



Rocky Mountain Ham Radio

BASIC IP & ROUTER Training



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Inside TCP/IP

Inside the TCP/IP standard there are several protocols for handling data communication:

- TCP (Transmission Control Protocol) communication between applications (Checksums and Error Correction included)
- UDP (User Datagram Protocol) simple communication between applications (Fire and Forget, no error correction)
- IP (Internet Protocol) communication between computers
- ICMP (Internet Control Message Protocol) for errors and statistics (i.e. ping)
- DHCP (Dynamic Host Configuration Protocol) for dynamic addressing (gives out your addresses)



TCP Uses a Fixed Connection



- TCP is for communication between applications. This is what most traffic on the internet is made of. http/https/ssh etc.
- If one application wants to communicate with another via TCP, it sends a communication request. This request must be sent to an exact address. After a "handshake" between the two applications, TCP will set up a "full-duplex" communication between the two applications.
- The "full-duplex" communication will occupy the communication line between the two computers until it is closed by one of the two applications.
- UDP is very similar to TCP, but simpler and less reliable. This is used for VoIP, IP Site Connect, Allstar, IRLP, Echolink.

IP Routers



- When an IP packet is sent from a computer, it arrives at an IP router.
- The IP router is responsible for "routing" the packet to the correct destination, directly or via another router.
- The path the packet will follow might be different from other packets of the same communication. The router is responsible for the right addressing, depending on traffic volume, errors in the network, or other parameters.
- In order to route, you have to know the next hop. Sometimes called the gateway.

TCP/IP Addressing



- TCP/IP uses 32 bits, or four numbers between 0 and 255, to address a computer.
- Each computer must have an IP address before it can connect to the Internet.
- Each IP packet must have an address before it can be sent to another computer.
- This is an IP address: 192.168.73.7
This might be the same IP address:
www.rmham.org

An IP Address Contains 4 Numbers.



- Each computer must have a unique IP address.
- Run a command on your laptop in a dos window:
 - windows: `ipconfig /all`
 - mac/linux: `ifconfig -a`this will show your ip address.
- TCP/IP uses four numbers to address a computer. The numbers are always between 0 and 255.
- IP addresses are normally written as four numbers separated by a period, like this:
192.168.1.50

32 Bits = 4 Bytes



- In computer terms, TCP/IP uses **32 bits** addressing. One **byte** is 8 bits. TCP/IP uses **4 bytes**.
- One byte can contain 256 different values:
- 00000000, 00000001, 00000010, 00000011, 00000100, 00000101, 00000110, 00000111, 00001000and all the way up to 11111111.
- Now you know why a TCP/IP address is four numbers between 0 and 255.

Domain Names



- A name is much easier to remember than a 12 digit number.
- Names used for TCP/IP addresses are called domain names.
- **rmham.org** is a domain name.
- When you address a web site, like `http://www.rmham.org`, the name is translated to a number by a Domain Name Server (DNS).
- All over the world, DNS servers are connected to the Internet. DNS servers are responsible for translating domain names into TCP/IP addresses.
- When a new domain name is registered together with a TCP/IP address, DNS servers all over the world are updated with this information.

TCP Protocols (There are a lot!)



- TCP
- IP
- HTTP
- HTTPS
- SSL
- SMTP
- MIME
- IMAP
- POP
- FTP
- NTP
- DHCP
- SNMP
- LDAP
- ICMP
- ARP
- RARP
- BOOTP
- PPTP

Subnet Mask Quick Ref



Subnet mask quick reference							
Host Bit length	math	Max hosts	Subnet mask	Mask octet	Binary mask	Mask length	Subnet length
0	$2^0=$	1	255.255.255.255	4	11111111	32	0
1	$2^1=$	2	255.255.255.254	4	11111110	31	1
2	$2^2=$	4	255.255.255.252	4	11111100	30	2
3	$2^3=$	8	255.255.255.248	4	11111000	29	3
4	$2^4=$	16	255.255.255.240	4	11110000	28	4
5	$2^5=$	32	255.255.255.224	4	11100000	27	5
6	$2^6=$	64	255.255.255.192	4	11000000	26	6
7	$2^7=$	128	255.255.255.128	4	10000000	25	7
8	$2^8=$	256	255.255.255.0	3	11111111	24	8
9	$2^9=$	512	255.255.254.0	3	11111110	23	9
10	$2^{10}=$	1024	255.255.252.0	3	11111100	22	10
11	$2^{11}=$	2048	255.255.248.0	3	11111000	21	11
12	$2^{12}=$	4096	255.255.240.0	3	11110000	20	12
13	$2^{13}=$	8192	255.255.224.0	3	11100000	19	13
14	$2^{14}=$	16384	255.255.192.0	3	11000000	18	14
15	$2^{15}=$	32768	255.255.128.0	3	10000000	17	15
16	$2^{16}=$	65536	255.255.0.0	2	11111111	16	16
17	$2^{17}=$	131072	255.254.0.0	2	11111110	15	17
18	$2^{18}=$	262144	255.252.0.0	2	11111100	14	18
19	$2^{19}=$	524288	255.248.0.0	2	11111000	13	19
20	$2^{20}=$	1048576	255.240.0.0	2	11110000	12	20
21	$2^{21}=$	2097152	255.224.0.0	2	11100000	11	21
22	$2^{22}=$	4194304	255.192.0.0	2	11000000	10	22
23	$2^{23}=$	8388608	255.128.0.0	2	10000000	9	23
24	$2^{24}=$	16777216	255.0.0.0	1	11111111	8	24

Private Address Space



- 10.0.0.0/8 (10.0.0.0 to 10.255.255.255)
10.0.0.0/8 is normally used for larger networks, since there are approximately 16.8 million IP addresses available within that block. They chop it up into lots of smaller groups of subnets for each geographic location, which are then subdivided into even smaller subnets. Smaller companies typically use the 172.16.0.0/12 range, chopped up into smaller subnets, although there's no reason they can't use 10.0.0.0/8 if they want to. Home networks typically use a /24 subnet within the 192.168.0.0/16 subnet.
- 172.16.0.0/12 (172.16.0.0 to 172.31.255.255)
- 192.168.0.0/16 (192.168.0.0 to 192.168.255.255)
- 169.254.0.0/16 (169.254.0.0 to 169.254.255.255)
These addresses are used for private address self-assignment when a DHCP server isn't available.



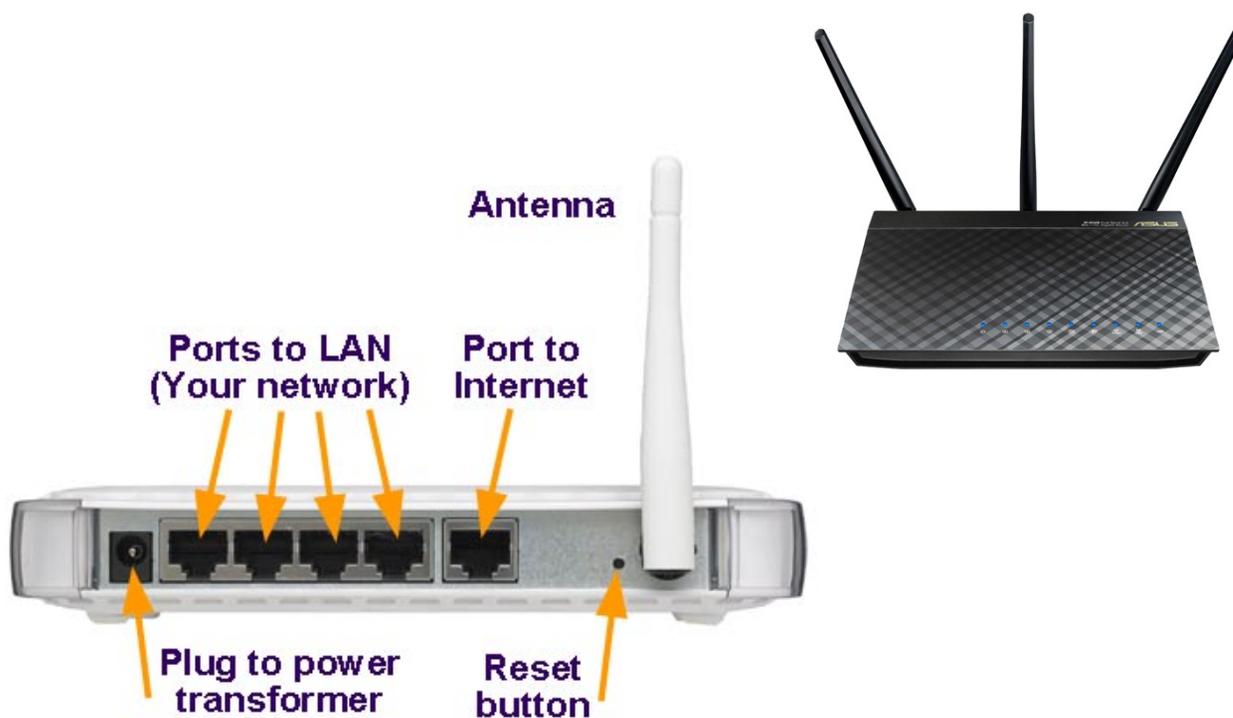
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HOME ROUTERS



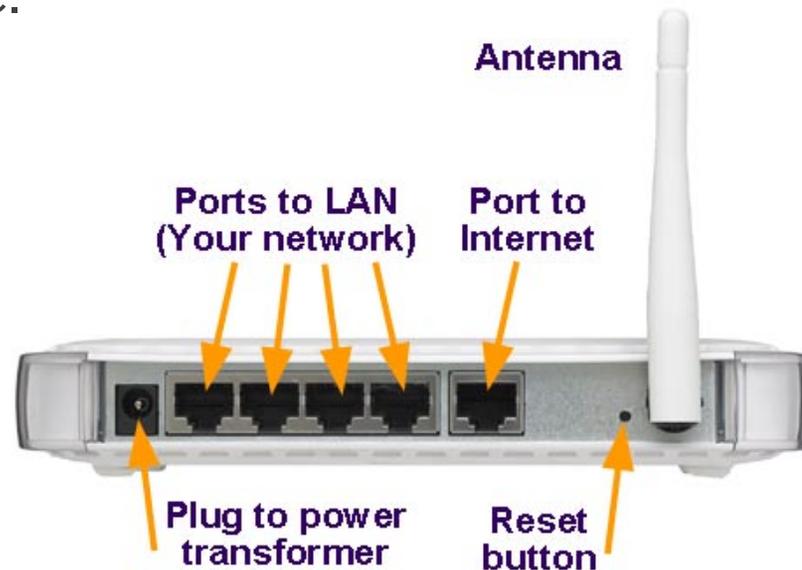
Your Home Network

- There are many manufacturers of home routers, but they are all the same. They are easy to set up by design. They are not usually very flexible and designed to connect to a single ISP.



Your Home IP Config

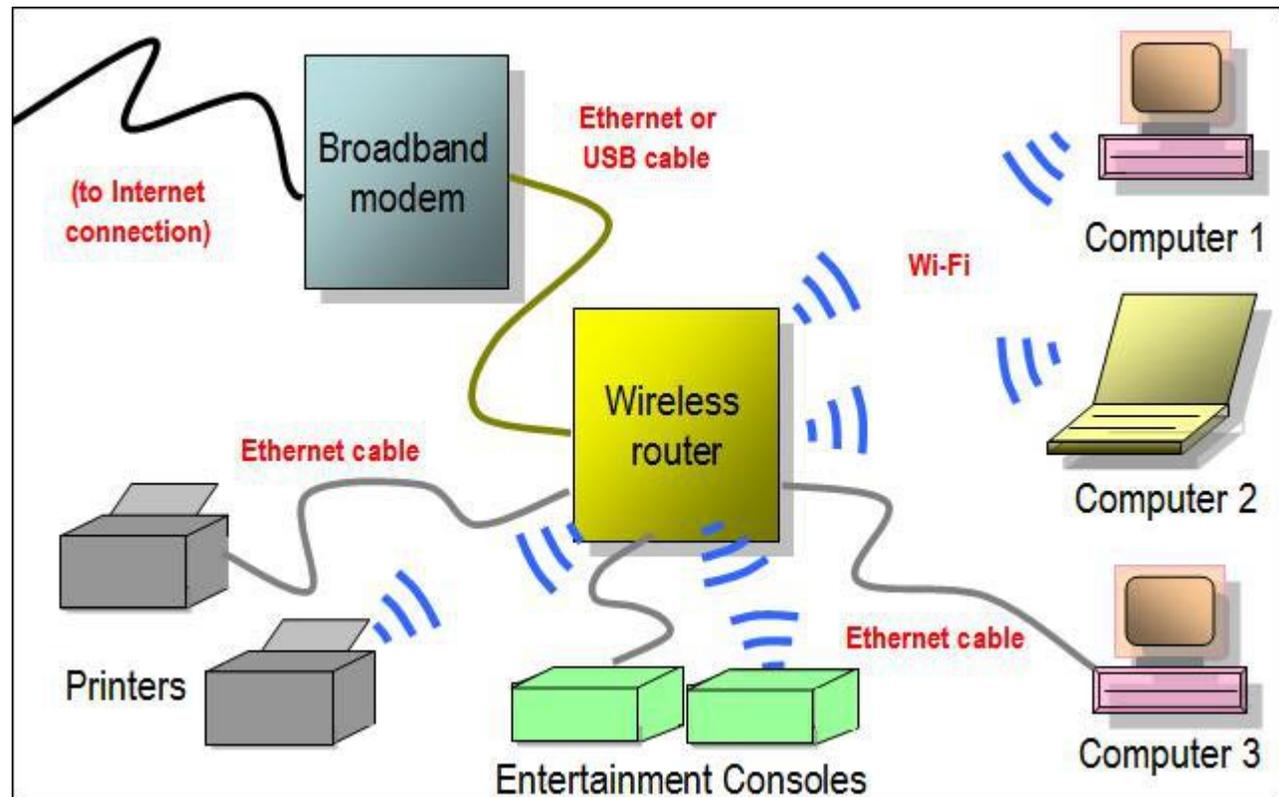
- Your home or LAN (Local Area Network) is likely on a 192.168.x.x, 172.16.x.x or 10.x.x.x network. These are in the private address space as shown before.



- The Internet or WAN (Wide Area Network) port of your router is usually DHCP but sometimes can be a Static IP Address and is specific to your ISP installation.

Your Network Configuration

- All of your home network devices need to have different IP Addresses. Things like printers and network attached storage units should have dedicated IP addresses so they can be reliably accessed. Use DHCP for transient devices.



Network Layout

- Most home networks are /24 or 255.255.255.0 which is 255 IP addresses. .1 is usually the router. 0 and 255 are unusable as they are reserved for TCP/IP functions. That leaves 253 usable IP addresses.



- Dedicate adequate space in your network for transient devices. These will use DHCP. I use . 100-200.
- Use WPA-2 encryption on your Wireless Access Point. The longer the password, the safer you are. It's much more secure than WEP but can still be broken with free tools.
- Install static IP addresses in all of your stable devices, printers, drives, anything that needs to be accessed remotely.

Network Layout

- Wired networks are faster and more secure. If you're concerned about security, use MAC Address Filtering on your Wireless Access Point.



- Use a wire if you're trying to transfer big files.
- Use good network gear. Do not use the cheapest device you can find! You get what you pay for.
- Install static IP addresses in all of your stable devices, printers, drives, anything that needs to be accessed remotely.



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ROUTING TABLES, ROUTES, OSPF



Multi Gateway Router

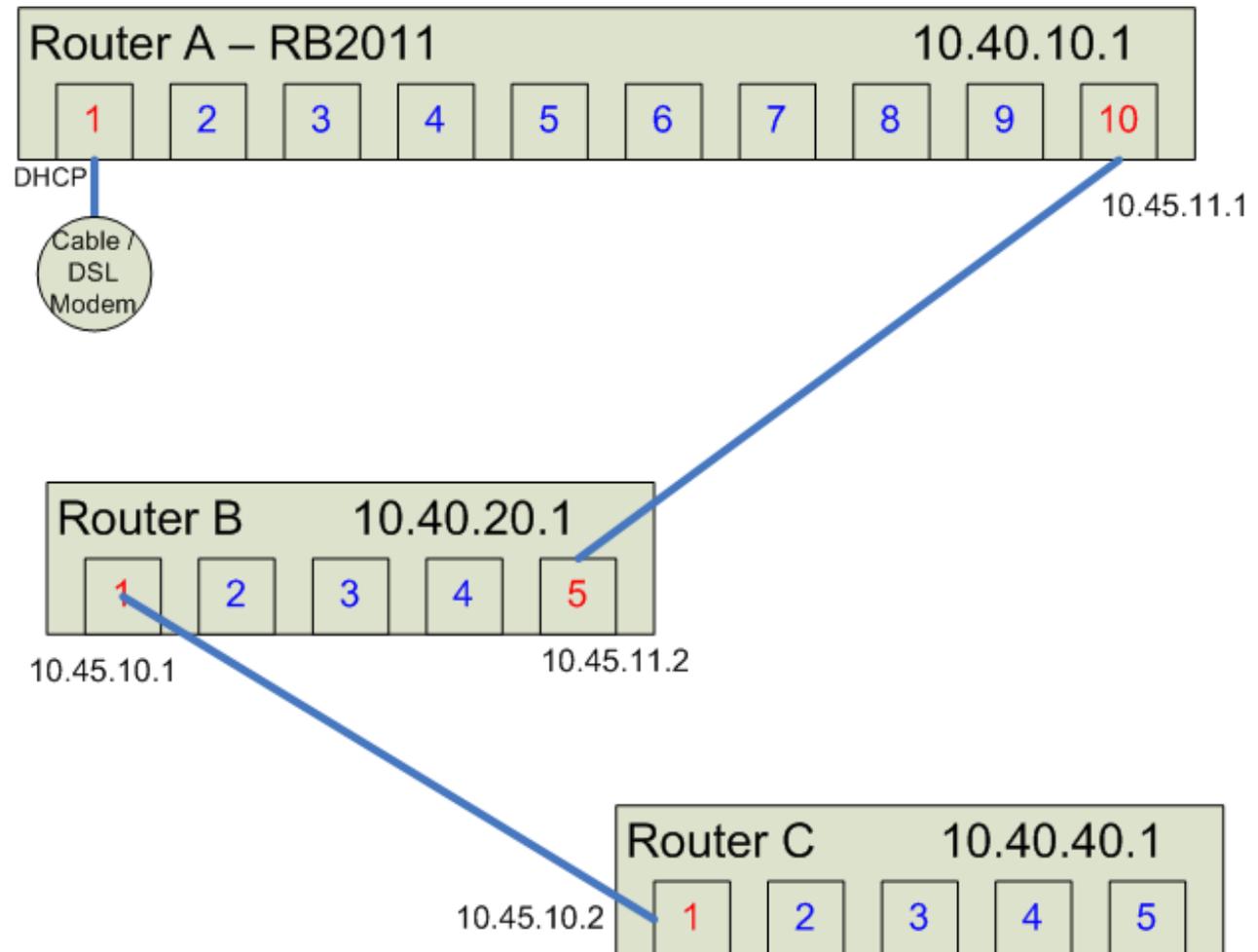
- Each interface has a different IP and Gateway on the way to different routers.
- Different subnets may travel out different router ports to get there.



Route List					
Routes					
Nexthops					
Rules					
VRF					
+ - [check] [X] [filter]					
	Dst. Address	Gateway	Distance	Routing Mark	Pref. Source
AS	▶ 0.0.0.0/0	10.20.20.1 reachable ether1-K2AD LINK	1		
S	▶ 0.0.0.0/0	10.20.1.2 reachable ether6-LEE HILL	20		
AS	▶ 10.0.0.0/16	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.1.0.0/16	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.5.0.0/16	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.10.0.0/16	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.11.0.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.20.0.0/24	10.20.20.1 reachable ether1-K2AD LINK	1		
DAC	▶ 10.20.1.0/24	ether6-LEE HILL reachable	0		10.20.1.1
AS	▶ 10.20.2.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.20.3.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
DAC	▶ 10.20.4.0/24	ether9-HORSETOOTH reachable	0		10.20.4.1
AS	▶ 10.20.5.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.20.6.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.20.7.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.20.8.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
DAC	▶ 10.20.9.0/24	ether7-LOOKOUT reachable	0		10.20.9.1
AS	▶ 10.20.10.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.20.11.0/24	10.20.1.2 reachable ether6-LEE HILL	1		
AS	▶ 10.20.12.0/24	10.20.20.1 reachable ether1-K2AD LINK	1		

Multiple Routers

- Multiple Routers are single routers connected by Ethernet and routed appropriately.



Automatic Routing

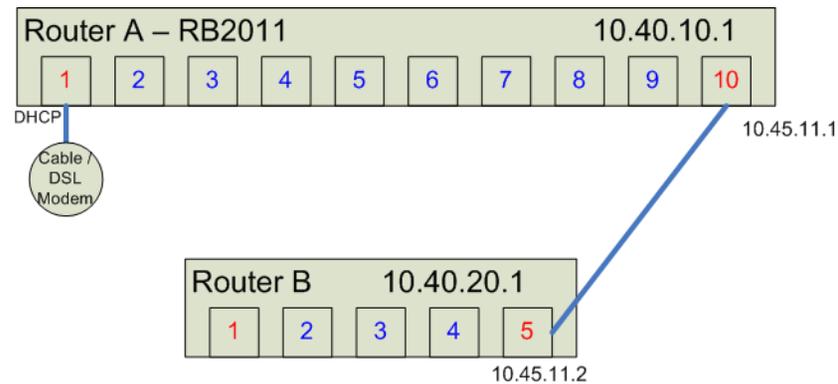


- There are very solid and tested tools for distributing routing tables automatically. RIP/OSPF/BGP which can simplify (or complicate) the job of routing. There are other protocols, but we're not going to get that deep!
- OSPF – Open Shortest Path First – is by far the most popular routing protocol for private networks. It's very fast and reliable and relatively easy to set up.
- RIP – Router Information Protocol – is another widely used protocol which is relatively easy to set up.

Note: I do not recommend you set this up on any real world network unless you are SURE of the consequences associated with this. It can be a bear and have unintended results which can mean a lot of driving!!! Take it from experience.

How do I get from A to B?

- Your router only knows the “next hop” in any route. It may have multiple interfaces to go multiple directions, but there’s still only one hop to go any direction. The next router.



Router A

10.40.10.1/24 - 10.45.11.1/24 <-> 10.45.20.1/24 - 10.45.11.2/24

Router B

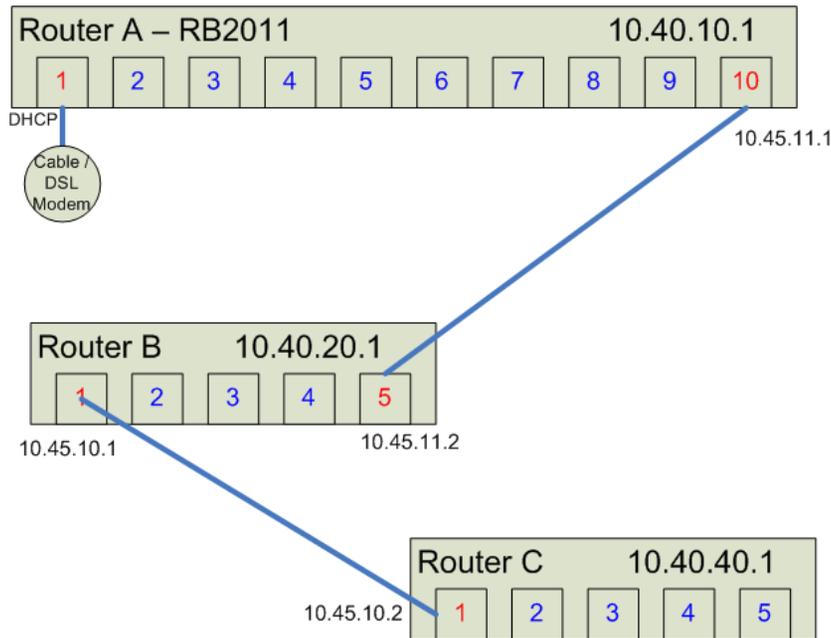
Routing Table In router A

10.40.10.0/24 next hop 10.45.11.2

Routing Table In router B

10.40.20.0/24 next hop 10.45.11.1

Lets Add a Router C



- Since you've now added another router, you need to be able to tell each of these routers where the others are.

Router A

Router B

10.40.0.1/24 - 10.45.0.1/24 < -
>10.45.0.2/24 -10.40.1.1/24

Router B

Router C

10.40.1.1/24 - 10.45.1.1/24 < -
>10.45.1.2/24 -10.40.2.1/24

Routing Table In router A

10.40.1.0/24 next hop 10.45.0.2

10.40.2.0/24 next hop 10.45.0.2

Routing Table In router B

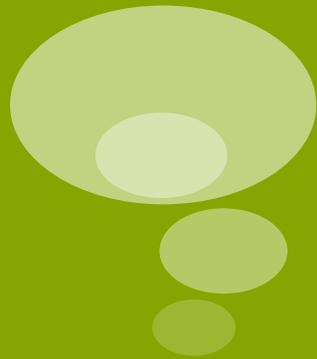
10.40.0.0/24 next hop 10.45.0.1

10.40.2.0/24 next hop 10.45.1.2

Routing table in Router C

10.40.0.0/24 next hop 10.45.1.1

10.40.1.0/24 next hop 10.45.1.1



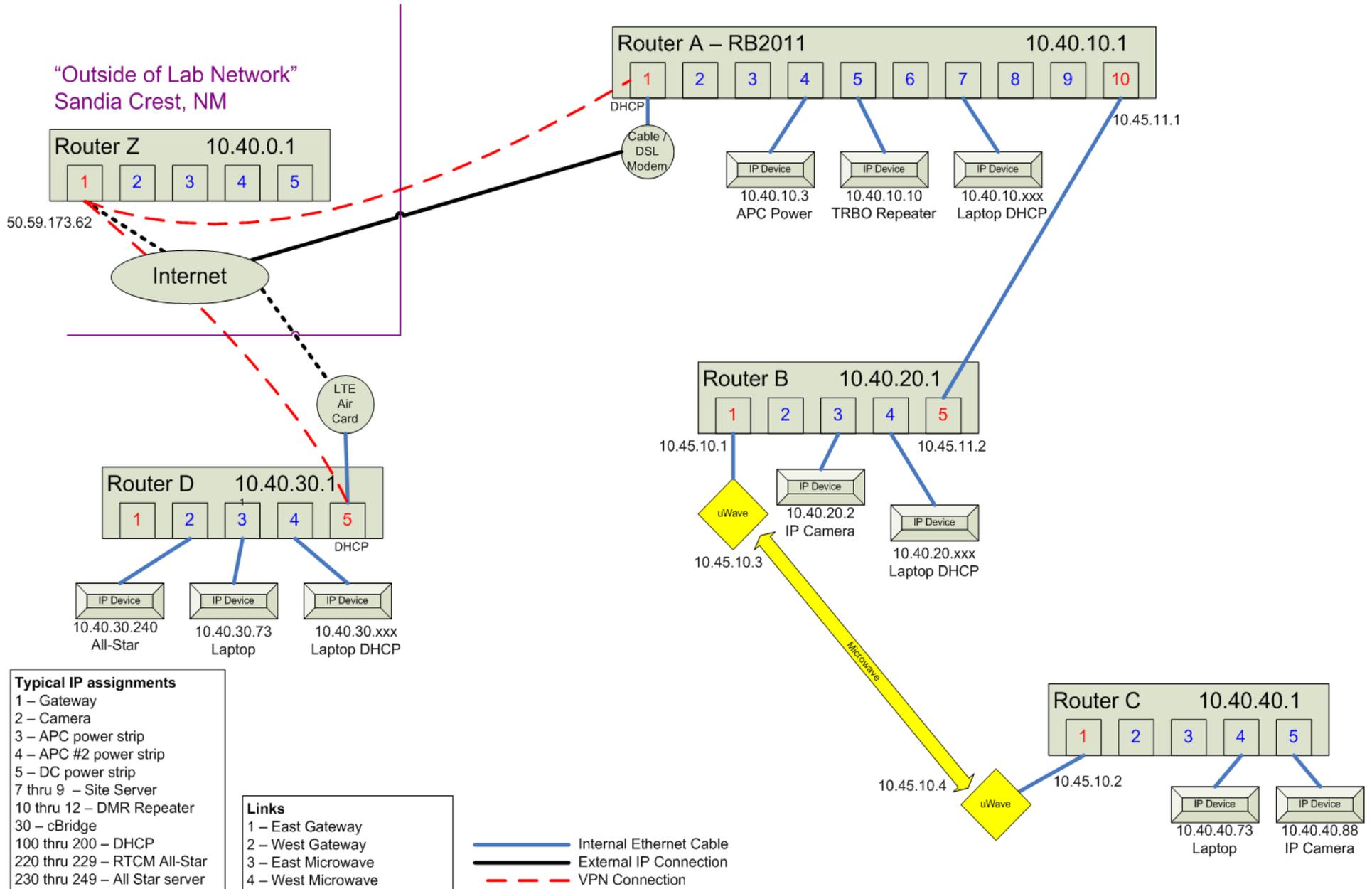
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PRACTICAL LAB



Practical Lab

RMHAM New Mexico --- Lab Setup





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USE CASES and LAB EXERCISES



Lab Exercises

1. Each table configures a router (Router A, B, C and D)
 - Winbox
2. Build your backhaul
 - Microwave
 - Ethernet cable
 - Air Card
3. Connect your router to the neighbors (see drawing)
4. Connect user IP device
5. Test Connectivity
 - Ping
 - Traceroute



Use Cases – Let's Debug a failure

Scenario 1

- Goal: Find error in routing table
- Symptom: IP camera on router C not sending video to laptop on Router A
- Bug: change routing table in router C



Use Cases – Let's Debug a failure

Scenario 2



- Goal: Connect a DMR Repeater to the network
- Action: Program and add repeater at Site A, connecting to Router A, LAN port, using IP 10.40.10.10
- Causes: (not disclosed to lab)
 - Power off repeater with APC (no response to ping)
 - Misconfigure UDP or Auth Key



BACKUP SLIDES