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Critical Concepts of the 200-120 CCNA Routing and Switching Exam

Critical Concepts of the 200-120 CCNA Routing and Switching Exam

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Introduction

In the spring of 2013, Cisco announced major updates to their Cisco Certified Network Associate (CCNA) curricula, including a new version of the CCNA Routing and Switching exam (200-120 CCNA).

This paper provides a review of the CCNA Routing and Switching exam's critical concepts, as an aid to students preparing to pass the latest version of the CCNA Routing and Switching exam.

Global Knowledge offers a *CCNA Accelerated (CCNAx) Boot Camp*; this boot camp is an accelerated version of the two courses that comprise the CCNA Routing and Switching exam preparation curricula: *Interconnecting Cisco Networking Devices Part 1 (ICND1*) and *Interconnecting Cisco Networking Devices Part 2 (ICND2).* All of these courses are now at version 2.0.

Please Note: This document is only intended as a review of some of the CCNA concepts; additional training, knowledge, and studying are needed in order to pass the exam. Refer to www.cisco.com/go/ccna for detailed information about the exam.

OSI Model Layers

OSI Layer	Purpose	Examples
Application	Provides services to network applications. This layer is responsible for determining resource availability, identifying communication peers, and synchronizing communication between the applications.	• Simple Mail Transport Protocol (SMTP) • Telnet • File Transfer Protocol (FTP) • Trivial File Transfer Protocol (TFTP) • Hypertext transfer Protocol (HTTP)
Presentation	Provides the coding and conversion functions that are applied to the data to/from the application layer. This layer ensures that there is a common scheme used to bundle the data between the two ends.	• ASCII (text) • EBCDIC (text) • JPEG (image) • GIF (image) • TIFF (image) • MPEG (sound/video) • QuickTime (sound/video)
Session	Establishes, maintains, and terminates communications sessions between upper layer applications.	• Session Control Protocol (SPC) • Remote Procedure Call (RPC) from UNIX • Zone Information Protocol (ZIP) from AppleTalk
Transport	Responsible for end-to-end data transmission. Can be either reliable (connection-oriented) or best effort (connectionless). This layer organizes data from various upper layer applications into data streams, handles end-to-end flow control, multiplexing, virtual circuit management, and error checking and recovery.	• Transmission Control Protocol (TCP) from IP • User Datagram Protocol (UDP) from IP

OSI Layer	Purpose	Examples
Network	This layer allows data flows to access the network. The network layer addresses define a network hierarchy. Network devices are normally grouped together based on their common network layer address.	• Internet Protocol (IP) version 4 (IPv4) • IP version 6 (IPv6)
Data Link	Provides either reliable or best effort transmission of data across a physical medium. Most networks use a best effort data link layer, such as Ethernet. The data Link Layer for local area networks (LANs) provides a physical address to each device called a Media Access Control (MAC) address. MAC addresses are typically burned into the network interface card (NIC). The LAN data link layer also uses a Logical Link Control (LLC) to indicate the type of network layer data that is encapsulated inside the frame.	LAN: • Ethernet/IEEE 802.3 (include Fast Ethernet, Gigabit Ethernet, etc.) • Token Ring /IEEE 802.5 • FDDI (from ANSI) Wide area network (WAN): • High-Level Data-link Control (HDLC) • Point-to-Point Protocol (PPP) • Frame Relay
Physical	Defines the electrical, mechanical, and functional specifications for maintaining a physical link between network devices. This layer is responsible for such characteristics as voltage levels, timing and clock rates, maximum transmission distances, and the physical connectors used.	LAN: • Category 5 cabling WAN: • EIA/TIA-232 • EIA/TIA-449 • V.35

OSI Model vs. TCP/IP Protocol Suite

OSI Model Layer Number	OSI Model Layer	TCP/IP Protocol Suite Layer	Protocol Data Unit	Network Device
7	Application	Application	Data	
6	Presentation			
5	Session			
4	Transport	Transport	Segment	
3	Network	Internet	Packet (or Datagram)	Multilayer Switch or Router
2	Data Link	Link* (or Network Access)	Frame	Layer 2 Switch or Bridge
1	Physical		Bits	Hub

***The Link or Network Access layer is sometimes shown as the separate Data Link and Physical layers.**

TCP/IP Transport Layer Protocols

TCP is a reliable, connection-oriented, protocol that uses sequence and acknowledgement numbers to provide reliability. TCP verifies that the remote end is listening prior to sending data, using a three-way handshake: SYN, SYN/ACK, ACK.

UDP is a best-effort, connectionless, protocol that does not have sequence or acknowledgement numbers, and does not do end-to-end verification.

TCP Header

The TCP header is at least 20 octets:

Source Port (16 bits)											Destination Port (16 bits)
Sequence Number (32 bits)											
Acknowledgement Number (32 bits)											
Header length (4 bits)	resv	ns	cwt	ece	urg	ack	psh	rst	syn	fln	Window Size (16 bits)
Checksum (16 bits)											Urgent Pointer (16 bits)
Options											
data											

UDP Header

The UDP header is eight octets:

Source Port (16 bits)	Destination Port (16 bits)
UDP length (16 bits)	Checksum (16 bits)
data	

TCP and UDP Port Numbers

Well-known port numbers range from 1 to 1023 (typically used for well-known applications). Registered port numbers are 1024 to 49151. 49152 to 65535 are dynamically assigned port numbers (and are typically used as source port numbers). Examples are shown in the following table:

Application	Port	Transport
File Transfer Protocol (FTP)	20/21	TCP
Secure Shell (SSH)	22	TCP
Telnet	23	TCP
Simple Mail Transfer Protocol (SMTP)	25	TCP
Domain Name Services (DNS)	53	UDP/TCP
Trivial Files Transfer Protocol (TFTP)	69	UDP
Simple Network Management Protocol (SNMP)	161	UDP
Routing Information Protocol (RIP)	520	UDP

Internet Layer Protocols

IP: Provides the logical addressing structure and offers connectionless, best-effort delivery of packets (datagrams). IPv4 and IPv6 are described in the following sections.

Internet Control Message Protocol (ICMP): Provides control and feedback messages between IP devices.
Address Resolution Protocol (ARP):- Using a destination IPv4 address, ARP resolves (discovers) the appropriate destination MAC (Layer 2) address to use. Thus, ARP maps a Layer 3 IPv4 address to a Layer 2 MAC address.
Reverse Address Resolution Protocol (RARP): Using a source MAC address, RARP retrieves an IP address form the RARP Server. RARP maps source Layer 2 address to a Layer 3 address; it is an early form of Dynamic Host Configuration Protocol (DHCP).

DHCP: DHCP is built on a client-server model, as follows:

- The DHCP "server" allocates network addresses and delivers configuration parameters.
- The DHCP "client" is a device that requests initialization parameters, including its IP address, from a DHCP server.

DHCP supports three mechanisms for IP address allocation:

1. **Automatic:** DHCP assigns a permanent IP address to a client.
2. **Dynamic:** DHCP assigns an IP address from a pool of addresses to a client for a limited period of time (called a lease). Dynamic allocation is the only mechanism that allows automatic reuse of an address that is no longer needed by the client to which it was assigned.
3. **Manual:** A specific client IP address is assigned by the network administrator, and DHCP is used simply to convey the assigned address to the client.

DHCP has four phases:

1. **DHCP discover:** Broadcast from client
2. **DHCP offer:** Unicast from server
3. **DHCP request:** Broadcast from client
4. **DHCP acknowledgement:** Unicast from server

Domain Name System (DNS): Resolves domain names to IP addresses.

IPv4

IPv4 Packet Header

The IPv4 header is at least 20 octets:

<table>
<tr><td>Version (4 bits)</td><td>Internet Header Length (4 bits)</td><td>Type of Service (8 bits)</td><td colspan="3">Packet Length (16 bits)</td></tr>
<tr><td colspan="3">Identification (16 bits)</td><td>Flags (3 bits)</td><td colspan="2">Fragment Offset (13 bits)</td></tr>
<tr><td>Time to Live (8 bits)</td><td colspan="2">Protocol (8 bits)</td><td colspan="3">Header Checksum (16 bits)</td></tr>
<tr><td colspan="6">Source Address (32 bits)</td></tr>
<tr><td colspan="6">Destination Address (32 bits)</td></tr>
<tr><td colspan="5">Options</td><td>Padding</td></tr>
</table>

The IPv4 packet header protocol field indicates the type of information contained in the packet. Example values are 6 = TCP and 17 = UDP.

IPv4 Address Format

IPv4 addresses are 32 bits long. They are usually written in dotted decimal format: each 8-bit octet is written as a decimal number, and dots are put in between these numbers.

Thus, when converting between binary and decimal for IPv4 addresses, always remember to convert 8 bits. An 8 bit number has a decimal value between 0 and 255.

Converting Binary to Decimal

Each bit, depending on its position in the binary number, has a decimal value:

Bit Position♦	7	6	5	4	3	2	1	0
Exponent Value	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Decimal Value of Bit	128	64	32	16	8	4	2	1

♦ **By convention, bits are numbered starting at bit 0 = least-significant or right-most bit**

To convert a binary number to decimal, multiply each bit value in the number by its decimal value, and then sum the results. For example, to convert the 8-bit binary number 11010110 to decimal, do the following:

Bit Value	1	1	0	1	0	1	1	0
Decimal Value of Bit	128	64	32	16	8	4	2	1
Bit Value x Decimal Value of Bit	128	64	0	16	0	4	2	0

The sum of these results is = 1*128 + 1*64 + 0*32 + 1*16 + 0*8 + 1*4 + 1*2 + 0*0 = 214. Therefore, the binary number 11010110 is 214 decimal.

Converting Decimal to Binary

To convert a decimal number (of 0 through 255) to binary, start at the left most bit (bit 7). If the decimal number is bigger than or equal to the decimal value of the bit, put a "1" in the binary value of the number, and subtract the decimal value of the bit from the number. Otherwise put a "0" in the binary value of the number. Repeat for the rest of the bits.

For example to convert **147**:

- Start at bit 7. Since 147 is bigger than or equal to $\mathbf{2^7}$ = 128, bit number 7 is a "1". We now have **147 - 128 = 19** remaining.
- Since 19 is less than $\mathbf{2^6}$ = 64, bit number 6 is a "0".
- Since 19 is less than $\mathbf{2^5}$ = 32, bit number 5 is a "0".
- Since 19 is bigger than or equal to $\mathbf{2^4}$ = 16, bit number 4 is a "1". We now have **19 - 16 = 3** remaining.
- Since 3 is less than $\mathbf{2^3}$ = 8, bit number 3 is a "0".
- Since 3 is less than $\mathbf{2^2}$ = 4, bit number 2 is a "0".
- Since 3 is bigger than or equal to $\mathbf{2^1}$ = 2, bit number 1 is a "1". We now have **3 - 2 = 1** remaining.
- Since 1 is bigger than or equal to $\mathbf{2^0}$ = 1, bit number 0 is a "1". We now have **1 - 1 = 0** remaining; this means we are finished converting.
- Thus, the binary representation of **147** is **1 0 0 1 0 0 1 1**

IPv4 Address Classes

Class	**Network (N) and Host (H) Octets**	**First Bits in First Octet**	**Numerical Range of 1st octet**	**Number of Networks**	**Number of Hosts per Network**
A	N.H.H.H	0xxx	1 – 126*	126	16,777,214
B	N.N.H.H	10xx	128 – 191	16,384	65,534
C	N.N.N.H	110x	192 – 223	2,097,152	254
D**	N/A	111x	224 – 239	N/A	N/A
E**	N/A	1111	240 – 255	N/A	N/A

*** 0 is reserved; 127 is reserved for the loopback address.**
**** Class D is used for multicast group addressing, and Class E is reserved for research use only.**

Reserved IPv4 Addresses

Some IPv4 addresses are reserved:

- **Network address:** The address with all binary 0s in the host field is the address of the network itself
- **Directed broadcast address:** The address with all binary 1s in the host field is the broadcast address on the network
- **Local broadcast address:** 255.255.255.255, used as a destination, goes to all devices within the broadcast domain (does not cross a router)
- **Local loopback address:** 127.0.0.1, used by a device to send a message to itself for testing
- **All zeroes address:** 0.0.0.0, can only be used in source address field to indicate the device itself

Private IPv4 Addresses

The private IPv4 addresses are as follows:

- 10.0.0.0 through 10.255.255.255
- 172.16.0.0 through 172.31.255.255
- 192.168.0.0 through 192.168.255.255

Subnet Masks

Subnet bits are "borrowed" from host bits. The subnet mask indicates how to interpret the IP address; every address has a subnet mask as an "interpreter":

- A binary "1" in the subnet mask indicates that the corresponding bit in the IP address is a subnet or network bit. The number of network bits is determined by the address class.
- A binary "0" in the subnet mask indicates that the corresponding bit in the IP address is a host bit.

With "s" subnet bits, the number of subnets is 2^s.

With "h" host bits, the number of hosts per subnet is: $2^h - 2$.

Default Subnet Masks

Default Class A (N.H.H.H) mask: 255.0.0.0; this can also be written as /8, where 8 is the number of binary "1"s in the mask.

Default Class B (N.N.H.H) mask: 255.255.0.0; this can also be written as /16.

Default Class C (N.N.N.H) mask: 255.255.255.0; this can also be written as /24.

Example Subnet Masks for Class C Addresses

Decimal Mask	Subnet Bits (s)	Host Bits (h)	Number of Subnets = 2^s	Number of Hosts = $2^h - 2$
255.255.255.0	0	8	N/A	254
255.255.255.128	1	7	2	126
255.255.255.192	2	6	4	62
255.255.255.224	3	5	8	30
255.255.255.240	4	4	16	14
255.255.255.248	5	3	32	6
255.255.255.252	6	2	64	2

Example Subnet Masks for Class B Addresses

Decimal Mask	Subnet Bits (s)	Host Bits (h)	Number of Subnets = 2^s	Number of Hosts = $2^h - 2$
255.255.0.0	0	16	N/A	65,534
255.255.128.0	1	15	2	32,766
255.255.192.0	2	14	4	16,382
255.255.255.0	8	8	256	254
255.255.255.128	9	7	512	126
255.255.255.240	12	4	4096	14
255.255.255.252	14	2	16384	2

Example Subnet Masks for Class A Addresses

Decimal Mask	Subnet Bits (s)	Host Bits (h)	Number of Subnets = 2^s	Number of Hosts = $2^h - 2$
255.0.0.0	0	24	N/A	16,777,214
255.128.0.0	1	23	2	8,388,606
255.192.0.0	2	22	4	4,194,302
255.255.255.0	16	8	65,536	254
255.255.255.192	18	6	262,144	62
255.255.255.240	20	4	1,048,576	14
255.255.255.252	22	2	4,194,304	2

Steps for Planning IPv4 Addresses

1. Determine the address space to use (either a public or private network number).
2. Determine the number of subnets and number of host (device) addresses per subnet required.
3. From #2, determine the number of subnet bits to use (*s,* where 2^s = # subnets).
4. From #3, determine the subnet mask to use.
5. Apply the subnet mask (from #4) to the IP address space (from #1) to determine the subnet and host (device) addresses.
6. Assign the host (device) addresses to specific device interfaces.

Steps for Determining the Subnet Address from a Given IPv4 Address and Mask

Given a device IPv4 address and its subnet mask:

1. Write the address in binary.
2. Write the mask in binary, below the address.
3. Draw a vertical line between the binary 1s and the 0s in the mask; extend this line up into the address bits. This line divides the network/subnet bits from the host bits in the address.
4. Make four copies of the address bits that are above the 1s in the mask; these are network/subnet bits.
5. In the first of these copies, fill in all the bits to the right of these bits with 0s. This sets all of the host bits to binary "0" and is the address of the subnet.
6. In the last of these copies, fill in all the bits to the right of these bits with 1s. This sets all of the host bits to binary "1" and is the address of the directed broadcast on the subnet.
7. In the second of these copies, fill in all the bits to the right of these bits with 0s, except put a 1 in the last bit. This is the address of the first host on the subnet. In the third of these copies, fill in all the bits to the right of these bits with 1s, except put a 0 in the last bit. This is the address of the last host on the subnet.
8. To determine the address of the next subnet, increment the subnet bits by 1.

IPv4 VLSM Example

Variable length subnet mask (VLSM) means to use a different (variable length) subnet mask on different subnets of the same major network (a given class A, B, or C network). VLSM allows the address space to be used more efficiently.

For example, you are given the address space 172.17.0.0/16 and you need to address some LANs that may have up to 300 device addresses, and some point-to-point WANs (which have only two device addresses).

For the LANs you need nine host bits ($2^9 - 2 = 510$ host addresses) and for the WANs you need two host bits ($2^2 - 2 = 2$ host addresses).

Therefore, for the LANs you can use 16 – 9 = 7 subnet bits, which would allow 2^7 = 128 subnets. The addresses of these subnets are as follows (with the subnet bits highlighted):

172.17.00000000.00000000 = 172.17.0.0/23
172.17.00000010.00000000 = 172.17.2.0/23
172.17.00000100.00000000 = 172.17.4.0/23

And so on, up to the last subnet:
172.17.11111110.00000000 = 172.17.254.0/23

The first of these can be used for addressing the LANs. Any unused subnet can be further subnetted for the WANs. For example, if the last subnet is not used for a LAN, it can be further subnetted for the WANs. Since only two host bits are required for the WANs, 9 – 2 = 7 subnet bits can be used, which would allow 2^7 = 128 WAN subnets. The addresses of these subnets are as follows (with the WAN subnet bits highlighted darker):

172.17.11111110.00000000 = 172.17.254.0/30
172.17.11111110.00000100 = 172.17.254.4/30
172.17.11111110.00001000 = 172.17.254.8/30

And so on, up to the last subnet:
172.17.11111111.11111100 = 172.17.255.252/30

IPv6

IPv6 Advanced Features

Larger address space	Global reachability and flexibility Aggregation Multihoming Autoconfiguration Plug-and-play End-to-end without network address translation (NAT) Simplified renumbering
Mobility and security	Built in to IPv6
Simpler header	Routing efficiency Scalable performance and forwarding rate No checksums Extension headers Flow labels
Transition richness	Dual stack Tunneling (including 6to4 and manual tunnels) Translation

Hexadecimal and Converting Between Binary and Hexadecimal

IPv6 addresses are written in hexadecimal.

The hexadecimal system, commonly called "hex", uses 16 symbols (as compared to the two symbols used in binary or the 10 symbols used in decimal). Since there are only 10 Arabic numbers (zero through nine), we have to use six new symbols. For these, we borrow from the alphabet, where:

- Decimal 10 becomes Hexadecimal A
- Decimal 11 becomes Hexadecimal B
- Decimal 12 becomes Hexadecimal C
- Decimal 13 becomes Hexadecimal D
- Decimal 14 becomes Hexadecimal E, and
- Decimal 15 becomes Hexadecimal F

(The letters A through F can be upper or lower case, or a mixture.)

Each hexadecimal digit can be represented by exactly 4 bits:

Decimal	Hexadecimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111

To convert a hexadecimal number to binary, convert each hexadecimal symbol to its binary equivalent. For example, the hexadecimal number:

```
af34 = 1 0 1 0 1 1 1 1 0 0 1 1 0 1 0 0
         \     / \     / \     / \     /
           a       f       3       4
```

In Cisco devices, hexadecimal numbers are sometimes indicated by "0x" preceding the number. The above example number would therefore appear as **0xaf34**. (IPv6 addresses do not use this notation.)

IPv6 Addresses

IPv4 vs. IPv6 Address

IPv4	IPv6
Addressing is 4 octets or 32 bits long	Addressing is 16 octets or 128 bits long
Usually written in dotted decimal, for example: 192.168.128.129	Usually written in hex with colons in between each 16 bit field, for example: 2001:0DB8:0010:0006:0006:0000:0000:0001
Binary example: 11000000.10101000.10000000.10000001	Binary example: 00100000 00000001 00001101 10111000 00000000 00010000 00000000 00000110 00000000 00000110 00000000 00000000 00000000 00000000 00000000 00000001
4,294,467,295 IPv4 addresses	3.4 X 10^{38} IPv6 addresses

IPv6 Address Representation

As mentioned, IPv6 addresses are usually written in hex with colons in between each 16 bit field, for example: 2001:0DB8:0010:0006:0006:000A:0000:0001

There are two ways to shorten IPv6 addresses:

- Within a 16-bit field, leading zeroes are optional. Thus, the example can be shortened to: 2001:DB8:10:6:6:0:0:1
- Once within the address multiple fields of zeroes may be replaced by "::". Thus, the example can be further shortened to: 2001:DB8:10:6:6::1

IPv6 EUI-64 Interface ID

The lower 64 bits of an IPv6 address can use the EUI-64 bit formatted MAC address. The process to convert a 48-bit MAC address to this format is:

- 0xFFFE is inserted in the middle of the 48-bit MAC address
- The 7th bit of the first octet is inverted (because the meaning of this bit is the opposite of its meaning in a MAC address)

IPv4 vs. IPv6 Header

The IPv6 header has less fields than the IPv4 header (and is sometimes therefore called a "simpler" header), but it is longer because it contains the longer IPv6 addresses.

The following fields in the IPv6 header also appear in IPv6, with the same name:

- Version
- Source address
- Destination address

The following fields in the IPv6 header and IPv4 header have similar functions:

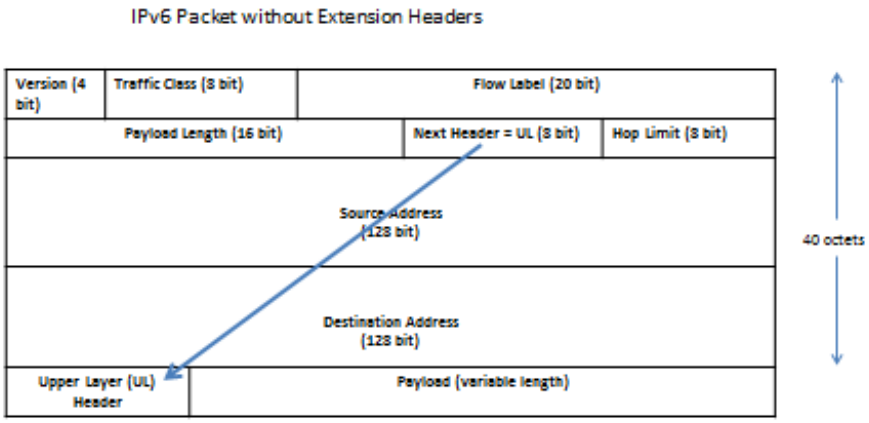
IPv4 Field Name	IPv6 Field Name
Type of service	Traffic class
Total length	Payload length
Time to live	Hop limit
Protocol	Next header

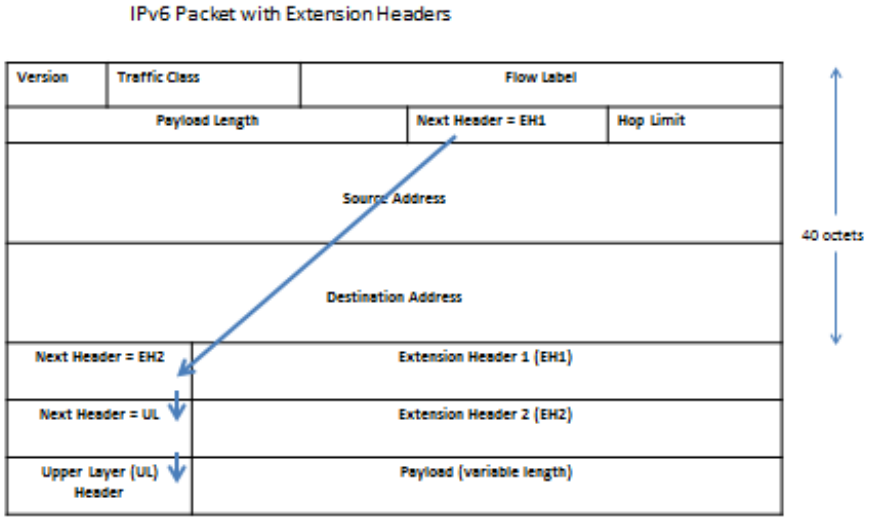
The following IPv4 header fields do not appear in IPv6:

- Internet header length
- Identification
- Flags
- Fragment offset
- Header checksum
- Options
- Padding

The flow label field is new in the IPv6 header.

IPv6 Header Detail





IPv6 Address Types

- **Unicast**
  - Address for a single interface
  - Several types including:
    - global aggregatable, 2000::/3
    - loopback, ::1/128
    - link-local, FE80::/10
    - unspecified, ::
- **Multicast**
  - One-to-many; enables more efficient use of the network
  - FF00::/8

- **Anycast**
  - One-to-nearest (allocated from unicast address space)
  - Multiple devices share the same address; all anycast nodes should provide the same service
  - Source devices send packets to anycast address; routers decide on closest device to reach that destination
  - For load balancing and content delivery services
  - Note: the 128 highest addresses within each /64 subnet prefix are reserved for use as anycast addresses

IPv6 Address Assignment

- Static
  - With manual interface ID, or
  - With EUI-64 format interface ID
- Dynamic
  - Stateless autoconfiguration, or
  - DHCPv6

Ethernet

MAC Addresses

A MAC address is a 48 bit number. The vendor code is the first 24 bits, and the last 24 bits represent a vendor assigned number. MAC addresses are written in hexadecimal. There are many ways to represent these addresses.; some example representations are:

0000.0c12.3456
00:00:0c:12:34:56
00.20.AF.12.34.56
020701123456
00-AA-12-34-56-78

Ethernet Frame Types

Field lengths shown are in bytes; SOF = Start of Frame; FCS = Frame Check Sequence

Ethernet II

8	6	6	2	46 –1500	4
Preamble	Dest MAC	Source MAC	Type	DATA	FCS

Type field value shows type of protocol being carried, values are 0x05DD to 0xFFFF.

IEEE 802.3

7	1	6	6	2	46 –1500	4
Preamble	SOF	Dest MAC	Source MAC	Length	802.2 Header + DATA	FCS

Length field value shows length of packet, values are 0x0001 to 0x05DC (1 to 1500 bytes).

IEEE 802.2 LLC

1	1	1 or 2
Destination Service Access Point (DSAP)	Source Service Access Point (SSAP)	Control

- DSAP: Defines the communications pathway to the next level (network) protocol on the receiving side.
- SSAP: Defines the communications pathway from the next level (network) protocol on the sending side.
- Control: Defines the type of transmission.

IEEE 802.2 LLC SNAP

1	1	1	3	2
DSAP (0xAA)	SSAP (0xAA)	Control (0x03)	OUI	Protocol

- DSAP: Fixed at 0xAA.
- SSAP: Fixed at 0xAA.
- Control: Fixed at 0x03.
- OUI: Organizationally Unique Identifier (from the MAC address).
- Protocol: Type field from the original Ethernet II frame type.

IEEE 802.1q

6	6	2	2	2	46 - 1500	4
Dest MAC	Source MAC	TPID	TCI	Length or Type	DATA	CRC

TPID (Type Identifier) - 0X8100

TCI (Tag Control Information)

- 3 bits for priority (802.1p)
- 1 bit for Token Ring Encapsulation Flag
- 12 bits for virtual LAN (VLAN) ID

Ethernet Cables

There are two types of unshielded twisted pair (UTP) cables for Ethernet: straight-through and crossover. Both have eight wires.

A straight-through cable is used to connect dissimilar devices, such as PC-to-switch, router-to-switch. In a straight-through cable each of the eight individual wires goes straight through the cable so that the pin out on each end is the same:

- Pin 1 on one end goes to Pin 1 on the other end
- Pin 2 on one end goes to Pin 2 on the other end
- And so on…

A crossover cable is used to connect similar devices, such as switch-to-switch. In a crossover cable some of the wires cross over when going through the cable so that the transmitted information on one end becomes the received information on the other end. The pin configuration is:

- Pin 1 on one end goes to Pin 3 on the other end
- Pin 2 on one end goes to Pin 6 on the other end
- Pin 3 on one end goes to Pin 1 on the other end
- Pin 4 on one end goes to Pin 4 on the other end
- Pin 5 on one end goes to Pin 5 on the other end
- Pin 6 on one end goes to Pin 2 on the other end
- Pin 7 on one end goes to Pin 7 on the other end
- Pin 8 on one end goes to Pin 8 on the other end

Fiber is also used for Ethernet. Two types are single mode (usually with laser) and multimode (usually with light emitting diode [LED]). Most of light travels in core; cladding around core confines the light. The buffer or coating protects the fiber.

WANs

WAN Connection Types

Connection	Characteristics
Ethernet	• Uses Ethernet to connect to service provider's network
Leased Line	• A pre-established, private connection from one site to another through a provider's network; also called a dedicated circuit or a dedicated connection • A point-to-point connection between two end points • Used when there is a constant flow of data, or when a dedicated amount of bandwidth is required • One router interface is connected to one destination site • Example encapsulations: Point-to-Point Protocol (PPP), High-Level Data Link Control (HDLC)
Circuit Switching	• A dial-up connection through a provider's voice-grade network, either using an analog modem or an Integrated Services Digital Network (ISDN) connection • Used when a slow-speed connection is sufficient, or when there is not much of a need to transfer a lot of data • One call establishes a circuit to one destination site • Example encapsulations: PPP, HDLC
Packet or cell Switching	• Each site only uses one physical connection to the provider's network, however there may be multiple virtual circuits (VCs) to various destinations • Typically less expensive than leased lines, because various data streams are mixed across a single link • Used when a dedicated connection is needed, but cost savings is important • Examples – Frame Relay, X.25, ATM (ATM uses fixed-size frames called cells to achieve faster and more predicable transport through the network)
Internet (using a virtual private network [VPN])	• Each site uses a broadband connection (digital subscriber line [DSL], cable or broadband wireless) to connect to an Internet Service Provider (ISP), and uses VPN technology to ensure secure communication.

WAN Terminology

- **Customer Premise Equipment (CPE):**- Network devices/equipment physically located at the customer's location/site. Customer is typically required to procure and maintain this equipment. Equipment could include routers and Channel Service Unit/ Data Service Unit (CSU/DSU).
- **Central Office (CO):** The facility that provides WAN services to the customer. Source of analog phone service, ISDN service, DSL service, frame relay connections, X.25 connections, and leased lines.
- **Local Loop:** The link from the provider's CO to the customer's demarcation point. Also called the "last mile", this is normally not more than a few miles long.
- **Demarcation Point (Demarc):** The line between the customer site and the provider network. The CPE is inside the demarc; the local loop is outside the demarc.
- **Toll Network:** The provider's network, inside the WAN cloud.

WAN Devices

WAN devices include:

- Routers, to route between LANs and WANs
- Access servers, to terminate dial-in connections
- Modems, to convert between digital and analog signals
- CSU/DSU, to provide termination for digital signals
- WAN switches, such as Frame Relay switches and public switched telephone network (PSTN) switches
- Core routers, such as those in a multiprotocol label switching (MPLS) network

Serial WAN Cables

Serial WAN cables connect a data terminal equipment (DTE) device (which is typically a router) to a data circuit-terminating equipment (DCE) device (for example, a CSU/DSU or modem). The DTE end for a Cisco router has a 60 pin connector or a 26 pin connector. The types of DCE interfaces include: EIA/TIA-232, EIA/TIA-449, V.35, and X.21.

WAN Serial Encapsulation Types

Connection	Characteristics
Cisco HDLC	• A Cisco-proprietary serial encapsulation • Allows multiple network-layer protocols to be sent • Default encapsulation for all serial interfaces on a Cisco router • One router interface only goes to one destination
PPP	• An open-standard serial encapsulation • Allows multiple network-layer protocols to be sent • Allows optional link-layer authentication (challenge handshake authentication protocol [CHAP] or password authentication protocol [PAP]) • One router interface only goes to one destination
Frame Relay	• Uses switched virtual circuits (SVCs) or permanent virtual circuits (PVCs) • Allows multiple network-layer protocols to be sent • Each virtual circuit is a private channel between two end points • One router interface may have many virtual circuits, going to the same location or various locations
X.25	• An older, but still available, packet switching standard • Uses SVCs or PVCs • Allows multiple network-layer protocols to be sent • Each virtual circuit is a private channel between two end points • One router interface may have many virtual circuits, going to the same location or various locations

Frame Relay Terminology

- **Local Access Rate:** Connection rate between a frame relay site and the frame relay provider.
- **Virtual Circuit:** Logical connection between two end points.
- **PVC:** A circuit that is always available. The bandwidth for the circuit is always allocated.
- **SVC:** A circuit that is built when needed. The bandwidth is not available when the circuit is closed.
- **Data Link Connection Identifier (DLCI):** The locally significant reference to one end of a virtual circuit. The DLCI numbers are assigned by the frame relay provider.
- **Committed Information Rate (CIR):** The maximum average data rate that the network tries to deliver, through the PVC from one end to the other. Each PVC may have a unique CIR.
- **Inverse Address Resolution Protocol (IARP):** The process used by a frame relay device, such as a router, to discover the network-layer information of the devices at the other end of the PVCs.
- **Local Management Interface (LMI):**- Signaling between the frame relay device (the router) and the frame relay switch (the provider). LMI messages do not travel across the entire PVC.

How Protocol Layers Interact

A field in the frame, such as the type field or 802.2 header in an Ethernet frame, indicates the type of Layer 3 (network layer) information contained in the frame.

The protocol field in an IP packet indicates the type of Layer 4 (transport layer) information contained in the packet.

The port number field in a TCP or UDP segment indicates the type of application layer information contained in the segment.

LAN Switches

LAN Switch Functions

Address Learning: Dynamically learns MAC addresses by reading the source MAC address of each arriving frame. If an address is not in the current MAC address table, and there is enough space to store it, the address and the inbound port are stored.

Forward/Filter: Compares the destination MAC address in an arriving frame to the MAC address table. If the address is in the table, the switch only forwards the frame out the port specified in the table, thus filtering it from other ports. If the MAC address is not in the MAC address table (it is an unknown MAC address), or if it is a broadcast or multicast frame, the switch floods the frame out every other port (within the same VLAN), except the port on which it arrived. Note that the switch does not change the addresses in the frame.

Loop Avoidance: Since the default behavior of a switch is to forward unknown unicast, broadcast, and multicast frames, it is possible for one frame to loop endlessly through a redundant (multiple path) network. Thus the Spanning Tree Protocol (STP) is used, to stop loops in a redundant switch network.

Collision Domains and Broadcast Domains

All devices that share the same bandwidth could potentially have an Ethernet collision, and are said to be in the same collision domain. All devices to which a broadcast frame will go are said to share the same broadcast domain.

All ports on a hub are in the same collision domain and in the same broadcast domain.
Each port on a Layer 2 switch is in its own collision domain. All ports on a Layer 2 switch that are in the same VLAN are in the same broadcast domain.

Each port on a router is in its own collision domain and in its own broadcast domain.

Switching/Bridging Issues

Redundant Topology: Unknown frames are flooded out all ports (within the same VLAN) except the port on which the frame arrived. If there are multiple paths, then a flooded frame may return back in to the same switch on another port, thus creating a loop.

Multiple Frame Copies: Unknown frames are flooded out all ports (within the same VLAN) except the port on which the frame arrived. If there are multiple paths (redundancy), then a frame destined for a device may be forwarded over each of the multiple paths. The destination device would then receive multiple copies of the same frame.

MAC Database Instability: Unknown frames are flooded out all ports (within the same VLAN) except the port on which the frame arrived. The switch dynamically learns MAC addresses by reading the source MAC address of each arriving frame and recording the address and inbound port in its MAC address table. If there are multiple paths (redundancy), a switch may learn the same MAC address on different ports, at slightly different times. Thus, the MAC address table would change very quickly and may become unstable. The end result may also be an incorrect port number for a given MAC address.

802.1d Spanning Tree Protocol

A solution to bridging/switching issues is the IEEE 802.1d STP:

- Bridges/switches communicate with bridge protocol data units (BPDUs). BPDUs are sent by default every two seconds and include the bridge ID and the root ID.
- Each bridge/switch has a unique bridge ID, which is the priority (or priority and extend system ID = VLAN ID) followed by the base MAC address of the bridge/switch.
- The bridge/switch with the lowest bridge ID becomes the root bridge. All other bridges/switches are called non-root bridges.
- All ports on the root bridge are called designated ports and are forwarding.
- All non-root bridges calculate their best (lowest cost) way to the root; the port used for that path is called a root port. Every non-root bridge has one root port. In case of a tie, the switch uses the port on which it receives the BPDU with the lowest bridge ID; if these are the same, then it uses the port on which it receives the bridge ID with the lowest port ID.
- Every segment must have a designated port. If a segment is not connected to a root bridge, the non-root bridges on the segment determine which of them will have the designated port. The bridge with the lowest bridge ID will have the designated port; ties are broken the same way as above. All other ports on that segment will be blocked ports, which are also called non-designated ports. Blocked ports do not forward traffic, but do listen for BPDUs.
- If a port does not receive BPDUs for a time (max-age), it transitions to the listening state, and the topology recalculates the root, non-root, etc.
- Bridge/switch convergence is the time between a break occurring and STP calculating an alternate path. Convergence is typically 30 – 50 seconds.
- Cisco switches include STP enhancements:
  - Portfast provides immediate transition of the port into STP forwarding mode upon link up; portfast should only be enabled on ports not connected to another switch.
  - UplinkFast provides improved convergence time of STP in the event of the failure of an uplink on an access switch. UplinkFast only reacts to direct link failure (failure of a link on the same switch) so a port on the access switch must physically go down in order to trigger the feature.
  - BackboneFast can save a switch up to 20 seconds (max-age) when it recovers from a failure of a link on another switch.

802.1w Rapid Spanning Tree Protocol

IEEE 802.1w Rapid Spanning Tree Protocol (RSTP) is an enhancement to 802.1d:

- RSTP provides faster spanning tree convergence after a topology change and incorporates features equivalent to Cisco PortFast, UplinkFast and BackboneFast.
- An edge port corresponds to the PortFast feature, where a port is directly connected to an end station (and therefore cannot create a bridging loop) so it transitions to the forwarding state.
- The link type is automatically derived from the duplex mode of a port. A port that operates in full-duplex is assumed to be point-to-point, while a half-duplex port is considered as a shared port by default.

Comparison of Bridges and Switches

Bridges	Switches
Software based	Hardware-based (port-level application specific integrated circuits [ASICs])
Relatively slow	Comparatively fast
One STP per bridge	Possibly many instance of STP per switch (possibly one per VLAN)
Typically up to 16 Ports	Possibly hundreds of ports

Half-Duplex vs. Full-Duplex

Half-Duplex:

- Devices use the same pair of wire for transmit and receive, so only 50% of the bandwidth is available for sending or receiving (the same bandwidth is used to send and receive)
- Available bandwidth per device decreases as number of devices in the collision domain increases
- Devices connected via hubs (Layer 1 devices) share the available bandwidth

Full-Duplex:

- Uses one pair of wires for sending and another pair for receiving.
- Effectively provides double the bandwidth; can send and receive at the same time.
- Must be point-to-point connections, such as a PC or server-to-switch or router-to-switch.
- Every device has its own collision domain on each switch port.

STP on Trunks

When STP is run on trunks, there are a variety of possibilities:

- Cisco Inter-switch link (ISL) trunks use Per VLAN Spanning Tree (PVST), in which one instance of STP is run for each VLAN.
- 802.1q trunks may use common spanning tree (CST), in which one instance of STP is run for all VLANs.
- Cisco 802.1q trunks use PVST+, in which one instance of STP is run for each VLAN.
- 802.1s, multiple instances of spanning tree (MIST or MST, or MSTP), can also be run on 802.1q trunks. MSTP runs one instance of STP for a group of VLANs.
- On 802.1q trunks, Cisco switches support PVST+ or MSTP.
- With Rapid STP, PVST+ becomes PVRST+.

STP Port Costs

The STP cost is the sum of the costs along the path; the default costs are based on bandwidth as follows:

Bandwidth	STP Port Cost
10 Gbps	2
1 Gbps	4
100 Mbps	19
10 Mbps	100

EtherChannel

An EtherChannel is viewed as one logical port in STP. There are two negotiation protocols:

- Port Aggregation Protocol (PAgP): Cisco proprietary; desirable or auto options
- Link Aggregation Control Protocol (LACP): IEEE standard; active or passive options

Routers

A router maintains a routing table, which includes the destination network addresses that the router knows how to get to, and the best path to get to those destinations. The routing table may also contain a default route. A router discards packets for unknown networks.

Types of Routes

Connected

- When an address and subnet mask is configured on a router's interface, the router calculates the subnet on which that interface is on, and puts that information in the routing table as a connected route

Static

- Manually configured by an administrator; each static route must be configured on each router
- No overhead in processing, sending, or receiving updates
- Saves bandwidth and router CPU resources
- Routing table maintained by administrator

Dynamic

- A process that automatically exchanges information about available routes
- Uses metrics to determine the best path to a destination network
- The routing protocol must be configured on each router
- Bandwidth is consumed as routing updates are transmitted between routers
- Router CPU is used to process, send, and receive routing information
- Memory is required to maintain related tables
- Routing table maintained by routing process

Default

- Can be either static or dynamic
- A router uses the default route if it does not have an explicit route that matches the destination

Routing Protocols

Interior vs. Exterior

Interior

- Used within a common administrative domain called an Autonomous System (AS), which is typically controlled by a single organization
- Interior routing protocols are used within a corporate network

Exterior

- Used to connect Autonomous Systems
- Exchanges routing information between different administrative domains
- Exterior protocols are used to connect sites within a very large corporate network, or are used to connect to the Internet

Distance Vector vs. Link State vs. Advanced Distance Vector

Distance Vector

- Maintains a routing table of distance and vector (direction) to each network
- Sends periodic routing updates that include the "entire" routing table at each update, to its neighbors
- Received routing updates are processed, and the resulting routing table is sent by the router to its neighbors. Thus the updates are "second-hand information" (also called routing by rumor)
- Prone to routing loops (disagreement between routers) and count to infinity (routing metrics continue to accumulate indefinitely)
- Solutions to these problems include:
  - Spilt Horizon: Do not send updates back out the interface through which they were learned. This eliminates back-to-back router loops.
  - Define a maximum metric: eliminates count to infinity problem.
  - Route poisoning: Set the advertised metric to the maximum value on routes that have gone down.
  - Poison reverse: Overrides split horizon by informing the source of a route that it has gone down.
  - Hold-down timers: Eliminates long-distance loops by ignoring updates about "possibly down" routes that have metrics worse than the current metric.
  - Triggered updates: Send an individual update immediately when a route is thought to be down, rather than wait for the periodic update timer (also called flash updates).

Link State

- Uses "hello" packets to establish and maintain neighbor relationships
- Maintains a complete topological map (link state database [LSDB]) of the entire network, separate from the routing table (forwarding table)
- Sends updates only when necessary and only sends information that has changed, not the entire database. Does not send information from the routing table, but rather from the database.
- Routing table is individually calculated on each router from its LSDB, using the Shortest Path First (SPF) algorithm. When SPF runs, it is CPU intensive.
- The database typically requires as much memory as the routing table

Advanced Distance Vector

- Uses "hello" packets to establish and maintain neighbor relationships
- Sends updates only to neighbors and only when necessary; only sends information that has changed
- Maintains topology table containing all of the routing information received from its neighbors.

Classless vs. Classful

Classless

- Sends subnet mask with routing updates
- Supports VLSM, discontiguous networks, and does not have to automatically summarize routes at a major network boundary

Classful

- Does not send subnet mask with routing updates
- Does not support VLSM or discontiguous networks; automatically summarizes routes at a major network boundary

Examples of IPv4 Routing Protocols

Protocol	DV or LS	Internal or External	Classless or Classful	Characteristics
Routing Information Protocol (RIP)	DV	Internal	RIPv1 classful; RIPv2 classless	• Sends periodic updates every 30 seconds by default • Sends the entire routing table out every interface, minus the routes learned from that interface (split horizon) • Uses hop count as a metric • Has a maximum reachable hop count of 15 • RIPv1 sends updates out as a broadcast • RIPv2 uses the 224.0.0.9 multicast address, and automatically summarizes at a major network boundary, but can be configured for manual summarization
Enhanced Interior Gateway Routing Protocol (EIGRP)	Advanced DV	Internal	Classless	• Cisco proprietary protocol • Uses diffusing update algorithm (DUAL) • Sends triggered updates when necessary • Sends only information that has changed, not entire routing table • Uses a composite metric consisting of bandwidth, delay, reliability, load, and MTU; only uses bandwidth and delay by default (configurable) • Does track hop count but only uses it as a tie-breaker • Default maximum hop count is 224, but is configurable up to 255 maximum • Sends updates out on a multicast address of 224.0.0.10 • In Cisco IOS 15.0 and higher does not automatically summarize at a major network boundary. Can be configured for automatic or manual summarization.
Open Shortest Path First (OSPF)	LS	Internal	Classless	• IETF standard protocol • Sends triggered updates only when a change occurs; also refloods updates periodically (every 30 minutes) • Updates consist of link state advertisements (LSAs). LSAs are flooded to all routers in the area; thus routers receive the LSAs, not processed routes, as they do with distance vector protocols. LSAs are stored in LSDB.

				• Uses a cost metric; interface bandwidth is used to calculate cost on Cisco devices • Uses two multicast addresses: 224.0.0.5 and 224.0.0.6 • Does not automatically summarize at a major network boundary. Area border routers (ABRs) and autonomous system boundary routers (ASBRs) can be configured for manual summarization.
Border Gateway Protocol (BGP)		External	Classless	• Path vector routing protocol • Sends triggered updates when necessary • Sends only information that has changed, not entire routing table • Uses a complex metric system called attributes

Examples of IPv6 Routing Protocols

IPv6 routing protocols use link-local addresses. Examples are:

- Static
- RIP new generation (RIPng) (RFC 2080)
  - Uses FF02::9 multicast address
- OSPF version 3 (OSPFv3) (RFC 5340)
  - Uses FF02::5 and FF02::6 multicast addresses
- EIGRP for IPv6
  - Uses FF02::A multicast address
- IS-IS for IPv6 (RFC 5308)
- MP-BGP4 (RFC 2545/4760)

Administrative Distance

The administrative distance is a number between 0 and 255 that rates the trustworthiness of the source of the routing information. A lower the number is considered better. The administrative distance is used when a router learns about the same route from different routing sources. Some of the default administrative distances are as follows:

Route Source	Default Administrative Distance
Connected network	0
Static route	1
Internal EIGRP	90
OSPF	110
RIP (v1 and v2)	120
External EIGRP	170
Unknown	255

Metric

The metric is how a routing protocol measures the "best" path to a destination network. A lower the number is considered better. Some of the routing protocol metrics are as follows:

Routing Protocol	Metric
EIGRP	Composite metric; defaults to bandwidth and delay, so that the fastest, lowest delay path is best. With default weighting factors (K-values), the EIGRP metric = bandwidth + delay, where: • bandwidth = 256* 10^7 /[the smallest (slowest) bandwidth between the source and destination, in kbps] • delay = 256 * the cumulative interface delay along the path , in tens of microseconds
OSPF	Cost; on a Cisco router this is inversely related to bandwidth, so that the fastest path is best. Default interface cost = (reference bandwidth) /(interface bandwidth), where reference bandwidth defaults to 100 Mbps.
RIP (v1 and v2)	Hop count; the path with the least number of hops is best.

OSPF Concepts

Basic OSPF LSA Types

LSA Type	Description	Generated by	Flooded
1	Router LSA	Each router	Within area
2	Network LSA	Designated router (DR)	Within area
3	Summary LSA	ABR	To other areas
4	ASBR summary LSA	ABR of area with ASBR	To other areas
5	Autonomous system (AS) external LSA	ASBR	Throughout AS

OSPF States

State	Description
Down	No active neighbor detected
Init	Hello packet received from neighbor
Two-way	Router sees its own router ID in a received hello packet
Exstart	Master/slave roles created
Exchange	Database descriptor (DBD) packets sent
Loading	Routers exchange link state requests (LSRs) and link state updates (LSUs), to populate LSDB
Full	Neighbors fully adjacent

EIGRP Concepts

- Maintains a topology table containing all of the routing information received from its neighbors.
- The neighbor's metric to a destination is known as the advertised distance (AD).
- The metric of the link to get to the neighbor is added to the AD; this sum is known as the feasible distance (FD).

- DUAL is used to calculate best paths. The route with the lowest FD is the best path; it is called the "current successor" route and is offered to the routing table. The FD of the current successor becomes the metric in the routing table.
- Non-best routes that pass the "feasibility condition" are called feasible successors and can be used if the best route goes away. Feasible successors are kept in the topology table.
- The "feasibility condition" is: A route is a feasible successor if its AD is less than the FD of the current successor. This condition ensures that the EIGRP is loop-free.

Router Storage Locations

Memory Type	Contents
RAM	• Uncompressed Cisco IOS, running configuration, tables, etc.
NVRAM	• Startup configuration file
ROM	• Bootstrap • ROM Monitor (ROMMON) • Power on self-test (POST) • May have Cisco IOS subset (RxBoot)
Flash	• Compressed Cisco IOS • Binary file storage capabilities (if enough space)
PCMCIA	• Like Flash; some have multiple PCMCIA slots available
Share I/O	• I/O buffer for interfaces

IPv4 Access Control Lists (ACLs)

Type	Numbers	Criteria	Location where applied
Standard	1 – 99, 1300 - 1999; or name	• Source IP address	Close to the destination
Extended	100 – 199, 2000 – 2699; or name	• Source IP address • Destination IP address • Protocol number • Source port number • Destination port number	Close to the source

Router Boot Sequence

1. POST
2. Load and run bootstrap code
3. Find Cisco IOS:
    a. Check boot field of configuration register; if it is 0x2 through 0xF, look in NVRAM for "boot system" commands. Do what they say if there are any.
    b. If there are none, or if configuration register is 0x1 , check for a Cisco IOS image in Flash and load first one.
    c. If there is no file in Flash, attempt boot from network server and then from helper image in ROM (if there is one).
    d. If those fail or if the configuration register is 0x0, load ROM Monitor mode.
4. Load Cisco IOS into RAM
5. Load configuration from NVRAM, if it exists, into RAM.
6. If no configuration in NVRAM:
    a. If no active link to another router, prompt for initial configuration dialog.
    b. Otherwise try to load configuration from network server.

Configuration Register

The configuration register is a 16 bit number, written in hex. The default value is 0x2102, which in binary is 0010 0001 0000 0010.

The definition of the bits varies on different devices. Values for 3900/2900/1900 series routers are as follows:

Bit#	Description
15	Diagnostic mode display 0 = disable, 1 = enable
14	Network and subnet portion of IP broadcast address, 1 = use all zeroes, 0 = use all ones
13	Boot from ROM after six failures: 1 = yes, 0 = no
12 - 11	Used with bit 5 to change console line speed.
10	Host portion of IP broadcast address: 0 = ones, 1 = zeroes
9	Use secondary bootstrap: 0 = disable, 1 = allow
8	Break key : 1 = disable after first 60 seconds, 0 = allow
7	OEM display disable: 0 = display, 1 = no display
6	Ignore NVRAM: 0 = disable, 1 = enable
5	Change console line speed. Use with bits 12 & 11; bit order is 12, 11, 5 010 = 4.8, 000 = 9.6, 001 = 19.2, 011 = 38.4, 101 = 57.6, 111 = 115.2
4	Not used
3 - 0	Boot field: • 0x0 = use ROMMON mode • 0x1 = boot from first image in Flash • 0x2 through 0xF = examine NVRAM for "boot system" commands

Network Address Translation

NAT Addresses

NAT address types are:

- Inside local: The address assigned to a device on the "inside" network. This is typically a private address.
- Inside global: The address of a device on the "inside" network as it appears to devices on the "outside" network. This is typically a public address. For example, the inside local address 10.1.1.1 may be translated to the inside global address 209.165.201.1.
- Outside global: The address assigned to a device on the "outside" network.
- Outside local: The address of a device on the "outside" network as it appears to devices on the "inside" network. The outside global address may be translated to the outside local address, but typically translation is not done and these addresses are identical.

Types of NAT

There are three types of NAT:

- Static NAT: one-to-one
- Dynamic NAT: many-to-many (using a pool)
- Port address translation (PAT): many-to-one (using overloading)

First Hop Redundancy Protocols

Three first hop redundancy protocols:

- Hot Standby Router Protocol (HSRP): Cisco proprietary
- Gateway Load Balancing Protocol (GLBP): Cisco proprietary
- Virtual Router Redundancy Protocol (VRRP): IETF standard

Network Management

Syslog Severity Levels

Syslog severity levels are:

0: emergency
1: alert
2: critical
3: error
4: warning
5: notification
6: informational
7: debugging

NetFlow Flow

A NetFlow flow is a unidirectional sequence of packets with the following seven key fields identical:

- Source and destination IP addresses
- Source and destination port numbers
- Protocol type
- Type of service
- Input logical interface

Virtual Private Networks (VPNs)

Types of VPNs

Two types of VPNs:

- Site-to-site: connect networks together
- Remote access (for example, Cisco AnyConnect and Cisco SSL VPN): connect individual hosts to a corporate network

IP Security (IPSec)

IPSec is a framework that allows choices of many protocols depending on the features required. IPSec provides:

- Confidentiality: ensures only authorized devices can read the data sent
- Integrity: ensures data is not changed during transmission
- Authentication: ensures a device is communicating with an authorized device
- Anti-replay protection: verifies that each packet is unique and has not been duplicated.

Generic Routing Encapsulation (GRE) Tunnels

GRE:

- Cisco proprietary tunneling protocol
- IP protocol number 47
- Three protocols involved:
  - Passenger protocol: protocol being encapsulated
  - Carrier protocol: in this case, GRE
  - Transport protocol: protocol that carries the passenger protocol

Cisco IOS Command Line Interface (CLI) and Commands

Notes:

- In each of the following tables, the commands are listed in alphabetical order.
- Many of the commands can be used on routers and switches.
- Most commands have many parameters. In the following tables only a few of the parameters are shown. Refer to the Command Reference documentation on Cisco's web site for the full command syntax.

Cisco IOS EXEC Operating Modes

Mode	Prompt	Sample Functions
User	Router>	Read-only privileges; for example to examine interface status and examine router status
Privileged	Router#	Full privileges to read, write, modify, copy, and delete; for example to examine interface status, examine router status, and examine configuration, and copy configuration to device
Configuration	Router(config)#	Modify the running configuration

General Commands

Command	Meaning
?	Help
<control> <a>	Move to the beginning of the command line
<control> <b> or <left arrow>	Move backward one character
<control> <c>	Abort from setup mode
<control> <d> or <backspace>	Removes one character to the left of the cursor
<control> <e>	Move to the end of the command line
<control> <f> or <right arrow>	Move forward one character
<control> <n> or <down arrow>	Last (previous) command recall
<control> <p> or <up arrow>	More recent command recall
<control> <shift> <6>	Interrupt a Cisco IOS process, such as a ping or traceroute
<control> <shift> <6>, followed by <x>	The "escape sequence", used to suspend a Telnet or SSH session
<control> <r>	Redisplays a line
<control> <u>	Erases a line from the beginning of line
<control> <w>	Erases a word
<control> <z>	Exit from configuration mode back to privileged EXEC mode
<Esc> <B>	Move to the beginning of the previous word
<Esc> <F>	Move forward one word
<enter>	Resumes the last suspended telnet session
<tab> key	Keyword completion
Router#auto secure	Initiates a security audit and recommends changes for fixing security vulnerabilities
Router#clear counters	Resets the "show interface" counters to zero
Router#clear line	Disconnects a telnet session from a foreign host
Router#clock set	Sets the device's clock
Router#configure terminal	Enters configuration mode
Router#connect	Logs on to a host that supports Telnet, rlogin, or LAT
Router#copy flash0: tftp:	Copies a file from Flash memory to a TFTP server
Router#copy running-config startup-config	Copies configuration from RAM to NVRAM (overwrites)
Router#copy running-config tftp:	Copies configuration from RAM to TFTP server (overwrites)
Router#copy startup-config running-config	Executes configuration from NVRAM into RAM (executes line-by-line, merges, does not overwrite)
Router#copy startup-config tftp:	Copies configuration from NVRAM to TFTP server (overwrites)
Router#copy tftp: flash0:	Copies a file from a TFTP server to Flash memory
Router#copy tftp: running-config	Copies configuration from TFTP server into RAM (executes line-by-line, merges, does not overwrite)
Router#copy tftp: startup-config	Copies configuration from TFTP server to NVRAM (overwrites)
Router#debug	Starts the console display of the events on the device
Router#disable	Exit privileged EXEC mode
Router#disconnect	Disconnect a telnet session
Router>enable	Enter privileged mode
Router#erase startup-config	Erases the configuration in NVRAM
Router#exit	Exit from the device
Router#license boot module	Installs an evaluation license
Router#license clear	Clears a license
Router#license install	Installs a license

Command	Meaning
Router#license save	Saves a license
Router#logout	Exit from the device
Router#ping	Sends an "echo" and expects an "echo reply" (extended ping also allows ping for protocols other than IP)
Router#reload	Reloads the operating system
Router#resume	Resumes a suspended telnet session
Router#setup	Enters prompted dialog to establish an initial configuration
Router#show access-lists	Displays the contents of all ACLs configured
Router#show control-plane host open-ports	Displays a list of open TCP/UDP ports
Router#show CDP entry	Displays a single cached Cisco Discovery Protocol (CDP) entry; use "show cdp entry *" to display cached information on all neighbors
Router#show cdp interface	Displays values of CDP timers and CDP interface status
Router#show cdp neighbors	Displays a summary of CDP information received from neighbors. Use the "detail" keyword to display detailed CDP information received from neighbors.
Router#show cdp traffic	Displays information about interface CDP traffic
Router#show controllers	Displays the Layer 1 information about an interface (including cable type and DCE/DTE status for serial interfaces)
Router#show file system	Lists all of the file systems available on the device
Router#show flash0:	Displays information about flash memory
Router#show glbp	Displays GLBP information
Router#show history	Displays the list of recorded command lines during the current terminal session
Router#show interfaces	Displays information about interfaces or an interface, including the state of the interface
Router#show license	Displays information about all Cisco IOS Software licenses
Router#show logging	Displays the contents of logging buffers
Router#show processes	Displays the CPU utilization for each process
Router#show ntp associations	Displays the status of network time protocol (NTP) associations the device has
Router#show ntp status	Displays the status of NTP on the device, including if it is synchronized with the NTP server
Router#show running-config	Displays the active configuration (in RAM)
Router#show sessions	Displays a list of hosts to which you have established telnet connectivity
Router#show ssh	Displays a list of all active SSH connections to the device
Router#show standby	Displays HSRP information
Router#show startup-config	Displays the startup configuration (in NVRAM)
Router#show user	Displays a list of all active users on the device
Router#show version	Displays configuration of system hardware, software version, and configuration register value
Router#show vlans	Displays information about the VLANs defined on the router
Router#ssh	Connects to a host using SSH
Router#telnet	Connects to a host using Telnet. Use the optional port number to connect to a different service on the host device.
Router#terminal editing	Reenable advanced editing (use "no terminal editing" to disable advanced editing features). By default advanced editing is enabled

Command	Meaning
Router#terminal history size	Changes the number of command lines the system will record during the current terminal session
Router#terminal length	Controls the number of lines that are displayed without pausing
Router#terminal monitor	Forwards debug and error output to the current Telnet session (use "terminal no monitor" to turn this off)
Router#traceroute	Traces the route that packets are taking through the network
Router#undebug all	Turns off debugging (also use "no debug all")

Filtering Parameters on show Commands

The following parameters allow display of only specific parts of a show command's output. Use with the | character; for example: **show running-config | include hostname**

Parameter	Meaning
begin	Shows all output beginning from the line that matches the specified expression
exclude	Exclude all lines in the output that match the specified expression
include	Include all lines in the output that match the specified expression
section	Show the entire section of output that starts with the specified expression

General Configuration Commands

Command	Meaning
Router(config)#<control> <z>	Exit from configuration mode back to privileged EXEC mode
Router(config)#banner	Specifies a banner for the router (can be motd, idle, login, or exec banner)
Router(config)#boot system	Specifies the source of Cisco IOS images
Router(config)#cdp run	Enable CDP (CDP is enabled by default; use "no cdp run" to disable it)
Router(config)#config-register	Sets the 16-bit configuration register value
Router(config)#crypto key generate rsa	Generates RSA key pair and enables SSH server for authentication
Router(config)#enable password	Specifies the enable password
Router(config)#enable secret	Specifies the enable secret password
Router(config)#end	Exit from configuration mode
Router(config)#exec-timeout	Sets the timeout for a line EXEC session to specified minutes and seconds
Router(config)#exit	Exit from configuration mode
Router(config-line)#history size	Specifies the number of command lines the system will record on a line
Router(config)#hostname	Specifies the device's name
Router(config)#interface	Enters interface configuration mode (Ethernet, serial, loopback, etc.) Also used to enter subinterface configuration mode. For virtual interfaces (loopback, tunnel, etc.), the first time that this command is used for a specific interface, it creates that interface. Also used for VLAN interfaces.
Router(config)#interface range	Enters interface configuration mode for the specified range of addresses.
Router(config)#line	Enters line configuration mode (console, aux, vty)
Router(config-line)#login	Enables password checking on a line (console, aux, vty). Add the "local" keyword to cause the device to use the locally defined "username" commands for authentication.

Command	Meaning
Router(config)#logging {*address*}	Specifies the IP address of the syslog server that will receive logging messages.
Router(config)#logging console	Enables system messages (syslog messages) to go to all available tty lines.
Router(config)#logging on	Enables message logging.
Router(config-line)#logging synchronous	Used on a line (console, aux, vty), causes input to be redisplayed on a single display line, at the end of each console message that interrupts the input
Router(config)#logging trap {*severity*}	Defines the severity level of syslog messages that will be sent to the Syslog server.
Router(config)#ntp server	Define the NTP server to which the device will synchronize its time. This command makes the device an NTP client.
Router(config-line)#password	Specifies the password for a line (console, aux, vty)
Router(config)#service config	Enables the config service, which enables the router to automatically configure the system from a file specified in a boot command. Use the "no" form of the command to disable the service.
Router(config)#service finger	Enables the IP finger service. Use the "no" form of the command to disable the service.
Router(config)#service password-encryption	Specifies that any passwords set subsequent to this command will be encrypted. Using "no service password-encryption" will not decrypt the passwords, but subsequent passwords configured will not be encrypted.
Router(config)#service tcp-small-servers	Enables TCP small servers. Use the "no" form of the command to disable the servers; they are disabled by default.
Router(config)#service timestamps debug	Enables time stamps to be added to debug or log messages
Router(config)#service udp-small-servers	Enables UDP small servers. Use the "no" form of the command to disable the servers; they are disabled by default.
Router(config)# snmp-server community	Defines the community access string with read-only or read-write privilege.
Router(config)# snmp-server contact	Defines the system contact string.
Router(config)# snmp-server location	Defines the system location string.
Router(config)#tftp-server flash	Configures the device as a TFTP server.
Router(config-line)#transport input	Defines the transport protocols allowed on the line (SSH and/or telnet)
Router(config)#username	Defines host name and password for authentication. Use the "privilege" keyword to define the privilege level at which the user will be logged in. Use the "secret" keyword to encrypt the password with message digest 5 (MD5).

Interface Configuration Commands

Command	Meaning
Router(config-if)#cdp enable	Enable CDP on an interface (CDP is enabled by default; use "no cdp enable" to disable it)
Router(config-if)#clock rate	Sets clock rate in bps (used on DCE interfaces)
Router(config-if)#description	Adds a text description to the interface
Router(config-subif)# encapsulation dot1q {*vlan-number*}	Defines the data-link encapsulation and VLAN number for a subinterface; used for inter-VLAN routing on a subinterface
Router(config-if)#interface	Enters interface configuration mode (or sub-interface mode if already in interface mode)
Router(config-if)#interface *type.subinterface number* {point-to-point | multipoint}	Enters sub-interface configuration mode on a frame relay interface
Router(config-if)#media-type	On Cisco routers with more than one connector for an Ethernet interface, selects the media-type connector for the Ethernet interface (for example, use "10baset" for RJ-45 connectors)
Router(config-if)#shutdown	Administratively shutdown an interface (use "no shutdown" to bring the interface up)
Router(config-if)#standby *group ip address*	Activates HSRP on the interface, in the specified group. The address is the address of the HSRP virtual router that is created.
Router(config-if)#tunnel destination	Configures the specified IP address as the destination address for packets sent on the tunnel interface
Router(config-if)#tunnel mode	Configures the specified mode on the tunnel interface
Router(config-if)#tunnel source	Configures the specified IP address as the source address for packets sent on the tunnel interface

General Switch Commands

Command	Meaning
Switch#debug spanning-tree switch state	Starts the console display of STP port state changes
Switch#debug spanning-tree pvst+	Starts the console display of PVST+ events
Switch#show dtp interface	Displays the dynamic trunking protocol (DTP) parameters of the interface
Switch#show etherchannel port-channel	Displays EtherChannel port-channel information
Switch#show etherchannel summary	Displays a summary of the channel groups
Switch#show interfaces port-channel	Displays status of the specified port-channel interface
Switch#show interfaces switchport	Displays the switchport parameters of the interface
Switch#show interfaces trunk	Displays the trunk parameters of the interface
Switch#show mac address-table	Displays the switch's MAC address table
Switch#show port-security	Displays the port security status (can also specify an interface or an address)
Switch#show spanning-tree	Displays the details of the spanning-tree for each VLAN defined on the switch. Use the "vlan" keyword to display information about the spanning-tree on a VLAN.
Switch#show vlan	Displays information about the VLANs defined on the switch. Use the "id" keyword followed by a VLAN number to display information for the specified VLAN. Use the "brief" keyword to display one line of information about each defined VLAN.

General Switch Configuration Commands

Command	Meaning
Switch(config)#interface port-channel	Enters interface configuration mode for the EtherChannel specified
Switch(config)#ip default-gateway	Defines the address of the default gateway (which is the address of a router)
Switch(config)#spanning-tree mode rapid-pvst	Configures PVRST+ on the switch.
Switch(config)#spanning-tree portfast bpduguard default	Configures BPDU guard on all PortFast-enabled interfaces on the switch
Switch(config)#spanning-tree portfast default	Configures PortFast on all of the interfaces on the switch.
Switch(config)#spanning-tree vlan {*number*} root primary	Configures the switch to be the primary root bridge for the specified vlan
Switch(config)#spanning-tree vlan {*number*} root secondary	Configures the switch to be the secondary root bridge for the specified vlan
Switch(config)#vlan	Defines a VLAN and enters VLAN configuration mode
Switch(config)#vtp mode	Defines the VTP mode of the switch
Switch(config-vlan)#name	Defines the name of the VLAN

Switch Interface Configuration Commands

Command	Meaning
Switch(config-if)#channel-group {*number*} mode	Configures the interface as part of the port-channel with the specified number, using the specified mode
Switch(config-if)#duplex	Sets the duplex mode of the interface
Switch(config-if)#spanning-tree bpduguard enable	Enables the BPDU guard feature on the interface
Switch(config-if)#spanning-tree portfast	Configures PortFast on the interface.
Switch(config-if)#speed	Sets the speed of an interface with configurable speed
Switch(config-if)#switchport access vlan	Sets VLAN assignment of an interface
Switch(config-if)#switchport mode	Defines the mode of the switch interface (access, trunk, dynamic desirable, dynamic auto)
Switch(config-if)#switchport nonegotiate	Specifies that DTP negotiation frames are not sent on the interface
Switch(config-if)#switchport port-security	Enables port-security on the interface. Use other options on this command to configure the MAC address (or use sticky MAC address configuration), define the maximum number of secure MAC addresses, and define the violation mode.
Switch(config-if)#switchport trunk allowed vlan	Sets list of allowed VLANs on a trunk interface.
Switch(config-if)#switchport trunk native vlan	Defines the native VLAN on the trunk

General IP Commands

Command	Meaning
Router#debug eigrp packets	Starts the console display of EIGRP packets sent and received (good for debugging EIGRP authentication)
Router#debug ip eigrp	Starts the console display of IP-EIGRP packets sent and received
Router#debug ip ospf adj	Starts the console display of OSPF adjacency-related events (good for debugging OSPF authentication)
Router#debug ip ospf events	Starts the console display of the OSPF-related events
Router#debug ip ospf packet	Starts the console display of each OSPF packet received
Router#debug ip rip	Starts the console display of the IP RIP-related events on the router
Router#show hosts	Displays the cached list of host names and addresses (both static and obtained from a DNS server)
Router#show ip access-list	Displays the IP ACLs configured
Router#show ip arp	Displays the ARP table on the device
Router#show ip cache flow	Displays a summary of NetFlow information.
Router#show ip flow export	Displays NetFlow export information
Router#show ip interface	Displays IP-specific information about an interface, including if access-lists are applied; with the "brief" keyword, displays a summary of interface info.
Router#show ip eigrp interfaces	Displays EIGRP interface details
Router#show ip eigrp neighbors	Displays the EIGRP neighbors table
Router#show ip eigrp topology	Displays the EIGRP topology table
Router#show ip eigrp traffic	Displays the EIGRP traffic statistics
Router#show ip ospf	Displays OSPF timers and other statistics, including the number of times the SPF algorithm has run.
Router#show ip ospf interface	Displays OSPF interface details
Router#show ip ospf neighbor	Displays the OSPF neighbors table

Command	Meaning
Router#show ip protocols	Displays the details of the IP routing protocols that are running
Router#show ip route	Displays the IP routing table; use other keywords to display specific parts of the routing table
Router#show ip ssh	Displays IP SSH details on the device

IP Configuration Commands

Command	Meaning
Router(config-router)#area {*number*} authentication	Enables OSPF plaintext authentication for the area. (Use other parameters for null or MD5 authentication.)
Router(config-router)#auto-cost reference-bandwidth	Changes the reference bandwidth used in the OSPF cost calculation.
Router(config-router)#auto-summary	Enables automatic summarization of routes at major network boundaries, for RIPv2 and EIGRP. Use the "no" form of the command to disable this feature.
Router(config-router)#default-information originate	Generates a default external route into an OSPF routing domain; add the "always" keyword to specify that OSPF always advertises the default route regardless of whether the router has a default route in its own routing table.
Router(config-if)#ip address	Assigns an IP address and subnet mask to an interface. Use the "dhcp" option to specify that the interface obtains its address via DHCP.
Router(config-if)#ip authentication key-chain eigrp	Defines the key chain to use for EIGRP MD5 authentication on the interface
Router(config-if)#ip authentication mode eigrp	Enables EIGRP MD5 authentication on the interface
Router(config)#ip classless	Specifies that if a packet is received with a destination address within an unknown subnet of a directly attached network, the router will match it to the default route and forward it to the next hop specified by the default route.
Router(config)#ip domain-lookup	Turns on name service (DNS) lookups (use "no ip domain-lookup" to turn off DNS lookup)
Router(config)#ip domain-name	Defines a host domain for device
Router(config-if)#ip flow	Enables NetFlow on an interface
Router(config)#ip flow-export destination	Defines destination for NetFlow export information
Router(config)#ip flow-export version	Defines version (format) of NetFlow export information
Router(config)#ip host *name address*	Defines a static local host name to IP address mapping
Router(config)#ip http secure-server	Enables HTTPS server on the device
Router(config)#ip http server	Enables HTTP server on the device. Use the "no" form of the command to disable the HTTP server.
Router(config)#ip name-server	Defines one or more (up to 6) hosts that supply host name information (DNS). The address can be either an IPv4 or IPv6 address.
Router(config-if)#ip ospf {*process-number*} area {*area-number*)	Enables OSPF on the interface and defines which area it will run in. Allows the router to advertise the subnet to which the interface belongs.
Router(config-if)#ip ospf authentication	Enables OSPF plaintext authentication on the interface. (Use other parameters for null or MD5 authentication.)
Router(config-if)#ip ospf authentication-key	Defines the OSPF authentication key for plaintext authentication
Router(config-if)#ip ospf cost	Defines the OSPF cost of the interface

Command	Meaning
Router(config)#ip route {*dest-address*} {*subnet-mask*} {*next-hop* | *exit-interface*}	Defines a static route to an IP destination: Example: Router(config)# ip route 172.16.0.0 255.255.0.0 serial0 or Router(config)# ip route 172.16.0.0 255.255.0.0 172.16.1.1 Use an address/mask pair of 0.0.0.0 0.0.0.0 for a default route
Router(config)#ip ssh version 2	Enables SSH version 2 on the device
Router(config-keychain)# key {*number*}	For EIGRP, defines the key number of a key on a key chain, and enters keychain key configuration mode
Router(config)# key chain	For EIGRP, defines the name of a key chain and enters key chain configuration mode
Router(config-keychain-key)# key-string	For EIGRP, defines the key string (password) for a key on a key chain
Router(config-router)#maximum-paths	Defines the number of equal-metric paths over which the routing protocol will load balance.
Router(config-router)#network {*address*} [{*wildcard-mask*}]	For EIGRP, defines the networks that the routing protocol will run on. Starts up the routing protocol on all interfaces that are in that network (or match the network and wildcard mask) and allows the router to advertise that network.
Router(config-router)#network {*address*} {*wildcard-mask*} area {*area-number*)	For OSPF, defines the networks that the routing protocol will run on and which area they will run in. Starts up the routing protocol on all interfaces that match the address and wildcard mask, and allows the router to advertise those networks.
Router(config-router)#network {*network-number*}	For RIP, defines the networks that the routing protocol will run on. Starts up the routing protocol on all interfaces that are in that network and allows the router to advertise that network.
Router(config-router)#passive-interface {*interface*}	Causes the routing protocol not to send routing information on the specified interface.
Router(config)#router eigrp {*autonomous system-number*}	Defines EIGRP as an IP routing protocol and enters configuration mode for that protocol
Router(config)#router ospf {*process-number*}	Defines OSPF as an IP routing protocol and enters configuration mode for that protocol
Router(config)#router rip	Defines RIP as an IP routing protocol and enters configuration mode for that protocol
Router(config-router)#router-id	For OSPF, defines the OSPF router ID.
Router(config-router)#traffic-share	For EIGRP, defines how traffic is distributed among multiple unequal cost routes for the same destination network
Router(config-router)#variance	For EIGRP, defines unequal cost load balancing
Router(config-router)#version	For RIP, defines the version of RIP to use (1 or 2)

Wildcard Masks

Mask	Match	Don't Care	Example
0.0.0.0	Every octet	N/A	172.16.10.1 0.0.0.0 => matches 172.16.10.1
0.0.0.255	First three octets	Last octet	172.16.10.1 0.0.0.255 => matches 172.16.10.x
0.0.255.255	First two octets	Last two octets	172.16.10.1 0.0.255.255 => matches 172.16.x.x
0.255.255.255	First octet	Last three octet	172.16.10.1 0.255.255.255 => matches 172.x.x.x
255.255.255.255	N/A	Every octet	172.16.10.1 255.255.255.255 => matches x.x.x.x

General IPv6 Commands

Command	Meaning
Router#show ipv6 access-list	Displays the IPv6 ACLs configured
Router#show ipv6 eigrp interfaces	Displays EIGRP for IPv6 interface details
Router#show ipv6 eigrp neighbors	Displays the EIGRP for IPv6 neighbors table
Router#show ipv6 eigrp topology	Displays the EIGRP for IPv6 topology table
Router#show ipv6 ospf	Displays OSPFv3 timers and other statistics, including the number of times the SPF algorithm has run.
Router#show ipv6 ospf interface	Displays OSPFv3 interface details
Router#show ipv6 ospf neighbor	Displays the OSPFv3 neighbors table
Router#show ipv6 interface	Displays IPv6-specific information about an interface, including all of the interface's IPv6 addresses.
Router#show ipv6 neighbors	Displays the IPv6 neighbors table
Router#show ipv6 protocols	Displays the details of the IPv6 routing protocols that are running
Router#show ipv6 rip	Displays IPv6 RIPng -specific information, including the interfaces on which the protocol is running
Router#show ipv6 route	Displays the IPv6 routing table; use other keywords to display specific parts of the routing table

IPv6 Configuration Commands

Command	Meaning
Router(config-if)#ipv6 address *address/prefix*	Assigns an IPv6 address and prefix to an interface. Use the "eui-64" keyword to assign the 64 bit interface ID portion of the address using the EUI-64 format of the MAC address.
Router(config-if)#ipv6 address autoconfig	Specifies that the interface should obtain its IPv6 address using stateless autoconfiguration
Router(config-if)#ipv6 eigrp {*autonomous system-number*}	Enables EIGRP for IPv6 as an IPv6 routing protocol on the interface
Router(config-if)#ipv6 ospf {*process-number*} area {*area-number*)	Enables OSPFv3 as an IPv6 routing protocol on the interface and defines which area it will run in
Router(config-if)#ipv6 host *name address*	Defines a static local host name to an IPv6 address
Router(config-if)#ipv6 rip *name* enable	Enables RIPng with the specified name as an IPv6 routing protocol on the interface
Router(config)#ipv6 route {*dest-address/prefix*} [*exit-interface*] {*next-hop*}	Defines a static route to an IPv6 destination. Use an address/prefix of ::/0 for a default route
Router(config)#ipv6 router eigrp {*autonomous system-number*}	Defines EIGRP for IPv6 as an IPv6 routing protocol and enters configuration mode for that protocol
Router(config)#ipv6 router ospf {*process-number*}	Defines OSPFv3 as an IPv6 routing protocol and enters configuration mode for that protocol
Router(config)#ipv6 router rip *name*	Defines RIPng with the specified name as an IPv6 routing protocol and enters configuration mode for that protocol
Router(config)#ipv6 unicast-routing	Enables IPv6 routing
Router(config-rtr)#router-id	For OSPFv3, defines the OSPF router ID.
Router(config-rtr)#shutdown	Administratively shutdown a routing protocol (use "no shutdown" to bring the routing protocol up)

IP ACL Configuration Commands

Command	Meaning
Router(config-line)#access-class {*number* } in | out	Activates an ACL on a virtual terminal (VTY) line to restrict incoming or outgoing vty connections. NOTE: when used with "out", the address in the ACL is treated as a destination address
Router(config)#access-list {*number*} {permit |deny} {*source-ip*} [*wildcard-mask*]	Defines a standard ACL: • Number is in the range of 1-99, 1300-1999 • Wildcard mask allows a single line to match a range of IP addresses. Default wildcard mask is 0.0.0.0, which is an exact match of source IP address • The word "host" can be used before the address instead of putting a mask 0.0.0.0 after the address • A wildcard mask of 255.255.255.255 means match any IP address. The word "any" can be substituted for an address with a mask 255.255.255.255
Router(config)#access-list {*number*} {permit |deny} {*protocol*} {*source-ip*} {*wildcard-mask*} [{*operator source-port*}]{*dest-ip*} {*wildcard-mask*} [{*operator dest-port*}	Defines an extended ACL: • Number is in the range of 100 – 199, 2000 – 2699 • Protocol can be IP (which matches any protocol), ICMP, IGRP, EIGRP, OSPF, UDP, TCP, and others • Wildcard mask allows a single line to match a range of IP addresses • Port numbers are optional and can only be entered if the protocol is UDP or TCP. Port numbers are in the range of 1 – 65535 • With a protocol of ICMP, the port number becomes an ICMP type code • Operators are boolean: eq (equal), gt (greater than), lt (less than), neq (not equal), or range. • Wildcard mask of 0.0.0.0 is exact match of source IP address. The word "host" can be used before the address instead of putting a mask 0.0.0.0 after the address • A wildcard mask of 255.255.255.255 means match any IP address. The word "any" can be substituted for an address with a mask 255.255.255.255

Command	Meaning
Router(config)#ip access-list standard *name* Router(config-std-nacl)# [*seq-number*] {permit |deny} {*source-ip*} [*wildcard-mask*] Or Router(config)#ip access-list extended *name* Router(config-ext-nacl)# [*seq-number*] {*protocol*} {*source-ip*} {*wildcard-mask*} [{*operator source-port*}]{*dest-ip*} {*wildcard-mask*} [{*operator dest-port*}]	Defines a named ACL; same structure as standard or extended ACLs Seq-number defaults to 10 for the first line and increments by 10 by default
Router(config-if)#ip access-group {*number* | *name*} in | out	Activates an ACL on an interface; "in" or "out" specifies whether the traffic will be examined as it is coming in or going out of the interface respectively
Router(config)#ipv6 access-list standard {*name*} Or Router(config)#ipv6 access-list extended {*name*}	Defines an IPv6 named ACL; same structure as IPv4 standard or extended named ACLs

General Network Address Translation Commands

Command	Meaning
Router#debug ip nat	Starts the console display of every packet that the router translates with NAT or PAT
Router#show ip nat translations	Displays active translations
Router#show ip nat statistics	Displays translation statistics
Router#clear ip nat translation	Clears dynamic address translation entries. Use the "*" option to clear all entries.

Network Address Translation Configuration Commands

Command	Meaning
Router(config-if)#ip nat inside	Marks the interface as connected to the inside
Router(config-if)#ip nat outside	Marks the interface as connected to the outside
Router(config)#ip nat inside source static {*local-ip*} {*global-ip*}	Establishes a static translation between an inside local address and an inside global address
Router(config)#ip nat pool {*pool-name*} {*start-address*} {*end-address*} {netmask {*netmask*} | prefix-length {*prefix-length*}}	Defines a pool of global addresses to be allocated as needed
Router(config)#ip nat inside source list {*access-list-number*} pool {*name*}	Establishes dynamic source translation of addresses permitted by the ACL to addresses in the pool
Router(config)#ip nat source list {*access-list-number*} interface {*interface*} overload	Establishes dynamic source translation of addresses permitted by the ACL to the address of an interface; "overload" specifies that PAT is used

General DHCP Commands

Command	Meaning
Router#show dhcp lease	Displays DHCP addresses that are leased from a DHCP server
Router#show ip dhcp bindings	Displays DHCP IP-to-MAC address bindings
Router#show ip dhcp conflicts	Displays DHCP address conflicts
Router#show ip dhcp pool	Displays DHCP pool parameters

DHCP Configuration Commands

Command	Meaning
Router(dhcp-config)#default-router	Defines the DHCP pool default router
Router(dhcp-config)#dns-server	Defines the DHCP pool DNS server
Router(dhcp-config)#domain-name	Defines the DHCP pool domain name
Router(dhcp-config)#lease	Defines the DHCP pool lease in days
Router(config)#ip dhcp excluded-address	Defines the addresses that are to be excluded from DHCP pools
Router(config)#ip dhcp pool	Defines the DHCP pool name and enters DHCP configuration mode
Router(config-if)#ip helper-address	Enables forwarding of broadcasts that are received on the interface to the specified IP address.
Router(dhcp-config)#network	Defines the DHCP pool network number

General WAN Commands

Command	Meaning
Router#clear frame-relay inarp	Clears dynamically created Frame Relay maps, which are created by the use of Inverse ARP
Router#debug frame-relay lmi	Starts the console display of LMI packets between the router and the Frame Relay switch
Router#debug ppp authentication	Starts the console display of the PPP authentication – related events on the router
Router#debug ppp negotiation	Starts the console display of the PPP negotiation – related events on the router
Router#show frame-relay lmi	Displays the LMI traffic statistics
Router#show frame-relay map	Displays the mapping between network layer addresses and DLCIs, both static and dynamic
Router#show frame-relay pvc	Displays the status of each configured PVC as well as traffic statistics

WAN Configuration Commands

Command	Meaning
Router(config-if)#bandwidth	Defines the bandwidth (in kilobits per second) of the interface (used in routing protocol calculations)
Router(config-if)#encapsulation	Defines the data-link encapsulation for an interface (PPP, HLDC, frame-relay)
Router(config-subif)#frame-relay interface-dlci	Assigns a DLCI to the subinterface (only used on frame relay subinterfaces
Router(config-if)#frame-relay inverse-arp	Enables inverse ARP on an interface (only needed if it was disabled at some point, default is enabled)
Router(config-if)#frame-relay lmi-type	Defines the LMI format (to match the Frame Relay switch); router can autosense
Router(config-if)#frame-relay map	Defines how an interface (or subinterface) will reach a destination; maps destination protocol addresses to the local DLCI used to reach the destination; defines options including broadcast
Router(config-if)#ppp authentication	Sets password authentication on an interface, using CHAP or PAP. Specify both “chap” and “pap” if either would be acceptable.

Cisco ROMMON Commands

Notes:

- In each of the following tables, the commands are listed in alphabetical order.
- Most commands have many parameters. In the following tables only a few of the parameters are shown. Refer to Cisco's web site for the full command syntax.

Command	Meaning
rommon x>confreg	Sets the value of the configuration register
rommon x>reset	Resets the router

Windows Commands

Notes:

- In each of the following tables, the commands are listed in alphabetical order.
- Most commands have many parameters. In the following tables only a few of the parameters are shown. Refer to Microsoft's web site for the full command syntax.

Command	Meaning
arp -a	Displays the ARP table
ipconfig	Displays some of the current IP and IPv6 settings.
ipconfig /all	Displays all of the current IP and IPv6 settings.
ipconfig /release	Releases the current DHCP-learned address.
ipconfig /renew	Renews the DHCP-learned address.
netsh interface ipv6 show neighbors	Displays neighbor discovery table including mappings between IPv6 and MAC addresses.
ping *address*	Causes an ICMP echo message to be sent to the destination, which should cause an ICMP echo reply message to be returned.
ping *-t*	Causes continuous ICMP echo messages to be sent to the destination, which should cause ICMP echo reply messages to be returned.
route print	Displays the routing table.
tracert *address*	Displays the path of routes that a test packet traverses on the way to a destination address.

Cisco IOS Filenames and Packaging

Cisco IOS Filename Structure

Cisco IOS filenames are of the format: **c2900-universalk9-mz-SPA.152-4.M1.bin**

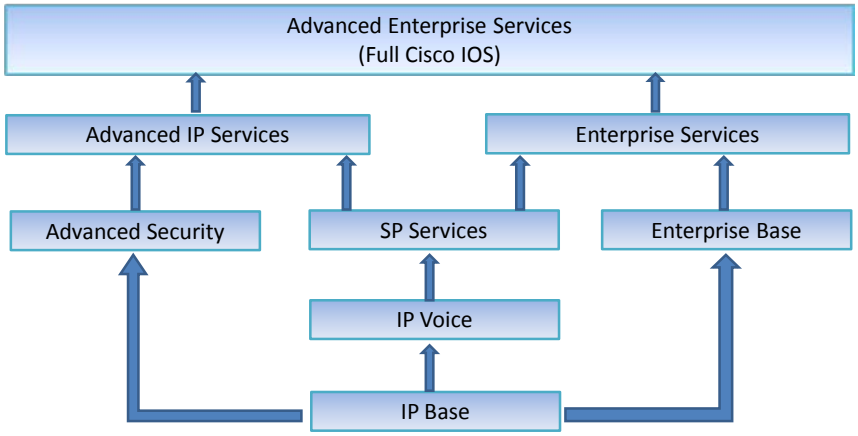
Platform: Cisco 2900 router
Feature Set: universal; includes all feature sets
Format: mz is run from RAM and compressed file
Version: major minor – revision; 152-4 is Major release 15, Minor release 2 revision 4M1
File extension: bin is binary

Feature Set Packaging starting in Cisco IOS 15.0

Starting in Cisco IOS version 15.0, there is one universal image. Multiple licenses can be installed and activated, depending on requirements.

Feature Set Packaging prior to Cisco IOS 15.0

In Cisco IOS versions prior to 15.0, there are eight packages to select from, depending on requirements:



Conclusion

This paper provides a review of the critical concepts related to the CCNA Routing and Switching exam, exam number 200-120. It is recommended that you use this paper as a review after your Global Knowledge Cisco Certified training. Global Knowledge courses related to the CCNA Routing and Switching exam include the following:

CCNAX v2.0 - CCNA Routing and Switching Boot Camp

ICND1 v2.0 - Interconnecting Cisco Networking Devices, Part 1

ICND2 v2.0 - Interconnecting Cisco Networking Devices, Part 2

Learn More

A follow-on certification to the CCNA Routing and Switching certification is CCNP Routing and Switching. Courses related to this certification are the following:

ROUTE - Implementing Cisco IP Routing v1.0

SWITCH - Implementing Cisco IP Switched Networks v1.0

TSHOOT - Troubleshooting and Maintaining Cisco IP Networks v1.0

Visit **www.globalknowledge.com** or call **1-800-COURSES (1-800-268-7737)** to speak with a Global Knowledge training advisor.

About the Author

Diane Teare is a professional in the networking, training, project management, and eLearning fields. She has more than 25 years of experience in designing, implementing, and troubleshooting network hardware and software, and has been involved in teaching, course design, and project management. Diane is the Course Director for CCNA and CCNP Routing and Switching courses with Global Knowledge, and teaches these and other Cisco and Project Management courses. She was the director of eLearning for Global Knowledge Canada, responsible for planning and supporting all the company's eLearning offerings in Canada, including Cisco courses. Diane is a professional engineer, and has a bachelor's degree in applied science in electrical engineering and a master's degree in applied science in management science. She currently holds her Cisco Certified Network Professional (CCNP), Cisco Certified Design Professional (CCDP), and Project Management Professional (PMP) certifications, and is a Cisco Certified Systems Instructor (CCSI). She authored or co-authored 10 Cisco Press titles; the latest of these is *Implementing Cisco IP Routing (ROUTE) Foundation Learning Guide*.