

Computer Networking

Basics:

- **Network:** A computer network is a digital telecommunications network for sharing resources between nodes, which are computing devices that use a common telecommunications technology
- **Node:** A computing device.
- **Bus network:** All the devices are connected on one single long cable.
- **Client:** A client is a piece of computer hardware or software that accesses a service available by a server
- **Server:** A server is a computer program or device that provides functionality for other programs or devices called clients
- **Protocol:** A set of rules used in communication between clients

Network Devices:

- **Repeater:** A repeater is an electronic device that receives a signal and retransmits it.
- **Hub:** A hub is essentially a multi-port repeater. Wireless Access Point is essentially a hub in the air.
 - **Active Hub:** These are the hubs that have their own power supply and can clean, boost, and relay the signal along with the network. It serves both as a repeater as well as a wiring center.
 - **Passive Hub:** These are the hubs that collect wiring from nodes and power supply from the active hub. They are generally used to relay signals with cleaning or boosting them.
 - **Intelligent Hub:** It works like active hubs and includes remote management capabilities. They also provide flexible data rates to network devices. It also enables an administrator to monitor the traffic passing through the hub and to configure each port in the hub.
- **Bridge:** A bridge is a repeater with add on the functionality of filtering content by reading mac addresses of source and destination. It was mostly used to interconnect two LANs.
 - **Transparent Bridge:** These are the bridges in which the stations are completely unaware of the bridge's existence.
 - **Source Routing Bridge:** In these bridges, routing operation is performed by the source station and the frame specifies the route to follow.
- **Switch:** A switch reads each frame and has the intelligence to transmit data to the port it is destined for based on MAC addresses.
- **Router:** A router is a device like a switch that routes data packets based on their IP addresses. The router is mainly a Network Layer device.
- **Wireless Access Point:** A wireless access point is a networking device that allows wireless-capable devices to connect to a wired network.
- **Wireless LAN Controller:** A WLAN controller is used to manage large scale deployments of light weight and normal wireless access points.
- **Firewall:** A firewall is a network security system that monitors and controls incoming and outgoing network traffic based on predetermined security rules.
- **IDS:** It's a software system that warns if there is an intrusion. They just get copies of packets that are analyzed.
- **IPS:** It's a software system can alert you if there may be a problem and block the same. They stay inline of the network and detect and block intrusions.
- **Email Security Appliance:** The Email Security Appliance is an email security gateway product. It is designed to detect and block a wide variety of email-borne threats, such as malware, spam, and phishing attempts.
- **Load Balancer:** A load balancer is a device that acts as a reverse proxy and distributes network or application traffic across several servers.

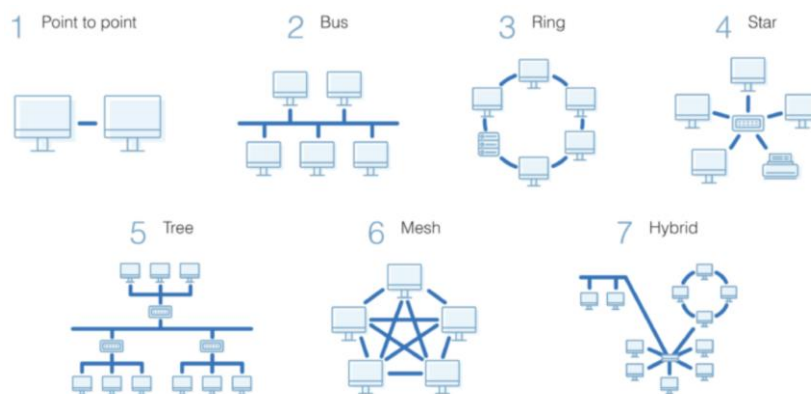
Types of Networks based on Area:

- **WAN:** A Wide Area Network is a telecommunications network that extends over a large geographical area for the primary purpose of computer networking.

- LAN: A Local Area Network is a computer network that interconnects computers within a limited area such as a residence, school and so on
- MAN: Metropolitan Area Network
- Wireless Local Area Network (WLAN)
- Campus Area Network (CAN)
- Storage Area Network (SAN)
- Passive Optical Local Area Network (POLAN)
- Enterprise Private Network (EPN)
- Virtual Private Network (VPN)
- Personal Area Network (PAN)

Types of Networks based on Topology:

- Mesh Topology
- Ring Topology
- Bus Topology
- Star Topology
- Hybrid Topology
- Point to Point Topology



Signaling:

- **Baseband Signaling:** Can only transmit a single signal at any given time.
- **Broadband Signaling:** Can transmit multiple signals at any given time.

Cable Types:

- **Coaxial Cabling:** Coaxial cable has an inner conductor that runs down the middle of the cable. This type of cabling comes in two types, thinnet and thicknet. Max Transmission Speed of 10 Mbps
- **Twisted-pair Cabling:** Has four pair of wires. It comes in two versions, UTP (Unshielded Twisted-Pair) and STP (Shielded Twisted-Pair). Uses 8P8C/RJ45 Connector
- **Fiber-optic Cabling:** Uses optical fibers to transmit data in the form of light signals. There are two types of fiber-optic cables - Single-mode fiber (SMF) and Multi-mode fiber (MMF). Uses ST/SC Connectors

Coaxial Cable



Twisted Pair



Fiber Optic

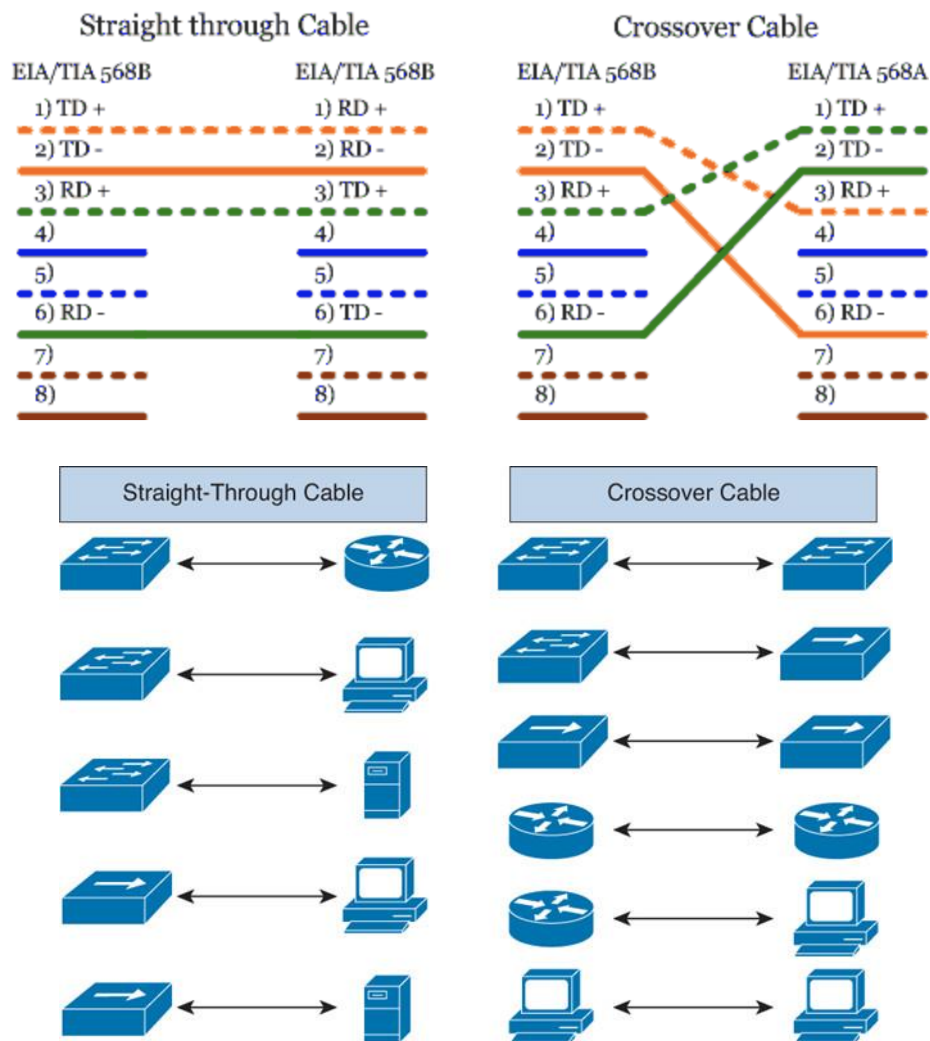


Ethernet Standards:

- **10Base-T** (IEEE 802.3): 10 Mbps with category 3 unshielded twisted pair (UTP) wiring, up to 100 meters long.
- **100Base-TX** (IEEE 802.3u): known as Fast Ethernet, uses category 5, 5E, or 6 UTP wiring, up to 100 meters long.
- **100Base-FX** (IEEE 802.3u): a version of Fast Ethernet that uses multi-mode optical fiber. Up to 412 meters long.
- **1000Base-CX** (IEEE 802.3z): uses copper twisted-pair cabling. Up to 25 meters long.
- **1000Base-T** (IEEE 802.3ab): Gigabit Ethernet that uses Category 5 UTP wiring. Up to 100 meters long.
- **1000Base-SX** (IEEE 802.3z): 1 Gigabit Ethernet running over multimode fiber-optic cable.
- **1000Base-LX** (IEEE 802.3z): 1 Gigabit Ethernet running over single-mode fiber.
- **10GBase-T** (802.3.an): 10 Gbps connections over category 5e, 6, and 7 UTP cables.

Ethernet Cable Forms:

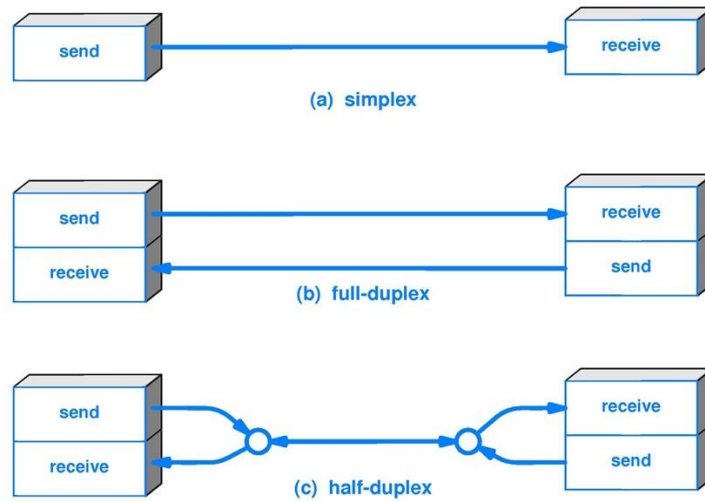
- **Straight-through Cable:** On a straight through cable, the wired pins match. Straight through cable use one wiring standard: both ends use T568A wiring standard or both ends use T568B wiring standard.
- **Crossover Cable:** Crossover cable uses two different wiring standards: one end uses the T568A wiring standard, and the other end uses the T568B wiring standard. Pin1->Pin3 and Pin2->Pin6



Medium Dependent Interface (MDI): It is a type of ethernet port connection that uses twisted-pair cabling to link two network devices. MDIX (MDI Crossover) is a version of MDI that enables connection between like devices.

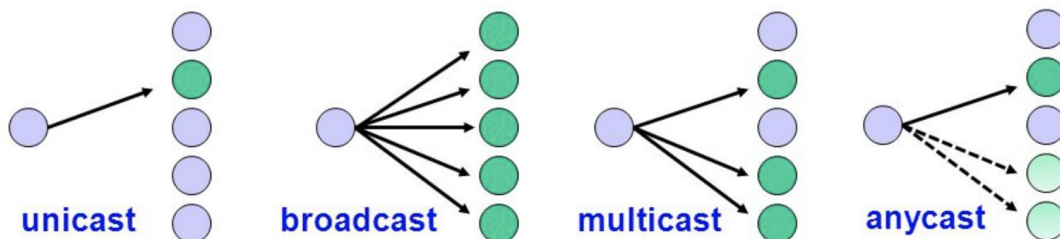
Data flow Types:

- **Simplex Mode:** Communication is unidirectional.
- **Half-Duplex Mode:** Each station can both transmit and receive, but not at the same time.
- **Full-Duplex Mode:** Both stations can transmit and receive simultaneously.



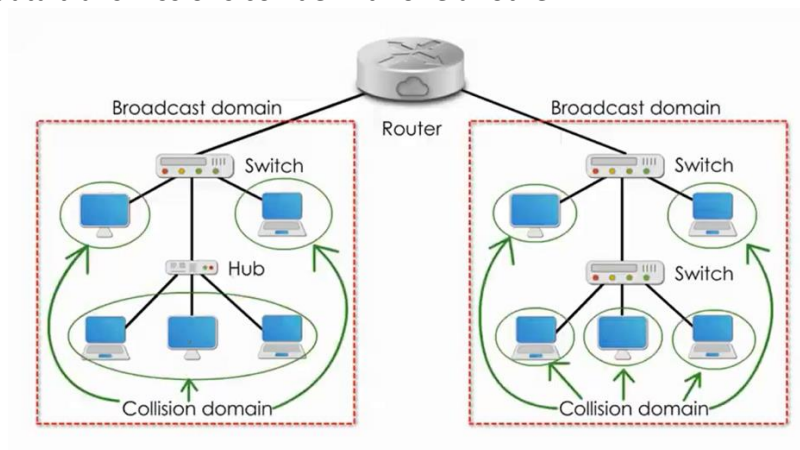
Communication Types:

- **Unicast:** Communication from one point to another point
- **Broadcast:** Communication from one point to all other points
- **Multicast:** Communication from one/more points to a set of other points
- **Anycast:** It is a network addressing and routing methodology in which a single destination IP address is shared by nodes in multiple locations.



Network Domain:

- **Broadcast Domain:** A broadcast domain is a logical division of a computer network, in which all nodes can reach each other by broadcast at the data link layer.
- **Collision Domain:** A collision domain is a network segment connected by a shared medium where simultaneous data transmissions collide with one another.



- 5 - the number of network segments
- 4 - the number of repeaters needed to join the segments into one collision domain
- 3 - the number of network segments that have active (transmitting) devices attached
- 2 - the number of segments that do not have active devices attached
- 1 - the number of collision domains

Types of Layered Models: Layers and Protocol Data Units (PDUs):

OSI Model:

1. Physical Layer (Bits)
2. Datalink Layer (Frame)
3. Network Layer (Packet)
4. Transport Layer (Segment)
5. Session Layer (Data)
6. Presentation Layer (Data)
7. Application Layer (Data)

TCP/IP Model (4):

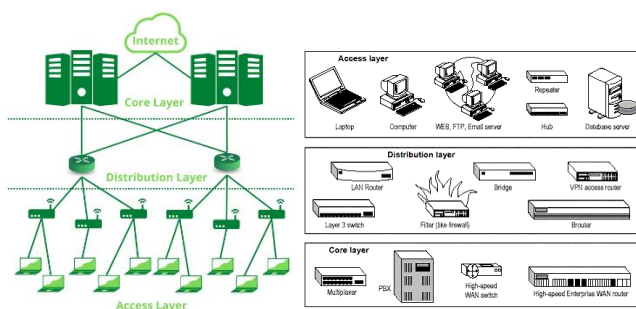
1. Physical Layer (Frame): Physical Addresses (MAC)
2. Network Layer (Packet): IP Addresses (IP)
3. Transport Layer (Segment): Port Addresses (Ports)
4. Application Layer (Data): Specific Addresses (Data)

TCP/IP Model (5 – In use by CCNA):

1. Physical Layer (Bits)
2. Datalink Layer (Frame): Physical Address (MAC)
3. Network Layer (Packet): IP Addresses (IP)
4. Transport Layer (Segment): Port Addresses (Ports)
5. Application Layer (Data): Specific Addresses (Data)

Cisco 3-Layer Model:

1. Core Layer: This layer is considered the backbone of the network and includes the high-end switches and high-speed cables such as fiber cables. This layer of the network does not route traffic at the LAN. In addition, no packet manipulation is done by devices in this layer. Rather, this layer is concerned with speed and ensures reliable delivery of packets
2. Distribution Layer: This layer includes LAN-based routers and layer 3 switches. This layer ensures that packets are properly routed between subnets and VLANs in your enterprise. This layer is also called the Workgroup layer.
3. Access Layer: This layer includes hubs and switches. This layer is also called the desktop layer because it focuses on connecting client nodes, such as workstations to the network. This layer ensures that packets are delivered to end user computers.



Math Review:

- Binary:

- IPv4 addresses use Binary.
- 2 possible values per bit (Base 2): 0,1
- Total number of outcomes for a given number: 2^n (For example, for 8 bits: $2^8 = 256$)
- To represent 255 in Binary

Base	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Binary Bit	1	1	1	1	1	1	1	1
Decimal	128	64	32	16	8	4	2	1

$$128+64+32+16+8+4+2+1 = 255$$

- IPv4 has 32 bits – 4 octets. $2^{32} = 429,496,729,6$ IP addresses
- Hexadecimal:
 - MAC addresses use Hexadecimal.
 - 16 possible values per bit (Base 16): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
 - Converting from Decimal to Hexadecimal (Ex: 224->E0):
 - 224 in Binary: 1110 0000 (Divide into 4 bits each)
 - $1110_2 = 14_{10} = E_{16}$
 - $0000_2 = 0_{10} = 0_{16}$
 - Result: E0

IPv4 Addressing:

- Internet Protocol v4 is a connectionless network layer protocol. Each packet is treated independently in this protocol which allows the packets to take different paths as needed.
- An IPv4 address is a layer 3 logical address assigned by an administrator. It is used to identify specific devices on a network and must be unique in internet.
- Private IP addresses are NATted to public address when traffic is sent onto internet.
- Format of IP address:
 - 32 bits 4 octets of 8 bits (1byte) each
 - Network Address Portion (Network ID)
 - Identifies a specific network.
 - Routers look at destination of IP address and match to network address.
 - Host portion (Host ID):
 - Identifies a specific endpoint on a network.
- Address Classes to accommodate different sizes of network and aid in classifying networks:

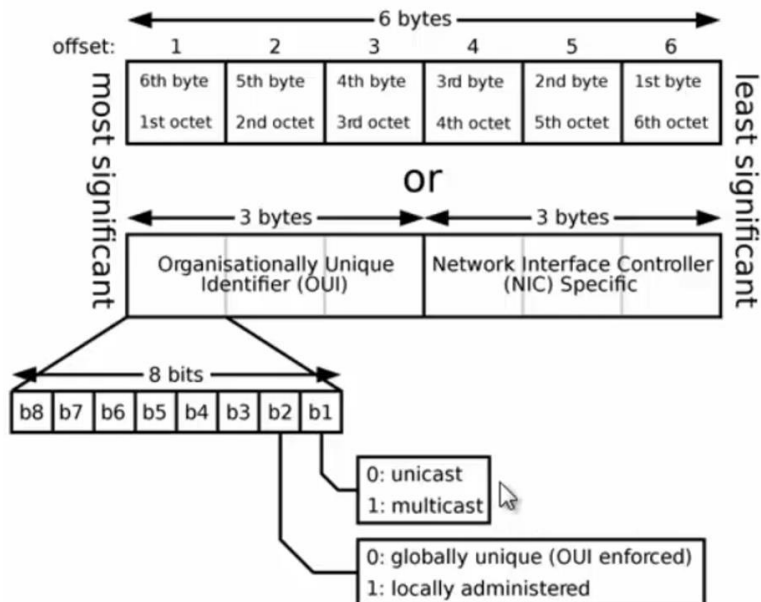
Class A – Unicast	0.0.0.0 to 127.255.255.255	8 network bits, 24 host bits
Class B – Unicast	128.0.0.0 to 191.255.255.255	16 network bits, 16 host bits
Class C – Unicast	192.0.0.0 to 223.255.255.255	24 network bits, 8 host bits
Class D – Multicast	224.0.0.0 to 240.255.255.255	
Class E – Reserved for future	241.0.0.0 to 255.255.255.255	

- Exceptions, Reservations and Special addresses:
 - 0.0.0.0/8 - Default network
 - 127.0.0.0/8 – Local Loopback address.
 - 224.0.0.X – Link local multicasts, generally used by routing tables.
 - 224.0.0.5-224.0.0.6 - OSPF
 - Directed Broadcast address: Fill 1s in the entire host portion of the address.
 - Local Broadcast address: Fill 1s in all 32 bits. Generally used for DHCP address
 - 10.0.0.0/8 – Private IP address range (not routable on internet)
 - 172.16.0.0/12 – Private IP address range (not routable on internet)
 - 192.168.0.0/16 – Private IP address range (not routable on internet)
 - 169.254.0.0/16 – Non-routable Link Local Addresses (Automatic Private IP Addressing)

- Subnet Masks:
 - Used to determine network and host portion of a given IP address through AND operation.
 - Is the device remote (route through default gateway) or local (ARP)?
 - Class A: 255.0.0.0
 - Class B: 255.255.0.0
 - Class C: 255.255.255.0
 - Discontinuous subnet masks not supported:
 $11110000.11111111.00000110.11000000$ (240.244.3.191)
 - Only contiguous subnet masks are supported.
 $11111111.11110000.00000000.00000000$ (255.240.0.0)
- Classless Inter Domain Routing (CIDR):
 - Replaces classful IP addressing with variable length subnet mask (VLSM)
 - CIDR notation /X where X denotes number of 1's present in binary form of a subnet mask.
 - Reduces wastage of big number of addresses.
 - Ex: /11 = 255.224.0.0
- Subnetting:
 - Work the following for a given IP address: Network address, First IP address, Last IP address, Broadcast address.
 - Binary method to work an IP address:
 - Subnet address: Fill the host portion with binary 0s.
 - Broadcast address: Fill the host portion with binary 1s.
 - First host: Fill the host portion with binary 0s and set the last bit to 1.
 - Last host: Fill the host portion with binary 1s and set the last bit to 0.
 - Ex: 172.16.35.123/20:
 - Subnet: **172.16.0010** 0000.0000 0000 = 172.16.32.0
 - 1st Host: **172.16.0010** 0000.0000 0001 = 172.16.32.1
 - Last Host: **172.16.0010** 1111.1111 1110 = 172.16.47.254
 - Broadcast: **172.16.0010** 1111.1111 1111 = 172.16.47.255
 - Number of hosts in a network: $2^h - 2$ (h = number of bits in host portion)
 - Number of networks: 2^n (n = number of bits in network portion)
 - Number of subnets: 2^n (n = number of bits in varying network octet)

MAC Address:

- 6 bytes or 48 bits in length: 24 bits OUI (Organizational unique identifier) and 24 bits of Station Address
- MAC addresses are unique to avoid collisions and conflicts.
- OUI bits can be used to represent nature of communication as shown below:



Carrier Sense Multiple Access/Collision Detection (CSMA/CD):

- Used to find if any other device sending traffic in a bus topology to avoid collisions in a CD.
- Before sending traffic, a device broadcasts if another device is communicating. If there is no response, it goes ahead and sends traffic.
- If a collision takes place, a backoff/jam signal is sent.

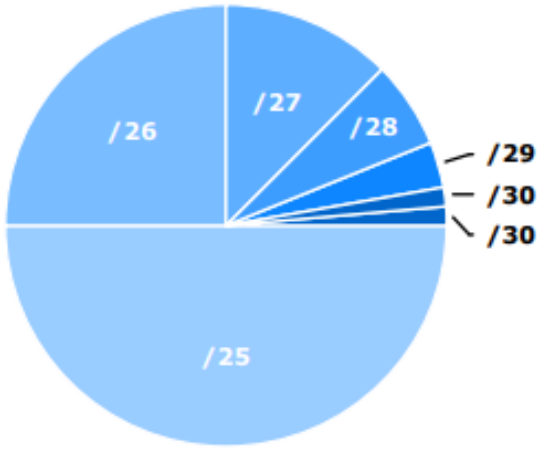
Connecting to Networking Devices:

- Connectors used: Serial Cable or RJ45 or USB.
- Protocols used: Telnet, SSH, GUI
- Review Cisco common CLI command reference

Dataflow through network:

IPv4 SUBNETTING

packetlife.net

Subnets				Decimal to Binary							
CIDR	Subnet Mask	Addresses	Wildcard	Subnet Mask		Wildcard					
/32	255.255.255.255	1	0.0.0.0	255	1111 1111	0	0000 0000				
/31	255.255.255.254	2	0.0.0.1	254	1111 1110	1	0000 0001				
/30	255.255.255.252	4	0.0.0.3	252	1111 1100	3	0000 0011				
/29	255.255.255.248	8	0.0.0.7	248	1111 1000	7	0000 0111				
/28	255.255.255.240	16	0.0.0.15	240	1111 0000	15	0000 1111				
/27	255.255.255.224	32	0.0.0.31	224	1110 0000	31	0001 1111				
/26	255.255.255.192	64	0.0.0.63	192	1100 0000	63	0011 1111				
/25	255.255.255.128	128	0.0.0.127	128	1000 0000	127	0111 1111				
/24	255.255.255.0	256	0.0.0.255	0	0000 0000	255	1111 1111				
/23	255.255.254.0	512	0.0.1.255	Subnet Proportion							
/22	255.255.252.0	1,024	0.0.3.255								
/21	255.255.248.0	2,048	0.0.7.255								
/20	255.255.240.0	4,096	0.0.15.255								
/19	255.255.224.0	8,192	0.0.31.255								
/18	255.255.192.0	16,384	0.0.63.255								
/17	255.255.128.0	32,768	0.0.127.255								
/16	255.255.0.0	65,536	0.0.255.255								
/15	255.254.0.0	131,072	0.1.255.255								
/14	255.252.0.0	262,144	0.3.255.255								
/13	255.248.0.0	524,288	0.7.255.255								
/12	255.240.0.0	1,048,576	0.15.255.255								
/11	255.224.0.0	2,097,152	0.31.255.255								
/10	255.192.0.0	4,194,304	0.63.255.255								
/9	255.128.0.0	8,388,608	0.127.255.255								
/8	255.0.0.0	16,777,216	0.255.255.255								
/7	254.0.0.0	33,554,432	1.255.255.255								
/6	252.0.0.0	67,108,864	3.255.255.255								
/5	248.0.0.0	134,217,728	7.255.255.255								
/4	240.0.0.0	268,435,456	15.255.255.255								
/3	224.0.0.0	536,870,912	31.255.255.255								
/2	192.0.0.0	1,073,741,824	63.255.255.255								
/1	128.0.0.0	2,147,483,648	127.255.255.255								
/0	0.0.0.0	4,294,967,296	255.255.255.255								
								Classful Ranges			
								A	0.0.0.0 – 127.255.255.255		
				B	128.0.0.0 - 191.255.255.255						
				C	192.0.0.0 - 223.255.255.255						
				D	224.0.0.0 - 239.255.255.255						
				E	240.0.0.0 - 255.255.255.255						
				Reserved Ranges							
				RFC 1918	10.0.0.0 - 10.255.255.255						
				Localhost	127.0.0.0 - 127.255.255.255						
				RFC 1918	172.16.0.0 - 172.31.255.255						
				RFC 1918	192.168.0.0 - 192.168.255.255						

Terminology

CIDR

Classless interdomain routing was developed to provide more granularity than legacy classful addressing; CIDR notation is expressed as /XX

VLSM

Variable-length subnet masks are an arbitrary length between 0 and 32 bits; CIDR relies on VLSMs to define routes

TCP AND UDP PORT NUMBERS

ECHO	7/TCP		
ECHO	7/UDP		
FTP-DATA	20/TCP		#FTP, DATA
FTP	21/TCP		#FTP, CONTROL
SSH	22/TCP		#SSH REMOTE LOGIN
TELNET	23/TCP		
SMTP	25/TCP	MAIL	
TIME	37/TCP	TIMSERVER	
TIME	37/UDP	TIMSERVER	
RLP	39/UDP	RESOURCE	#RESOURCE LOCATION
NAMESERVER	42/TCP	NAME	#HOST NAME SERVER
NAMESERVER	42/UDP	NAME	#HOST NAME SERVER
NICNAME	43/TCP	WHOIS	
DNS	53/TCP		#DOMAIN NAME SERVER
DNS	53/UDP		#DOMAIN NAME SERVER
BOOTPS	67/UDP	DHCPS	#BOOTSTRAP PROTOCOL
BOOTPC	68/UDP	DHCPC	#BOOTSTRAP PROTOCOL
TFTP	69/UDP		#TRIVIAL FILE TRANSFER
HTTP	80/TCP	WWW WWW-HTTP	#WORLD WIDE WEB
KERBEROS	88/TCP	KRB5 KERBEROS-SEC	#KERBEROS
KERBEROS	88/UDP	KRB5 KERBEROS-SEC	#KERBEROS
RTELNET	107/TCP		#REMOTE TELNET SERVICE
POP2	109/TCP	POSTOFFICE	#POST OFFICE PROTOCOL
POP3	110/TCP		#POST OFFICE PROTOCOL
SQLSERV	118/TCP		#SQL SERVICES
NTP	123/UDP		#NETWORK TIME PROTOCOL
NETBIOS-NS	137/TCP	NBNAME	#NETBIOS NAME SERVICE
NETBIOS-NS	137/UDP	NBNAME	#NETBIOS NAME SERVICE
IMAP	143/TCP	IMAP4	#INTERNET MESSAGE ACCESS PROTOCOL
SQL-NET	150/TCP		
SQLSRV	156/TCP		
SNMP	161/UDP		#SNMP
SNMPTRAP	162/UDP	SNMP-TRAP	#SNMP TRAP
BGP	179/TCP		
IRC	194/TCP		#INTERNET RELAY CHAT
MFTP	349/TCP		
MFTP	349/UDP		
LDAP	389/TCP		
HTTPS	443/TCP	MCOM	#HTTP OVER TLS/SSL
HTTPS	443/UDP	MCOM	#HTTP OVER TLS/SSL
ISAKMP	500/UDP	IKE	#INTERNET KEY EXCHANGE
CMD	514/TCP	SHELL	
SYSLOG	514/UDP		
ROUTER	520/UDP	ROUTE ROUTED	
TIMED	525/UDP	TIMESERVER	
DHCPV6-CLIENT	546/TCP		#DHCPV6 CLIENT
DHCPV6-CLIENT	546/UDP		#DHCPV6 CLIENT
DHCPV6-SERVER	547/TCP		#DHCPV6 SERVER
DHCPV6-SERVER	547/UDP		#DHCPV6 SERVER
LDAPS	636/TCP	SLDAP	#LDAP OVER TLS/SSL
MSEXCH-ROUTING	691/TCP		#MS EXCHANGE ROUTING
MSEXCH-ROUTING	691/UDP		#MS EXCHANGE ROUTING
FTPS-DATA	989/TCP		#FTP DATA, OVER TLS/SSL
FTPS	990/TCP		#FTP CTRL OVER TLS/SSL
TELNETS	992/TCP		#TELNET OVER TLS/SSL
WINS	1512/TCP		#WINDOWS NAME SERVICE
WINS	1512/UDP		#WINDOWS NAME SERVICE
L2TP	1701/UDP		
H.323	1718/TCP		#H.323 RAS (MULTICAST)
H.323	1719/TCP		#H.323 RAS (UNICAST)
H.323	1720/TCP		#H.323 CALL SIGNALLING
PPTP	1723/TCP		#POINT-TO-POINT

RADIUS	1812/UDP	TUNNELING PROTOCOL
SSO	2258/UDP	#RADIUS AUTHENTICATION
RDP	3389/TCP	#SINGLE SIGN OUT
MSFW-CONTROL	3847/TCP	#REMOTE DESKTOP PROTOCOL
SDP-PORTMAPPER	3935/TCP	#MICROSOFT FIREWALL
SDP-PORTMAPPER	3935/UDP	#SDP PORT MAPPER PROTOCOL
IPSEC	4500/TCP	#SDP PORT MAPPER PROTOCOL
IPSEC	4500/UDP	#MICROSOFT IPSEC NAT-T
SIP	5060/UDP	#MICROSOFT IPSEC NAT-T
SIP	5061/UDP	#NON-ENCRYPTED TRAFFIC
MS-LICENSING	5720/TCP	#SIP OVER TLS
MS-LICENSING	5720/UDP	#MICROSOFT LICENSING
MAN	9535/TCP	#MICROSOFT LICENSING
		#REMOTE MAN SERVER

IP PORT NUMBERS

IP	0	IP	# INTERNET PROTOCOL
ICMP	1	ICMP	# INTERNET CONTROL MESSAGE PROTOCOL
GGP	3	GGP	# GATEWAY-GATEWAY PROTOCOL
TCP	6	TCP	# TRANSMISSION CONTROL PROTOCOL
EGP	8	EGP	# EXTERIOR GATEWAY PROTOCOL
PUP	12	PUP	# PARC UNIVERSAL PACKET PROTOCOL
UDP	17	UDP	# USER DATAGRAM PROTOCOL
HMP	20	HMP	# HOST MONITORING PROTOCOL
XNS-IDP	22	XNS-IDP	# XEROX NS IDP
RDP	27	RDP	# "RELIABLE DATAGRAM" PROTOCOL
IPV6	41	IPV6	# INTERNET PROTOCOL IPV6
IPV6-ROUTE	43	IPV6-ROUTE	# ROUTING HEADER FOR IPV6
IPV6-FRAG	44	IPV6-FRAG	# FRAGMENT HEADER FOR IPV6
ESP	50	ESP	# ENCAPSULATING SECURITY PAYLOAD
AH	51	AH	# AUTHENTICATION HEADER
IPV6-ICMP	58	IPV6-ICMP	# ICMP FOR IPV6
IPV6-NONXT	59	IPV6-NONXT	# NO NEXT HEADER FOR IPV6
IPV6-OPTS	60	IPV6-OPTS	# DESTINATION OPTIONS FOR IPV6

Cisco Common CLI Reference

enable	Switch to enable mode from user mode
configure terminal	Switch to configure terminal mode from enable mode
disable	To go back to user mode
erase startup-config	Delete existing startup-config
show version	To see the version of the firmware installed
hostname	To change the hostname of the device
copy run start	Saving configuration to NVRAM
wr	Same function as copy run start
show ip int br	See interfaces on the router
show cdp neighbors	To view the neighbors connected
debug ip packet	To trace all packets
un all	Disable all debugging
ip dhcp pool <name> > network <cidr> > default-router <GW> > network <cidr> > dns-server <8.8.8.8>	To create a new dhcp pool, its network and other parameters in it
ip dhcp excluded <ipaddr>	To exclude an ip address being assigned