoIP Phone will work as long as it runs the SIP Protocol.	Zultys Zip2, HSC, $16
Battery, 7Ah	Gell Cell, 7Ah should be sufficient for a couple of hours of node use.	Various locations, such as Batteries and Lamps Plus, ~$35
CAT5 Cable, 1ft	Interconnects the Phone to the Router.	Frys, $1.29 
Barrel connector, Type M5.5 x 2.1mm, qty 2	Type M5.5 x 2.1mm, If you FAB the connector from scratch, you will need 2 of these.	Frys, Radio Shack, Jameco, Digikey, $1-$2 each. 

PowerPoles, 15A, 4 to 6 sets	Used to interconnect the above power cables. 6 sets required if you take the “cut power cable” approach.	HRO, Bag of 25, $10.00 
Power cable, qty 2 (phone to PP, Linksys to PP)	Barrel Connector 5.5x2.1mm positive center to Power Pole.	Fab cable, or cut the power adaptors’ power cable 12-18” from barrel connector and install Power Poles on both cut ends to keep the adaptor operational.
Power cable, Bat to phone and Linksys PP	Battery Flat Blade connector to two Power Pole connector sets.	Fab Cable. Brings battery power through fuses to Power Poles. Consider an in-line switch to avoid connecting / disconnecting the Power Poles.



Outdoor MESH Node (Linksys hardware)

For a wider area deployment, a MESH node with more gain is required. As with other aspects of Ham Radio, if you are going to invest in gain, first spend it on your antenna system. The same is true for Wi-Fi systems.

Outdoor MESH nodes could be used as a remote user station supporting a VoIP phone (think: MESH phone booth), or as a relay station linking various portions of a network together. High gain Omni antennas (like the one in this picture) are well suited for nodes in the middle of a network where multiple stations are within RF range. For tough to reach nodes, a higher gain Yagi may be required. In both cases, it is critical to keep the distance between the router and the antenna as short as possible.

Similar to the Indoor MESH node, once this node is operational, additional devices can be added depending on the application and need.

Parts List

Item	Description	Source, Other Notes
Linksys WRT54G Router	Linksys uses R-TNC (reverse polarity TNC) connectors. This unit should have removable antennas and presents an RP-TNC Female connector. Check the description for the correct model and version number.	eBay, Flea Market, ~$10-$40 
VoIP / SIP Phone	Optional; Configured for DHCP, SIP server address, and user login and password. Any VoIP Phone will work as long as it runs the SIP Protocol.	Zultys Zip2, HSC, $16
Battery, 7Ah or greater	Gell Cell, 7Ah should be sufficient for a couple of hours of node use.	Various locations, such as Batteries and Lamps Plus, ~$35

Item	Description	Source, Other Notes
Antenna, Omni	The type of antenna depends on the deployment plan for this node. External antenna to provide higher gain for external field use, usually **N Type Female** connectors.	Amazon, eBay; ~$32; Flea Market. 
Antenna, Yagi	Yagi's may come with a pigtail and require either N-Connector or SMA. Check the data sheet to make sure all your purchases fit together.	Amazon, eBay; ~$30; Flea Market. 
Coax, 18"	RP-TNC Male to **N-Connector Male** (or whatever your antenna requires)	Amazon, eBay, <$10 
Passive PoE Injector Cable Set	The CAT5 cable has 2 unused twisted pair that allows us to do Power over Ethernet (PoE). The Passive PoE injector cable is a pair that allows you to run data and power to the router over a single CAT5 cable. Power is handled by matched female and male barrel connectors that integrate with the RJ-45 connector. If there is no phone at the location, only the power portion of the connector is used at the battery location. If you do place a phone with this node, the Ethernet from the power source side of the injector plugs directly into the phone. A Switch or additional CAT5 cables could also be used if more devices are to connect to this node.	Amazon, eBay, ~$6 
CAT5 Cable, 10-20 ft	When used with the PoE Injector, this provides a single cable run from the battery to the mast-mounted Router. The length is based on the size of the mast you deploy and the distance to the battery.	Frys,
Tripod and Mast	This equipment ensures you get the mode up in the air to provide .wide area coverage.	There are plenty of options here: 1. Home Depot had roof tripods and mast sections. 2. OSH has light bar tripods that can be adapted with a mast.

Item	Description	Source, Other Notes
		3. Amazon Speaker Tripod Stands, telescopes to 6.5ft, ~$35
Router Enclosure	This is for external mounting of the router on the tripod. The router should be mounted as close to the antenna to minimize line loss.	OSH, sprinkler controller enclosure, $35, or equivalent. 
Barrel connector	Type M5.5 x 2.1mm, If you include a phone at this location and elect to FAB the connector from scratch, you will need at least 1 of these.	Frys, Radio Shack, Jameco, Digikey, $1-$2 each. 
PowerPoles, 15A, 4 to 6 sets	Used to interconnect the above power cables. 6 sets required if you take the “cut power cable” approach.	HRO, Bag of 25, $10.00 
Power cable, qty 2 (phone to PP, PoE to PP)	Barrel Connector 5.5x2.1mm positive center to Power Pole.	Fab cable, or cut the power adaptors’ power cable 12-18” from barrel connector and install Power Poles on both cut ends to keep the adaptor operational.
Power cable, Bat to phone and PoE PP	Battery Flat Blade connector to two Power Pole connector sets.	Fab cable. Brings battery power through fuses to Power Poles. Consider an in-line switch to avoid connecting / disconnecting the Power Poles.

Outdoor MESH Node (Ubiquiti hardware)

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), 5 GHz (M5) and 900 MHz (M900) frequencies. They all utilize Power-Over-Ethernet (POE) via a CAT 5 data cable.

Parts List

Item	Description	Source, Other Notes
AirGrid 	**M2HP** 2.4 GHz - 20dBi Antenna **M5HP** 5.0 GHz - 27dBi Antenna Complete antenna and radio system integrated in a weather proof package ready for mounting. Includes 115V to 24V POE injector/power supply.	Streakwave Wireless, eBay $69.00 and up.
Bullet  	**M2HP** 2.4 GHz **M5HP** 5 GHz Complete radio system integrated in a weather proof package ready for mounting. Has an 'N' connector for connection directly to antenna (may need a barrel connector) or via a short RF cable. POE injector/power supply sold separately.	Streakwave Wireless, eBay $79.00 and up. $15.00

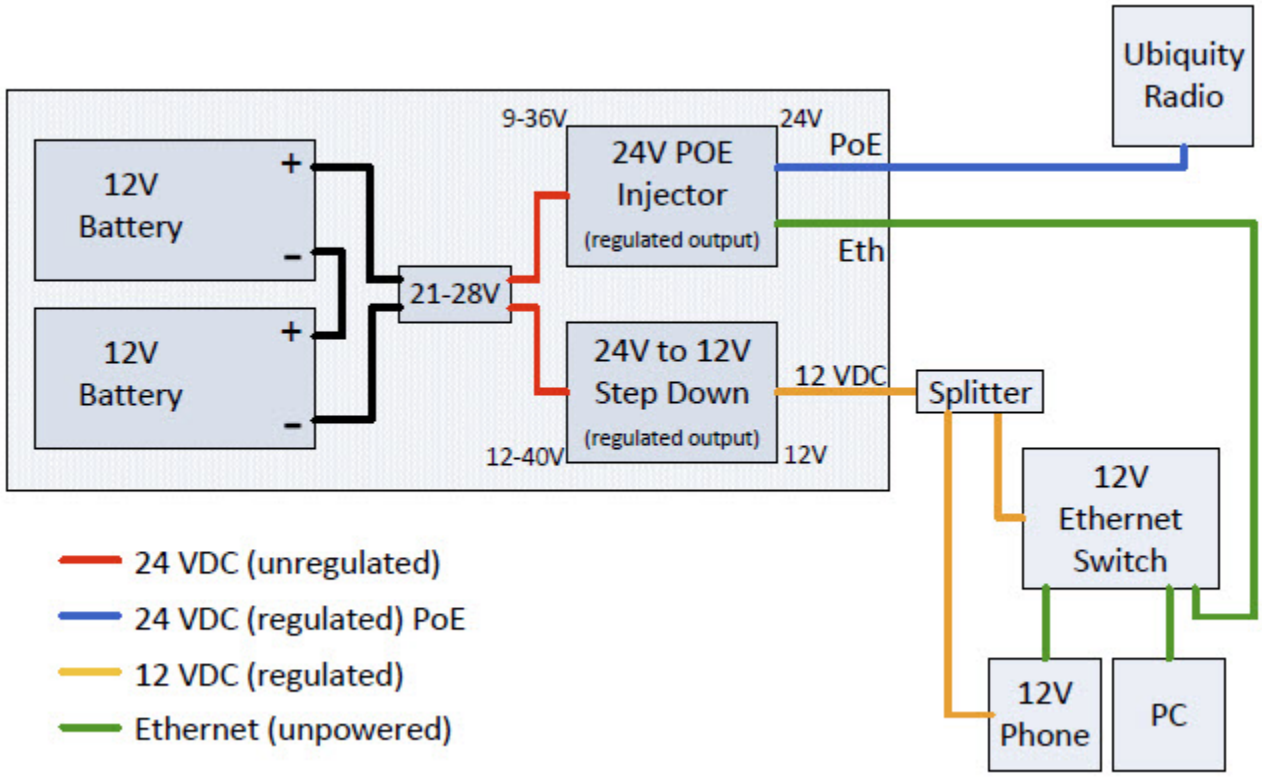
Nano 	**NSM2-US** 2.4 GHz - 11dBi Antenna 53° H&V Beamwidth, 27° Elevation **NSM5-US** 5 GHz - 17dBi Antenna 41° H&V Beamwidth, 15° Elevation Complete antenna and radio system integrated in a weather proof package ready for mounting. Includes 115V to 24V POE injector/power supply. 15 km+ range, 2x2 MIMO, dual-polarity.	Streakwave Wireless, eBay $89.00 and up.
Nano Loco 	**LocoM2-US** 2.4 GHz – 8dBi Antenna 60° H&V&E Beamwidth **LocoM5-US** 5 GHz – 13dBi Antenna 45° H&V&E Beamwidth **LocoM900** 900 MHz – 7.5dBi Antenna 60° H&V Beamwidth Complete antenna and radio system integrated in a weather proof package ready for mounting. Includes 115V to 24V POE injector/power supply. 15 km+ range, 2x2 MIMO, dual-polarity.	Streakwave Wireless, eBay $49.00 and up for M2 $67.00 and up for M65 $129.00 and up for M900
Rocket 	**M2** 2.4 GHz **M5** 5 GHz Ideal for Point-to-Point links requiring maximum performance. 50km+ range, 2x2 MIMO. Connects directly to a variety of Ubiquiti sector and omni antennas. Includes 115V to 24V POE injector/power supply.	Streakwave Wireless, eBay $89.00 and up.

Omni Antennas 	Available for all (M2, M5 and M900) frequencies and various dBi gains. Commonly used with Bullet or Rocket radios to provide 360° coverage. Some offer dual polarity. Most also have a small degree of down tilt.	Streakwave, eBay, Amazon, Halted Price varies.

The Ubiquiti devices utilize an 115V to 24VDC POE injector/power supply that is used to power the devices when commercial power is available.

While a Ubiquity device will operate from 11VDC to 25.5VDC, cable loss needs to be taken into consideration with POE devices. A 12VDC battery will not power the device over long cable runs and as the battery starts to sag issues with data throughput will develop. If at all possible provide a full 24 VDC to the device if you wish to maximize cable lengths. It has however been reported by many people they have successfully run a remote node from a 12VDC solar/battery system.

CAUTION: Two 12 volt fully charged batteries in series will exceed the 25.5 V maximum power of the device. *You will let the smoke out.* The figure below shows one way to provide power to the Ubiquiti node, an IP phone, and Ethernet Switch using batteries.



Example power configuration for powering Ubiquiti devices from batteries.

If the node needs to be powered from batteries, solar or other power sources then the devices below can be utilized to supply power to the Ubiquiti devices.

POE Converter/Injector 	**TP-DCDC-1224** Tycon Power Systems POE Converter 9-36VDC in 24VDC out, 19W DC to DC Converter This can be used with a 12V battery or solar system to provide a regulated 24VDC via a CAT 5or CAT 6 data cable to Ubiquiti devices.	Streakwave, eBay. $32.25 and up
DC 24V to 12V step-down converter 	**DC/DC Converter Regulator** Provides stable power to Internet Switch • Built-in over/under voltage input, overload, overhead, and short circuit full protection • Auto-recovery when device is back to normal operation • 100% waterproof & anti-shock protection	Amazon $15.00 and up.
POE Injector 	**POE Injector** Places DC power on unused pairs of CAT 5 cable. The POE Converter shown above will provide the same capability as this device along with power regulation when using batteries. This injector could be utilized if power regulation is not required.	Amazon, eBay, Frys $2.00 and up.
PoE 48V to 16V 	**802.3af 48V to Ubiquiti PoE** Ubiquiti Instant 802.3af Adapter Converts 802.3af standard 48V PoE to 16V PoE for use with Ubiquiti devices. Useful for connecting Ubiquiti devices to existing 802.3af standard switches or power injectors.	Streakwave $19.00

NetGear GS105E Switch	VLAN Capable Switch	Ebay, Frys, Amazon
	The Ubiquiti devices only have one port. To connect two Ubiquiti devices together so they pass traffic over a wired connection rather than WiFi you will need a VLAN capable Internet Switch. I.E. M2 to M5 devices	$50.00 and up.

Appendix A – Signal Strength

1. **Signal Strength**
    a. Signal strength in the digital world relates to the rate of packet loss at a given data rate. More lost packets effectively lower your data rate.
    b. Antenna Gain makes a big difference with signal strength

2. **Signal measurement**
    a. The decibel system only describes relative power, so a gain of 3 dB means your signal is 2 times as strong as it was before, but the dB scale doesn't define where you're starting from or what your 'zero' is.
    b. To make it absolute, we specify dBm, indicating that our scale is relative to 1 milliWatt of power.
    c. 0 dBm = 1 mWatt
    d. 30 dBm = 1 Watt
    e. Negative values represent small but positive numbers on a logarithmic scale.
    f. -85 dBm is less powerful (smaller) than -60 dBm.

To give you a sense of proportion:

Example:

Device:	Linksys WRT54G	
Frequency:	**2400**	MHz
Distance:	**1**	Km

	Watts	dBm	Cum dBm
transmit Power	**0.065**	18.12913357	18.12913
Feedline		**-1**	17.12913
Sector Antenna TX Gain		**13**	30.12913
Free Space Path Loss		-100.0442248	-69.9151
Recv Antenna RX Gain		**24**	-45.9151
Feedline		**-1**	-46.9151
Rain Fade (Estimate)		**-15**	-61.9151
Received Power			-61.9151

If rcvr sensitivity = -75 dBm, then	Link Margin =	13.08491
If rcvr sensitivity = -96 dBm, then	Link Margin =	34.08491

3. Noise Level

a. The noise level indicates the amount of background noise in your environment.

b. If the noise level is too high, it can result in degraded strength and performance for your wireless signal strength.

c. Noise level is measured in -dBm format (0 to -100). This is the power ratio in decibels (dB) of the measured power referenced to one milliwatt.

d. The closer the value to 0, the greater the noise level.

e. Negative values indicate less background noise. For example, -96dBm is a lower noise level than -20dBm.

4. Signal to Noise Ratio

a. If you have a -41dBm signal strength, and a -50dBm noise level, this results in a poor signal-to-noise ratio of +9dBm.

b. If you have a -41dBm signal strength, and a -96dBm noise level, this results in an excellent signal-to-noise ratio of +55dBm.

Appendix B – References

1. Broadband Hamnet, main site for info, software, etc. -- http://www.broadband-hamnet.org/
2. Northwest MESH Amateur Radio Networking -- http://nw-mesh.wikidot.com/
3. Montana Mesh Project -- http://www.meshstuff.com/hsmm-mesh-site/
4. dBm Reference -- http://en.wikipedia.org/wiki/DBm
5. Setting up your mesh node -- http://bloodhound.bbhndev.org/products/BBHN/wiki/HowTo/NodeSetup
6. Bandwidth discussion -- http://www.radio-electronics.com/info/wireless/wi-fi/80211-channels-number-frequencies-bandwidth.php
7.