Network + Section 7 - IP Addressing

IP Addressing

- Internet Protocol (IP) Address - An assigned numerical label that is used to identify Internet communicating devices on a computer network.
- Layer 2 between two devices that are internal to their own network or LAN. Based on MAC addresses.
- Layer 3 between two different networks or even two different subnets.
- IP address comes in two formats
    - IPv4 Internet Protocol v4
    - IPv6 Internet Protocol v6
- OBJ 1.4 Given a scenario, configure a subnet and use appropriate IP addressing schemes.
- OBJ 1.6 Explain the use and purpose of network services.

IPv4 Addressing

Dotted-Decimal Notation

10	1	2	3
172	21	243	67

- Each one of those numbers is known as an octet, they each have a decimal number that is used to represent an eight bit number.
    - They can only represent a value from 0 - 255.
    - When all 4 octets are combined we have four octets that contain eight bits each for a total of 32 addressable space.
    - If there is a 1 in the binary of the subnet mask, it's part of the network portion of the IP address.
    - If there is a 0 in the binary portion of the subnet mask, this means its part of the host portion.

	1st Octet	**2nd Octet**	**3rd Octet**	**4th Octet**
Dotted-decimal	192	168	1	4
Binary Digits	11000000	10101000	00000001	00000100
Subnet mask	255	255	255	0
Subnet mask	11111111	11111111	11111111	00000000

- IPv4 Addressing and classes or groupings of ranges

Class	1st Octet Value	Default Subnet Mask	Possible Host
A	1-127	255 0 0 0 N H H H	16.7 million (256 x 256 x 256)
B	128-191	255 255 0 0 N N H H	65,536 (256 x 256)
C	192-223	255 255 255 0 N N N H	256
D	224	-	-
E	240-255	-	268 million (reserved)

- Class D IP address space is reserved for multicasting or multicast routing.
    - Multicast Address - A logical identifier for a group of hosts in a computer network.
        - The multicast address doesn't have to align with a group of hosts.
- Class E IP address space is reserved for research and development or study only.
- Datagram would be rejected if Ip address was within the Class E IP address space.
- Classful Mask - The default subnet mask for a given class of IP addresses.
- Classless Inter-Domain Routing - Allows for borrowing some of those host bits and reassigning them to the network portion. CIDR Notation.
- Subnetting - Allows for the use of a classless subnet mask to create smaller networks with fewer hosts in each network.

Class	1st Octet Value	Default Subnet Mask	CIDR Notation
A	1-127	255 0 0 0 N H H H	/8
B	128-191		/16

		<table><tr><td>255</td><td>255</td><td>0</td><td>0</td></tr><tr><td>N</td><td>N</td><td>H</td><td>H</td></tr></table>	
C	192-223	<table><tr><td>255</td><td>255</td><td>255</td><td>0</td></tr><tr><td>N</td><td>N</td><td>N</td><td>H</td></tr></table>	/24

- There are 2 different types of IPv4 addresses
    - Public (Routable) - Can be accessed over the Internet and is assigned to the network by an Internet service provider.
        - Globally managed by ICANN.
            - Internet Corporation for Assigned Names and Numbers (ICANN) - Globally manages and leases publicly routable IP addresses.
                - ARIN (North America)
                - LACNIC (Latin America)
                - AFNIC (Africa)
                - APNIC (Asia Pacific)
                - RIPE (Europe)
    - Private (Non-Routable) - Can be used by anyone any time, but only within their own local area network.
        - Private IP ranges include those that start with either 10, 172, or 192.
        - When you go out to the internet your router performs Network Address Translation (NAT) which allows for routing of private IPs through a public IP.
- RFC 1918 - Used to document how organizations could conduct address allocation for private Internets (Intranets).

Class	Starting Value	IP Range	Possible Hosts
A	10	10.0.0.0 - 10.255.255.255	16.7 million (256 x 256 x256)
B	172.16-172.31	172.16.0.0- 172.31.255.255	1.05 million (16 x 256 x256)
C	192.168	192.168.0.0- 192.168.255.255	65,536 (256 x 256)

- Two special IP address
    - Loopback Address (127.0.0.1) - Creates a loopback to the host and is often used in troubleshooting and testing network protocols on a system.
        - This allows the host to send itself data without going out to a switch or a router.
        - Testing network protocols to ensure drivers are working properly.

    - Automatic Private IP Addresses APIPA - Used when a device does not have a static IP address or cannot reach a DHCP server.
        - Addresses begin with 169.254.0.0 to 169.254.255.255
        - This goes through a 4 step process when negotiating the DORA process with DHCP. If the host is unable to gain an IP address via DHCP the host will assign itself an IP address within the APIPA
            - Discover
            - Offer
            - Request
            - Acknowledge
- Virtual IP Address (VIP or VIPA) - An IP address that does not correlate to an actual physical network interface.
    - These virtual IP address spaces are usually used for
        - NAT
        - Fault-tolerance
        - Virtualization
    - Routers provide virtual IP addresses to provide redundancy in their connectivity options.
    - Routers often use virtual IP addresses to provide redundancy in their connectivity options.
- Subinterfaces - A virtual interface that is created by dividing up one physical interface into multiple logical interfaces.
    - These subinterfaces are used for inter-VLAN routing of traffic by creating two subinterfaces for one physical interface and then assigning each of those subinterfaces with an IP address from the appropriate subnet. Router can connect these two subnets.

IPv4 Data Flows

- Unicast - Data travels from a single source device to a single destination device.
- Multicast - Data travels from a single source device to multiple (but specific destination devices).
- Broadcast - Data travels from a single source device to all devices on a destination network.

Assigning IP Addresses

- Static Assignment - Manually typing in the IP address for the host, its subnet mask, default gateway, and DNS server.
    - Static assignment of IP addresses is impractical on large enterprise networks.
- Dynamic Assignment - Dynamic allocation of IP addresses.
    - Most SOHO network devices already run a DHCP server and are turned on by default.
- There are 4 components of a fully configured client.
    - IP Address
    - Subnet Mask
    - Default Gateway
    - Server Address
- Domain Name System (DNS) - Converts the domain names used by a website to the IP address of its server.
    - DNS is the internet's version of a phone book.

- Windows Internet Name Service(WINS) - Identifies NetBIOS systems on a TCP/IP network and converts those NetBIOS names to IP addresses.
    - Only works within a wWindows domain environment.
- When it comes to the dynamic assignment of critical addressing information for each client there are four methods.
    - Bootstrap Protocol (BOOTP) - Dynamically assigns IP addresses and allows a workstation to load a copy of their boot image over the network.
        - Oldest and least used. Introduced for diskless Unix workstations.
    - Dynamic Host Control Protocol (DHCP) - Assigns an IP based on an assignable scope or pool of addresses and provides the ability to configure numerous other options within it.
        - Each IP is leased for a period of time and returns to the pool when lease expires.
        - This IP Address Management manages the IPs being assigned and returned over time.
            - DHCP gives the client different variables that they need to communicate.
                - IP address
                - Subnet mask
                - Default Gateway
                - DNS/WINS server
        - DHCP is the modern implementation of BOOTP.
    - Automatic Private IP Addressing (APIPA) - Used when a device does not have a static IP address or cannot reach a DHCP server.
        - APIPA is selected by default under the TCP/IP properties under the alternate configuration tab. This allows a windows machine to assign itself an IP address automatically under a certain IP range.
        - Allows for the quick configuration of a LAN without the need for a DHCP server.
        - APIPA-assigned devices cannot communicate outside the LAN or with non-APIPA devices.
    - Zero Configuration (ZeroConf) - A newer technology based on APIPA which provides a lot of the same features and some new ones.
        - Assign an IPv4 link-local address to a client.
            - The client can resolve computer names to IP addresses without the need for DNS by using mDNS (or multicast domain name service)
        - Perform service discovery on a network.
            - Different manufacturers use zero config but are called something else.
                - Apple Bonjour - used for service discovery.
                - Windows Link-Local Multicast Name Resolution (LLMNR) - Is an extension of APIPA for name resolution and service discovery.
                - Linux SystemD - The systemd-resolved background service.

Computer Mathematics

- We learned to count in BASE-10 (decimals) - 0,1,2,3,4,5,6,7,8,9,...
    - There are only 10 options.
- Computers do everything in binary or BASE-2 numbering.
    - Base-2 (binary) 0,1,10,11, …
- Converting from decimal to binary.

128 (2^7)	64 (2^6)	(32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)
1	**0**	**0**	**1**	**0**	**1**	**1**	**0**
10010110							
128 + 16 + 4 +2+ = 150							
Populate the table with the binary digits Add up any columns that contain a 1							

128 (2^7)	64 (2^6)	(32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)
1	**0**	**1**	**0**	**0**	**1**	**1**	**0**
167							
167 -128 = 39 **39 - 64 = x** **39 -32 = 7** **7 - 16 = x**		**7 - 8 = x** **7 - 4 = 3** **3 - 2 = 1** **1 - 1 = 0**					
Use subtraction to convert decimal to binary							

Subnetting

- Subnetting - Taking a large network and splitting it up into smaller networks.
    - Subnet masks modify subnets and create better scoped networks.
        - By creating subnets this will allow us to
            - Efficiency
            - Security
            - Bandwidth control

Address Class	Default Subnet Mask	Assignable IP Calculation	Assignable IP addresses
Class A	255.0.0.0	2^{24} - 2 =	16,777,214
Class B	255.255.0.0	2^{16} - 2 =	65,534
Class C	255.255.255.0	2^8 - 8 =	254

- Public IPs cost money and you want to make sure you're paying for what you use, it can be expensive when you have to use multiple IPs.
- Calculating the number of subnets

    - Created subnets 2^s s = number of borrowed bits
    - /25 network 2^1 = 2 subnets 1 = number of borrowed bits
    - Assignable IP addresses 2^h - 2 h = number of host bits
    - /25 2^7 - 2 32 total - 25 network = 7 host
- Every network has to have two IP addresses reserved.
    - Network ID - First IP in the network.
    - Broadcast ID - Last one in the network.
- Example:
    - 192.168.1.0/24 2^0 = 1 subnet 0 = number of borrowed bits
    - This is a classful class c network
    - 192.168.1.9/24 32 total - 24 network - 8 host

192	**168**	**1**	**0**
255	**255**	**255**	**0**
11111111	**11111111**	**11111111**	**00000000**
Network bits			**Host bits**

- Example for creating a smaller subnet from 192.168.1.0/24
    - 192.168.1.0/26
    - 2^2 = number of borrowed bits 2 = number of borrowed bits
    - 2^2 = 4 subnets 2 = number of borrowed bits
    - 2^6 - 2 / 64 -2 = 62 32 total - 26 network = 6 host

192.168.0.1 to 19.168.1.3 (64 IPs)	**192.168.1.64 To 192168.1.127 (64 Ips)**
192.168.1.128 To 192.168.1.191 (64 Ips)	**192.168.1.192 To 192.168.1.255 (64 IPs)**
192.168.1.0/24 (256 IPs)	

- There can be no communication between subnets unless there is a router to forward that traffic.

192.168.0.1 to 19.168.1.3 (62 usable IPs)	**192.168.1.64 To 192168.1.127 (62 usable Ips)**
192.168.1.128 To 192.168.1.191 (62 usable Ips)	**192.168.1.192 To 192.168.1.255 (62 usable IPs)**

192.168.1.0/24 (256 IPs)

- Classless Interdomain Routing (CIDR) - Shorthand notation used to summarize continuous networks called using route aggregation.

192.168.1.0/26				
Network Address	**1st Octet**	**2nd Octet**	**3rd Octet**	**4th Octet**
192.168.1.1	**11000000**	**10101000**	**00000001**	**00000001**
192.168.1.2	**11000000**	**10101000**	**00000001**	**00000010**
19.168.1.3	**11000000**	**10101000**	**00000001**	**00000011**
...	**...**	**...**	**...**	**...**
192.168.1.63	**11000000**	**10101000**	**00000001**	**00111111**

- Variable-Length Subnet Mask (VLSM) - Allows subnets of various sizes to be used and requires a routing protocol that supports it.
    - There are other routing protocols that can do the same
        - RIP
        - OSPF
        - IS-IS
        - EIGRP
        - BGP
    - VLSM is a subnetting of subnets. Without VLSM all subnets wouldhave to be the same size. Using VLSM you can break subnets into the required chunks.

CIDR	Subnets	IPs
/30	**64**	**4**
/29	**32**	**8**
/28	**16**	**16**
/27	**8**	**32**
/26	**4**	**64**
/25	**2**	**128**
/24	**1**	**256**
/23	**2**	**512**
/22	**4**	**1024**

Memorize

CIDR	Subnets	IPs
/24	**1**	**256**

/21	8	2048	/25	2	128
/20	16	4096	/26	4	64
/19	32	8192	/27	8	32
/18	64	16384	/28	16	16
/17	128	32768	/29	32	8
/16	256	65536	/30	64	4

Subnetting Practice

- Are they asking about the **assignable** or the **total** number ofIPs?
- /31 CIDR Notation is usually used for point-to-point connection.
    - For example…connecting one router to another router.
    - /31 CIDR is mainly used by Cisco.
- /32 denotes a single host. That is one IP and there can be 256 subnets.

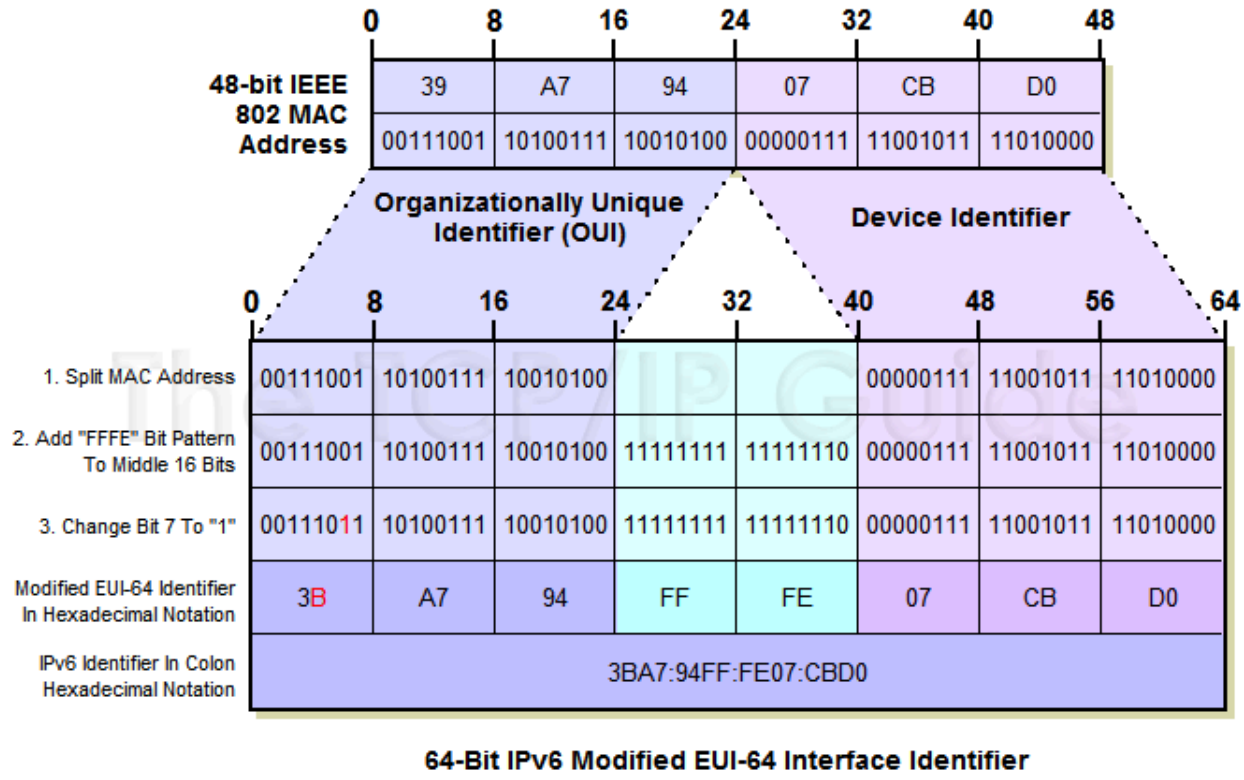
IPv6 Addressing

- Address Exhaustion - Running out of network addresses in IPv4.
- IPv6 = 2^{128} / 340 undecillion addresses
- IPv5 was an experimental protocol but some of its concepts have been incorporated into IPv6.
- Benefits of IPv6
    - Larger Address space
    - No broadcasts
    - No fragmentation / More security due to not breaking apart packets, IPv4 uses MTUs but this can be a security issue if packet length is longer, hence there is no need for fragmentation.
    - Can coexist with Ipv4
    - Simplified header
        - Instead of 12 fields in Ipv4 there are only 5 fields in Ipv6.
- Dual Stack - Running both the IPv4 and IPv6 protocols by your network devices simultaneously.
- Tunneling - Allows an existing IPv4 router to carry Ipv6 traffic.
    - IPv6 is going to be tunneled for encapsulating the IPv6 packets with IPv4 headers and carrying this IPv6 data over those IPv4 routers. Point to point tunnel encapsulating source and destination.

IPv6 Header		
Ver. 6	**Traffic Class**	**Flow Label**
Payload Length	**Next Header**	**Hop Limit**
Source IP Address		

Destination IP Address

- An IPv6 address uses hexadecimal digits and allows the use of shorthand notation.
    - Each hexadecimal digit is 4 bits, combining 4 hexadecimal digits together to make up a segment.
    - Each segment will contain 16 bits in it which is represented by the 4 hexadecimal digits, then a colon will be indeed and segments will continue to be added until 128 bits is reached which is 8 segments. No more than 32 hexadecimal digits.
    - IPv6 uses shorthand to simplify the IPv6 address.
- Example
    - 2018 : 0000 : 0000 : 0000 : 0000 : 0000 : 4815 : 54ae
    - 2018 : 0 : 0 : 0 : 0 : 0 : 4815 : 54ae
    - If there are segments that have all zeroes in them and no other hex is represented there, it can be summarized by using a double colon. This can only be done once within an IPv6 address.
    - 2018 : : 4815 : 54ae
- There are 3 different IPv6 addressing types.
    - Unicast - Used to identify a single interface.
        - Globally-routed - Similar to IPv4's unicast class A, B, and C addresses and begins with 2000-3999.
        - Link-local - Used like a private IP in IPv4 that can only be used on the local area network and begins with FE80.
            - Stateless Address Autoconfiguration (SLAAC) - Eliminates the need to obtain addresses or other configuration information from a central server.
                - Extended Unique Identifier (EUI) - Allows a host to assign itself a unique 64-bit IPv6 interface identifier called a EUI-64.
            - Independently assigns itself a link-local address itself, test the uniqueness of that address, assignee the address to itself, contact the router and provide direction to the node on how to proceed with the auto configuration.
    - Multicast - used to identify a set of interfaces and begins with FF.
    - Anycast - Used to identify a set of interfaces so that a packet can be sent to any member of a set.
        - Allocated from the Unicast address space.



64-Bit IPv6 Modified EUI-64 Interface Identifier

- DHCPv6 Protocol - Allows DHCP to automatically assign addresses from a DHCPv6 server.
- IPv6 will choose its own address based on its MAC address by default. It'll use something called NDP.
    - Neighbor Discovery Protocol (NDP) - Used to learn the Layer 2 addresses that are on a given network.
    - NDP is used for
        - Router Solicitation - client is going to send a message to locate the routers on its network needs to figure out what the default gateway is so it can get out of it's network and out to the internet.
        - Router advertisement - Advertises itself to solicit itself to ask questions.
        - Neighbor solicitation - IPv6 asks where are the other nodes on this network, this allows the interface to determine what link-layer addresses or layer two addresses are out there so it can learn from them and figure out how to talk to them directly.
        - Neighbor advertisement - Similar to router advertisement but this happens with your neighbors.
        - Redirection - routers can inform hosts that there are better first-hop router options out there to increase the efficiencies of your network.

IPv6 Data Flows

- Anycast - Data travels from a single source device to the device nearest to multiple (but specific) destination devices. Unique to IPv6.