CCNA: Cisco Certified Network Associate Study Guide

Internet Protocols, Addressing, Subnets

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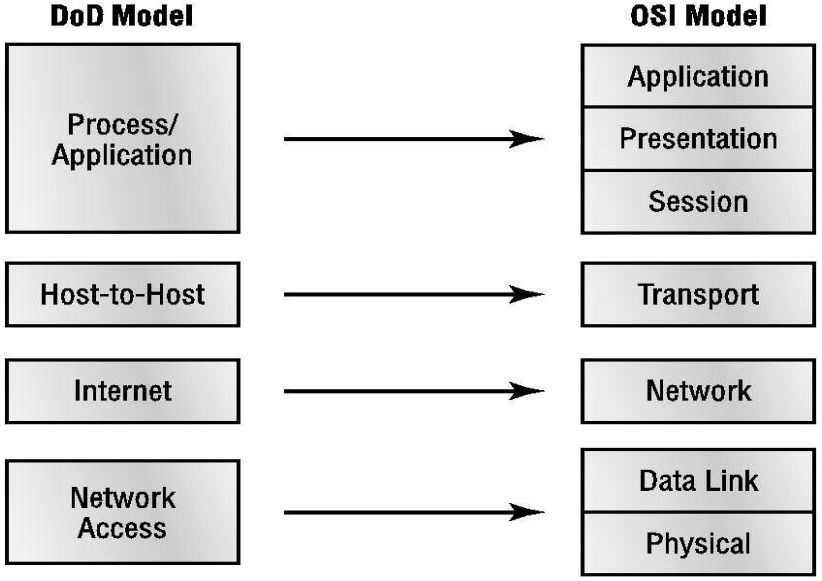
SYBEX

The CCNA exam topics covered in this chapter include the following:

Technology

- Evaluate TCP/IP communication processes and its associated protocols

TCP/IP and the DoD Model



The DoD model is basically a condensed version of the OSI model—it's composed of four, instead of seven, layers:

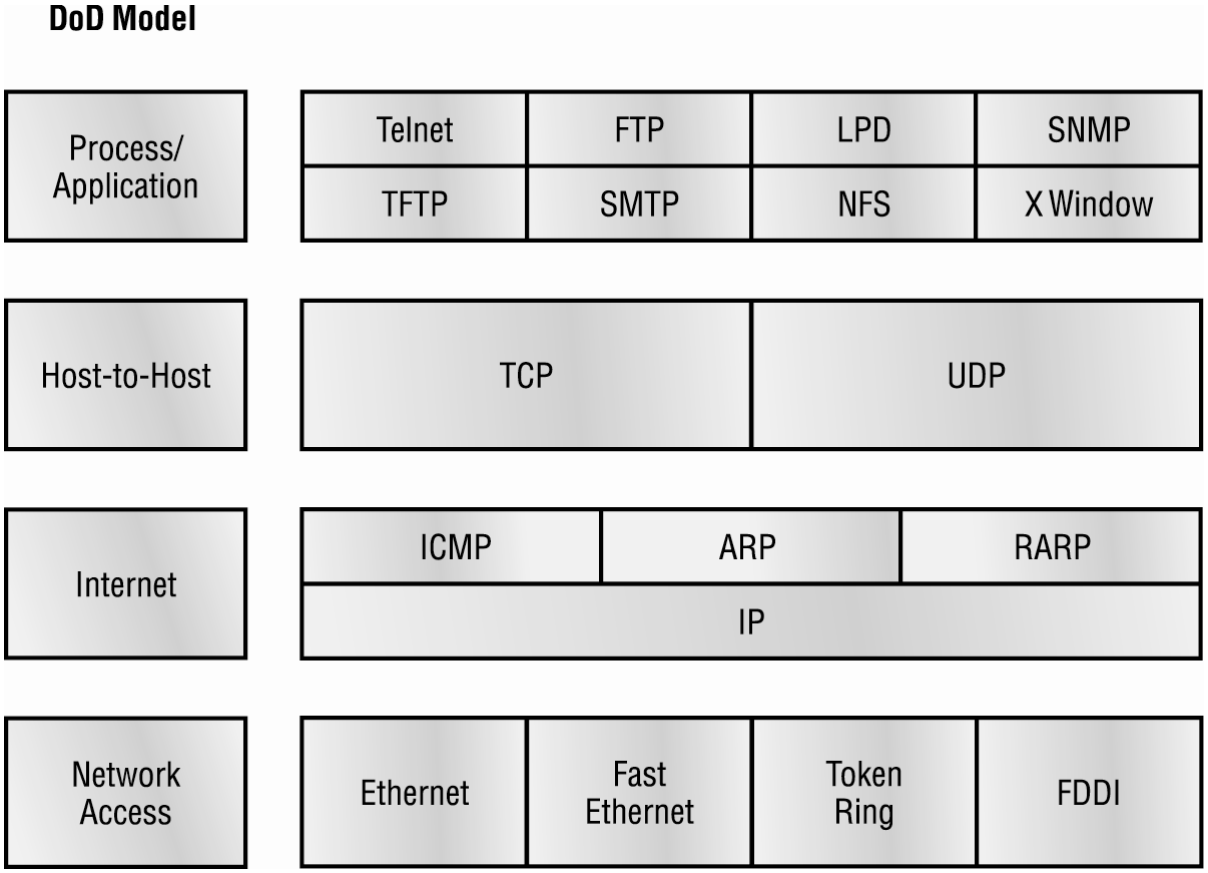
- Process/Application layer
- Host-to-Host layer
- Internet layer
- Network Access layer

A number of different models for TCP/IP protocol suite:

http://en.wikipedia.org/wiki/Internet_protocol_suite

TCP/IP and the DoD Model

The TCP/IP Protocol Suite



TCP/IP and the DoD Model

Internet Layer Protocols

- Internet Protocol (IP)
- Internet Control Message Protocol (ICMP)
- Address Resolution Protocol (ARP)
- Reverse Address Resolution Protocol (RARP)
- Proxy ARP

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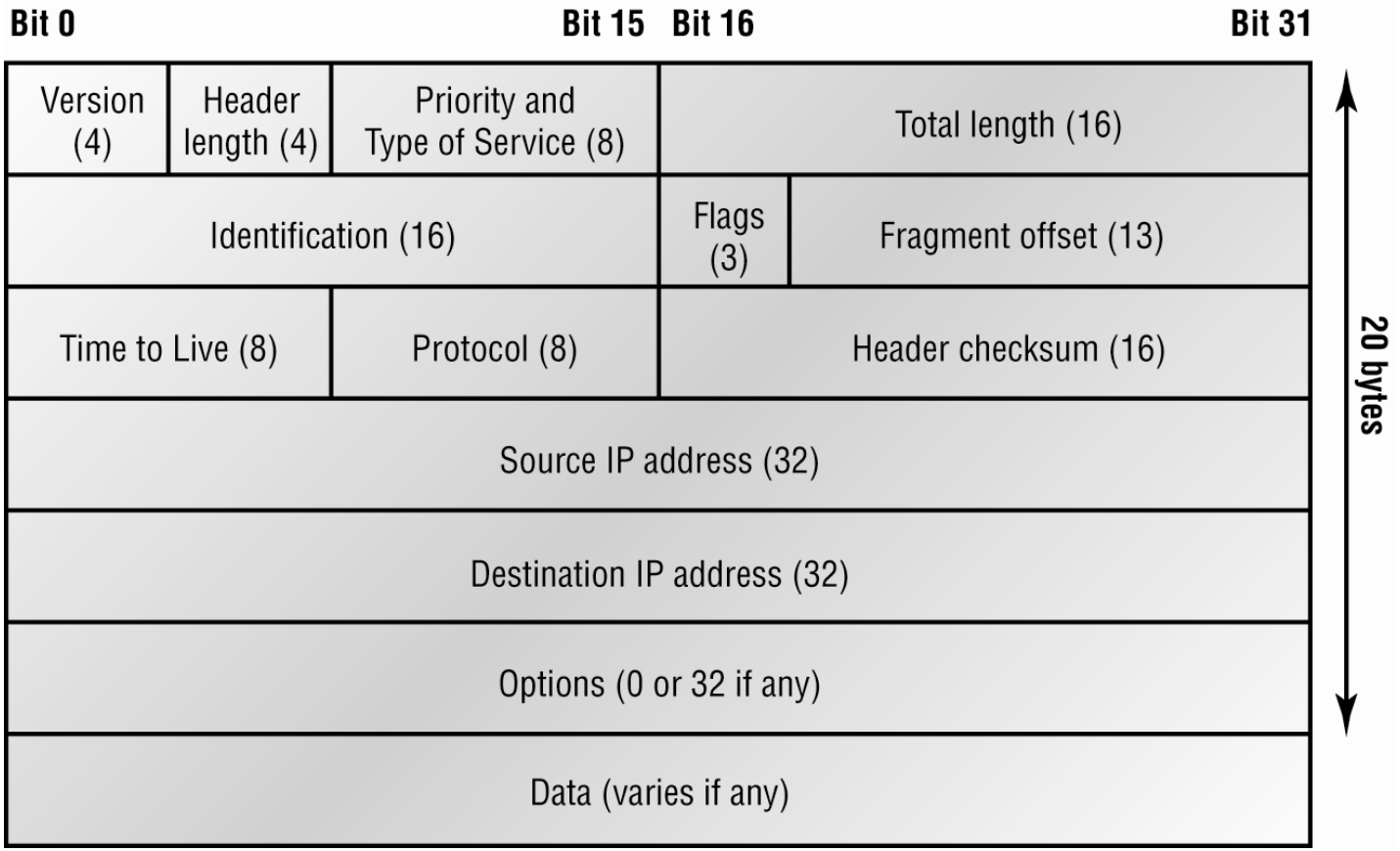
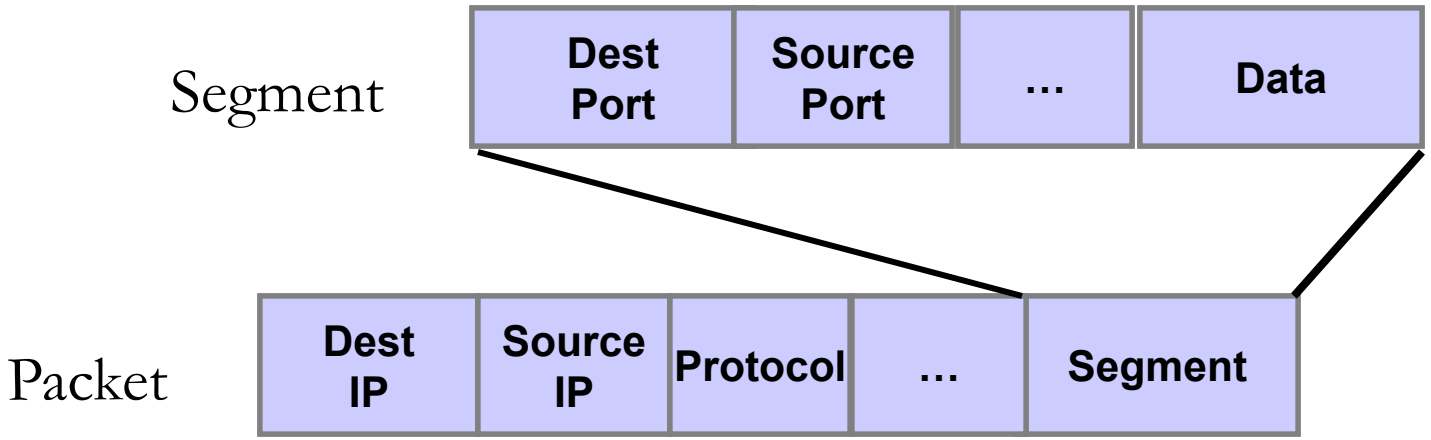
TCP/IP and the DoD Model

Internet Layer Protocols



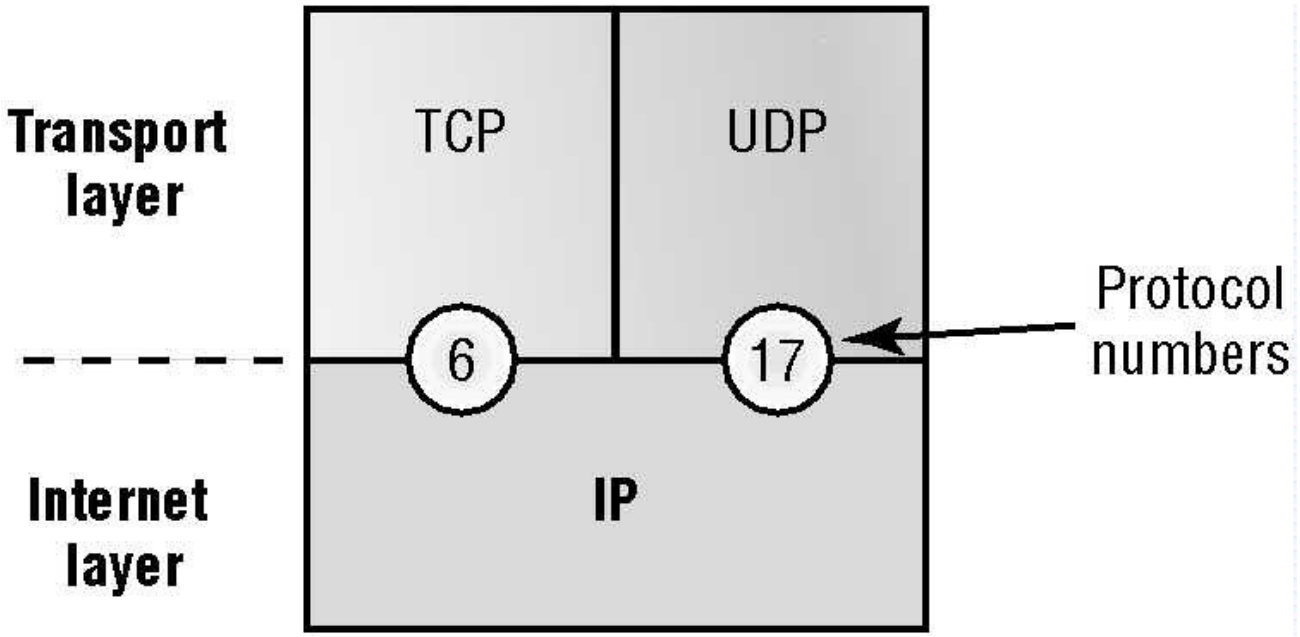
Internet Protocol (IP)

- Provides network addressing and routing through an internetwork
- Connectionless service



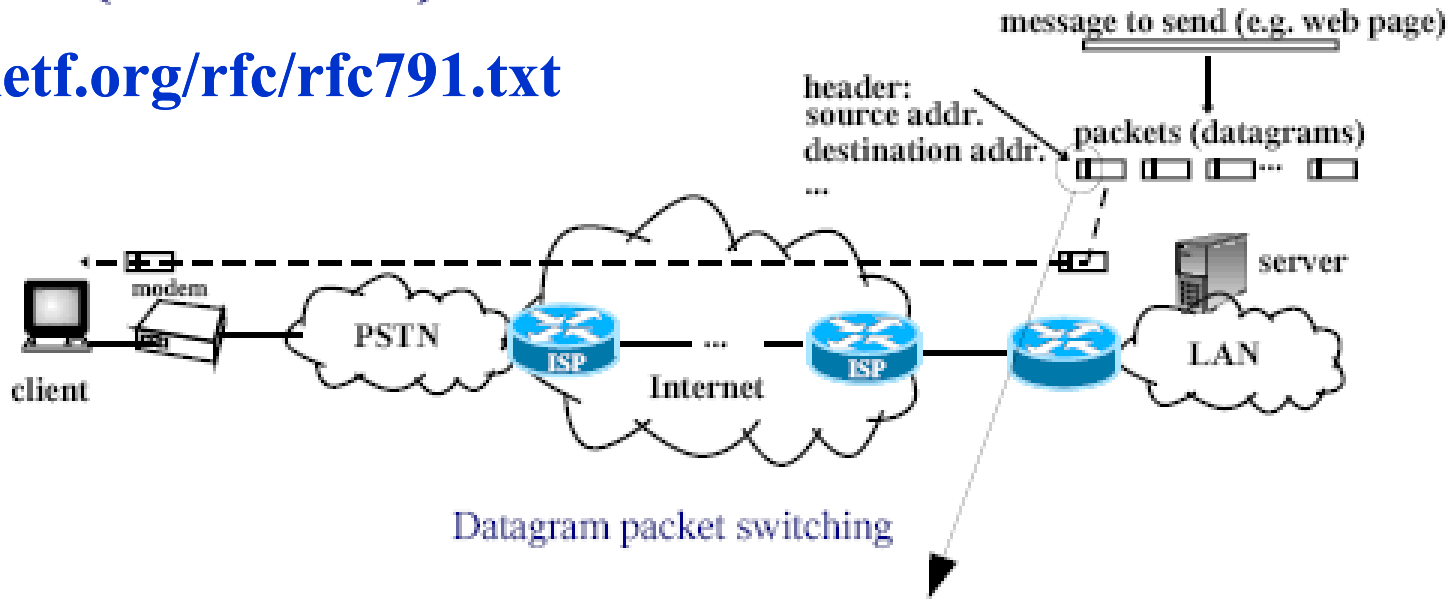
TCP/IP and the DoD Model

Internet Layer Protocols

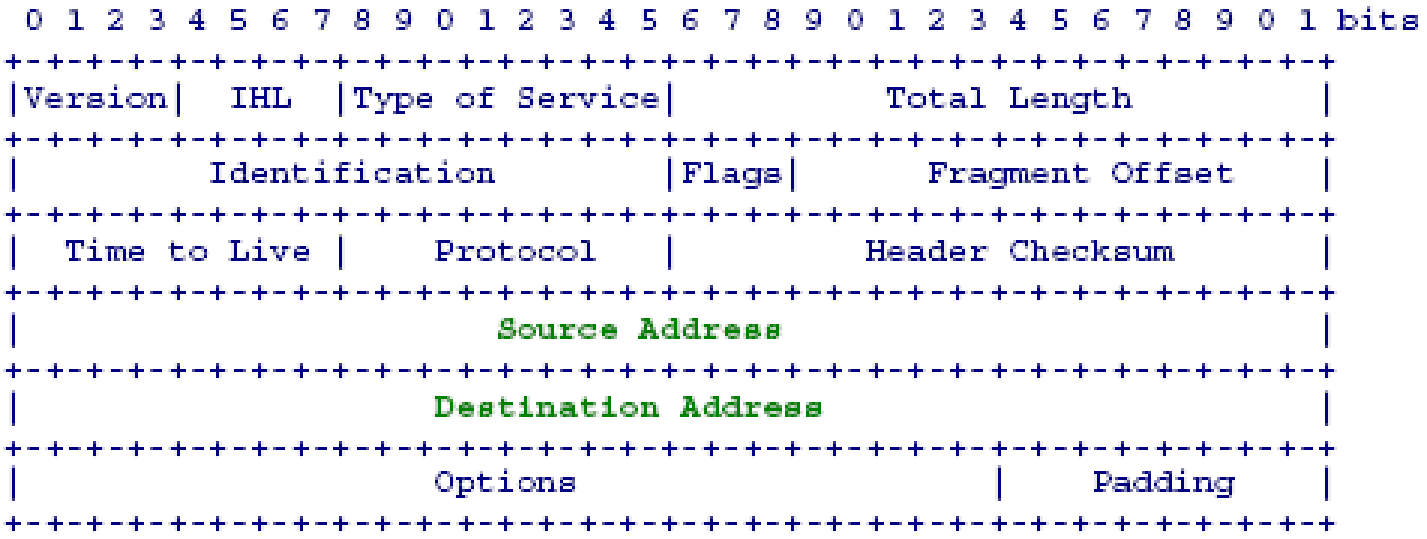


IP Addresses (RFC 791)

http://www.ietf.org/rfc/rfc791.txt

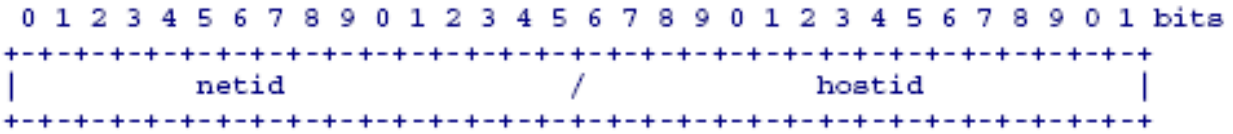


Datagram packet switching



IP datagram header

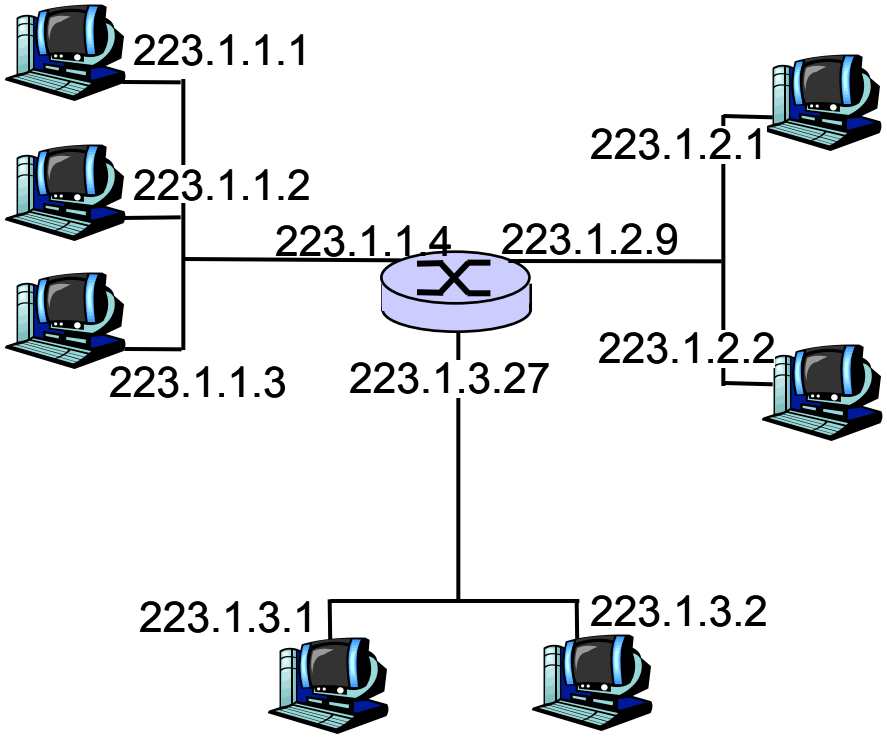
IP Addresses



- 32 bits (4 bytes).
- Dotted point notation: Four bytes in decimal, e.g. 147.83.24.28
- netid identifies the network.
- hostid identifies the host within the network.
- An IP address identifies an *interface*: an attachment point to the network
- All IP addresses in Internet must be different. To achieve this goal, Internet Assigned Numbers Authority, IANA (http://www.iana.net) assign address blocs to Regional Internet Registries, RIR:
  - RIPE: Europe, http://www.ripe.net.
  - ARIN: USA, http://www.arin.net.
  - APNIC: ASIA http://www.apnic.net.
  - LACNIC: Latin America, http://www.lacnic.net.
- RIR assign addresses to ISPs, and ISPs to their customers.

IP Addressing: introduction

- IP address: 32-bit identifier for host, router *interface*
- *interface:* connection between host/router and physical link
  - router's typically have multiple interfaces
  - host may have multiple interfaces
  - IP addresses associated with each interface



223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

IP Addressing

- Hierarchical Addressing Framework
- Network.node addressing, 32 bits (4-bytes)
- The Hierarchical advantage is increased ability of addresses

Binary to Decimal

The following table shows the decimal values of each bit location in a nibble and a byte. Remember, a nibble is 4 bits and a byte is 8 bits.

Nibble values	Byte values
8 4 2 1	128 64 32 16 8 4 2 1

What all this means is that if a one digit (1) is placed in a value spot, then the nibble or byte takes on that decimal value, and adds it to any other value spots that have a one. And if a zero (0) is placed in a bit spot, then you don't count that value.

SYBEX

Binary to Decimal Review

Converting binary to decimal examples:

128	64	32	16	8	4	2	1: Bit values
0	0	0	0	0	0	0	0 = 0
0	0	0	0	1	1	1	1 = 15
0	1	0	1	0	1	0	1 = 85
1	0	0	0	0	0	1	1 = 131
0	0	0	1	0	1	1	0 = 22
1	1	1	1	1	1	1	1 = 255

What is the hex equivalent of each binary number?

SYBEX

Binary (Cont.)

Bits	Binary	Decimal
0	00000000	0
1	10000000	128
2	11000000	192
3	11100000	224
4	11110000	240
5	11111000	248
6	11111100	252
7	11111110	254
8	11111111	255

IP Addressing

The Hierarchical IP Addressing Scheme

- Dotted-decimal, as in 172.163.30.56
- Binary, as in 10101100.00010000.00011110.00111000
- Hexadecimal, as in AC.10.1E.38

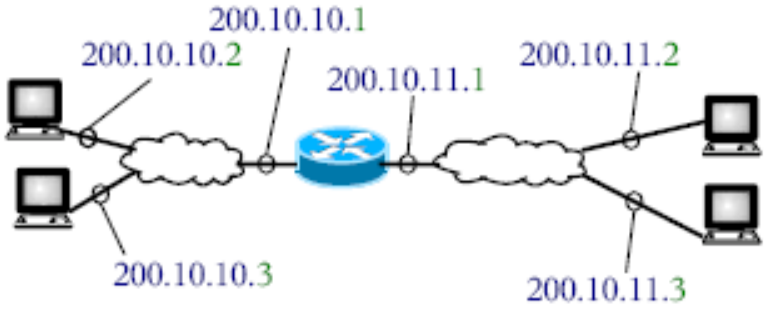
SYBEX

IP Addresses – Special Addresses

- Special addresses cannot be used for a physical interface.
- Each network has two special addresses: network and broadcast addresses.

netid	hostid	Meaning
xxx	all '0'	Identifies a network. It is used in routing tables.
xxx	all '1'	Broadcast in the net. xxx.
all '0'	all '0'	Identifies "this host" in "this net.". Used as source address in configuration protocols, e.g. DHCP.
all '1'	all '1'	broadcast in "this net.". Used as destination address in configuration protocols, e.g. DHCP.
127	xxx	loopback: interprocess communication with TCP/IP.

- Example:



IP Addressing [CISCO]

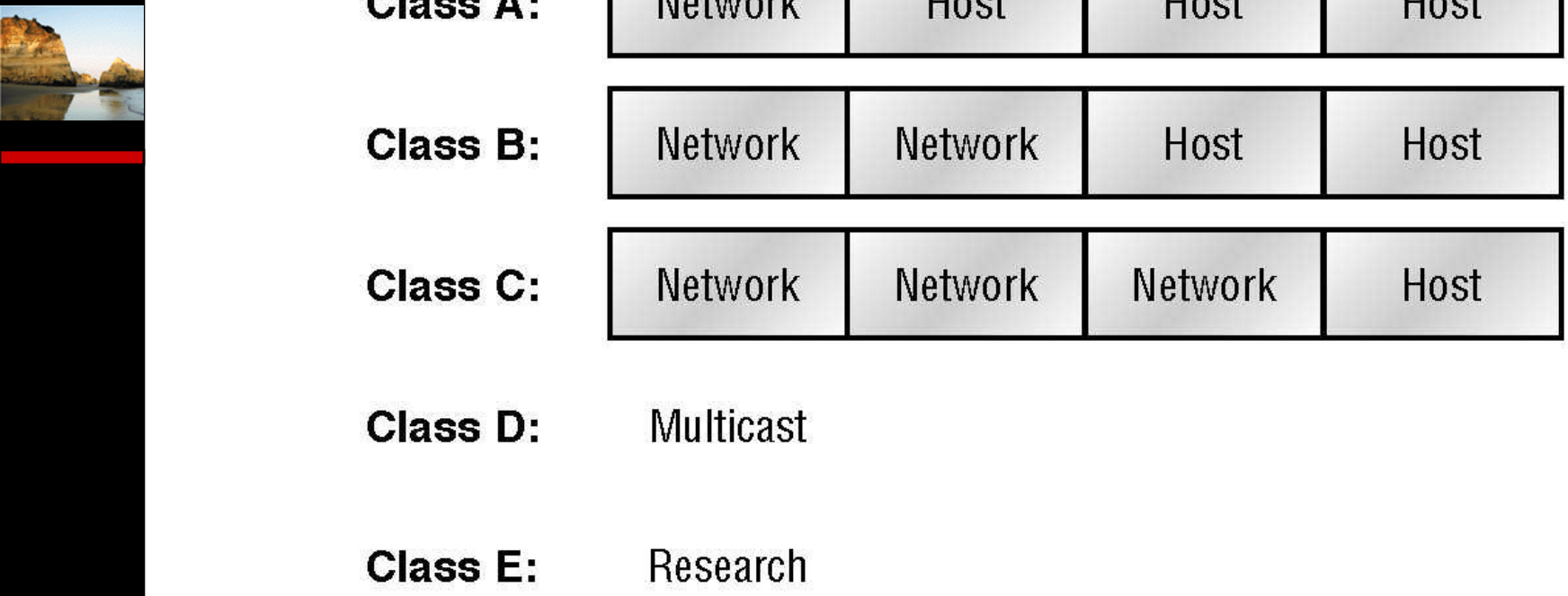
Reserved IP Addresses

Address	Function
Network address of all 0s	Interpreted to mean "this network or segment."
Network address of all 1s	Interpreted to mean "all networks."
Network 127.0.0.1	Reserved for loopback tests. Designates the local node and allows that node to send a test packet to itself without generating network traffic.
Node address of all 0s	Interpreted to mean "network address" or any host on specified network.
Node address of all 1s	Interpreted to mean "all nodes" on the specified network; for example, 128.2.255.255 means "all nodes" on network 128.2 (Class B address).
Entire IP address set to all 0s	Used by Cisco routers to designate the default route. Could also mean "any network."
Entire IP address set to all 1s (same as 255.255.255.255)	Broadcast to all nodes on the current network; sometimes called an "all 1s broadcast" or limited broadcast.

SYBEX

IP Addressing

Summary of the Three Classes of Networks



IP Addresses - Classes

- The highest bits identify the class.
- The size of netid/hostid varies in classes A/B/C.
- D Class is for multicast addresses (e.g. 224.0.0.2: "all routers")
- E Class are reserved addresses.

Classe	netid (bytes)	hostid (bytes)	Codification	range
A	1	3	0xxxx$\cdots$x	0.0.0.0 $\sim$ 127.255.255.255
B	2	2	10xxx$\cdots$x	128.0.0.0 $\sim$ 191.255.255.255
C	3	1	110xx$\cdots$x	192.0.0.0 $\sim$ 223.255.255.255
D	-	-	1110x$\cdots$x	224.0.0.0 $\sim$ 239.255.255.255
E	-	-	1111x$\cdots$x	240.0.0.0 $\sim$ 255.255.255.255

IP Addressing

Class A Addresses

- **Structure**
  - Network.*node.node.node*

- **Class A Valid Host IDs**
  - 10.*0.0.0* All host bits *off*
  - 10.*255.255.255* All host bits *on*
  - Valid hosts = 10.*0.0.1* - 10.*255.255.254*

    - 0's & 255s can be valid hosts but all hosts bits cannot all be off or on at the same time!
    - 2^{24}-2

SYBEX

IP Addressing

Class B Addresses

- **Structure**
  - Network.Network.*node.node*

- **Class B Valid Host IDs**
  - 172.16.*0.0* All host bits *off*
  - 172.16.*255.255* All host bits *on*
  - Valid hosts = 172.16.*0.1* - 172.16.*255.254*

    - 0's & 255s can be valid hosts but all hosts bits cannot all be off or on at the same time!
    - 2^{16}-2

IP Addressing

Class C Addresses

- **Structure**
  - Network.Network.Network.*node*

- **Class C Valid Host IDs**
  - 192.168.100.*0* All host bits *off*
  - 192.168.100.*255* All host bits *on*
  - Valid hosts = 192.168.100.*1* - 192.168.100.*254*

    - 0's & 255s can be valid hosts but all hosts bits cannot all be off or on at the same time!
    - 2^8-2

IP Addressing

Private IP Addresses

Address Class	Reserved address space
Class A	10.0.0.0 through 10.255.255.255
Class B	172.16.0.0 through 172.31.255.255
Class C	192.168.0.0 through 192.168.255.255

SYBEX

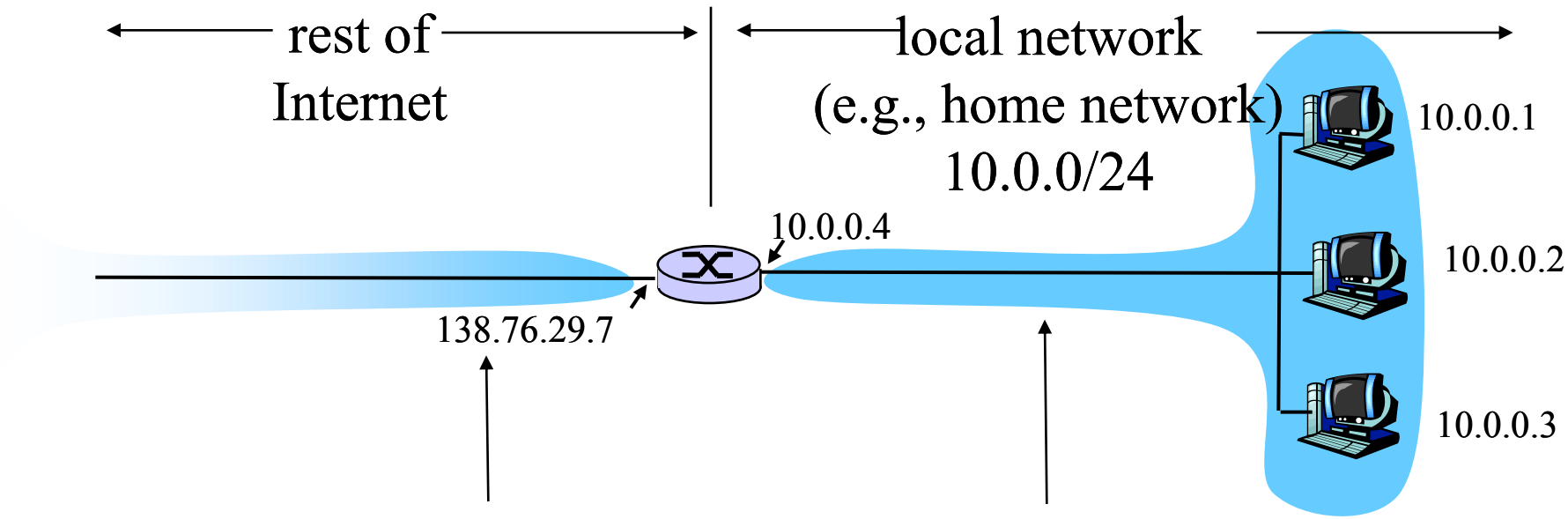
http://www.ietf.org/rfc/rfc1918.txt

IP Addresses – Private Addresses (RFC 1918)

- Most commercial OSs include the TCP/IP stack.
- TCP/IP is used to network many kind of electronic devices:

- Addresses assigned to RIR by IANA are called *public, global* or *registered.*
- What if we arbitrarily assign a registered address to a host:
  - It may be filtered by our ISP or cause trouble to the right host using that address.
- **Private addresses** has been reserved for devices not using public addresses. These addresses are not assigned to any RIR (are not unique). There are addresses in each class:
  - 1 class A network: 10.0.0.0
  - 16 class B networks: 172.16.0.0 ~ 172.31.0.0
  - 256 class C networks: 192.168.0.0 ~ 192.168.255.0

NAT: Network Address Translation



All datagrams *leaving* local network have same single source NAT IP address: 138.76.29.7, different source port numbers

Datagrams with source or destination in this network have 10.0.0/24 address for source, destination (as usual)

NAT: Network Address Translation

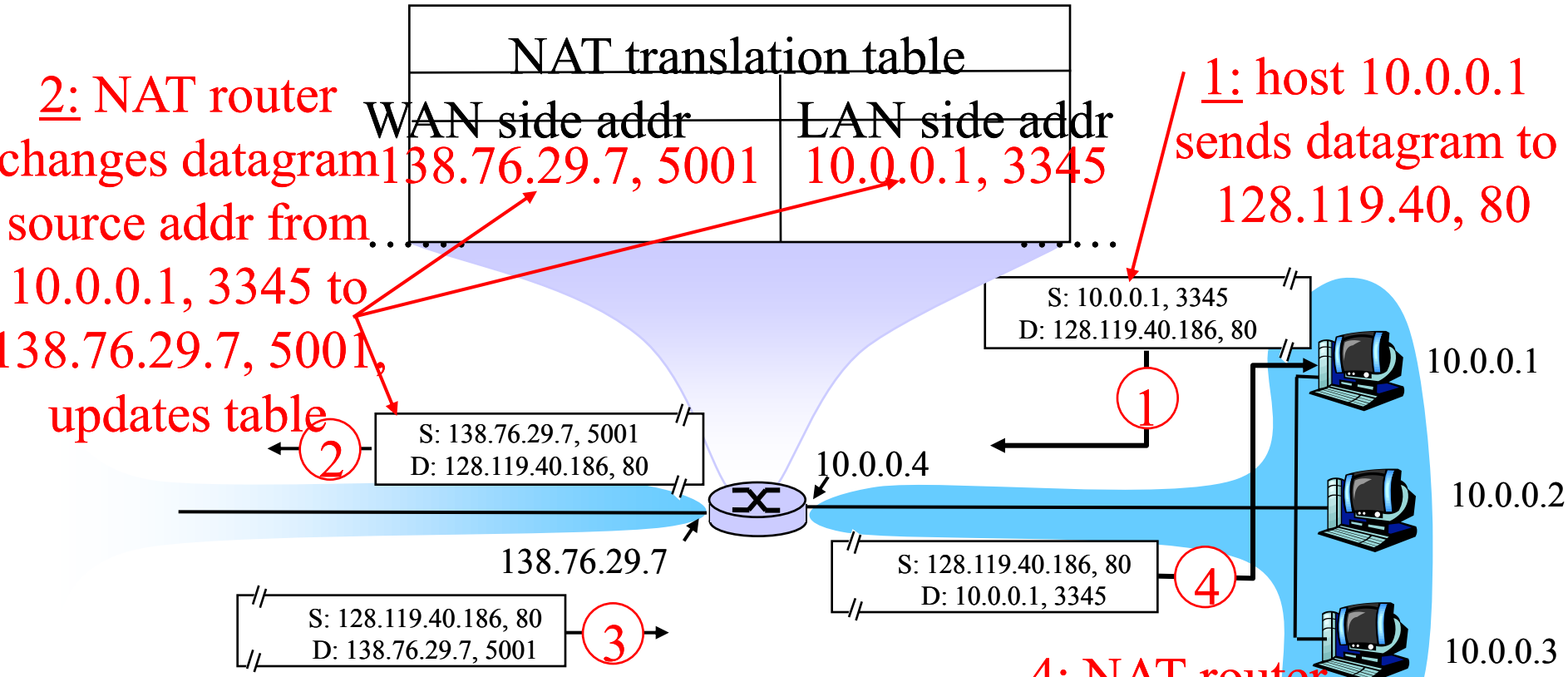
- Motivation: local network uses just one IP address as far as outside word is concerned:
  - no need to be allocated range of addresses from ISP: - just one IP address is used for all devices
  - can change addresses of devices in local network without notifying outside world
  - can change ISP without changing addresses of devices in local network
  - devices inside local net not explicitly addressable, visible by outside world (a security plus).

NAT: Network Address Translation

Implementation: NAT router must:

- *outgoing datagrams: replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)
  - . . . remote clients/servers will respond using (NAT IP address, new port #) as destination addr.
- *remember (in NAT translation table)* every (source IP address, port #) to (NAT IP address, new port #) translation pair
- *incoming datagrams: replace* (NAT IP address, new port #) in dest fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table

NAT: Network Address Translation



Broadcast Addresses

- Layer 2 Broadcasts—These are sent to all nodes on a Lan
- Broadcasts (layer 3)—These are sent to all notes on the network
- Unicast—These are sent to a single destination host
- Multicast—These are packets sent from a single source, and transmitted to many devices on different networks

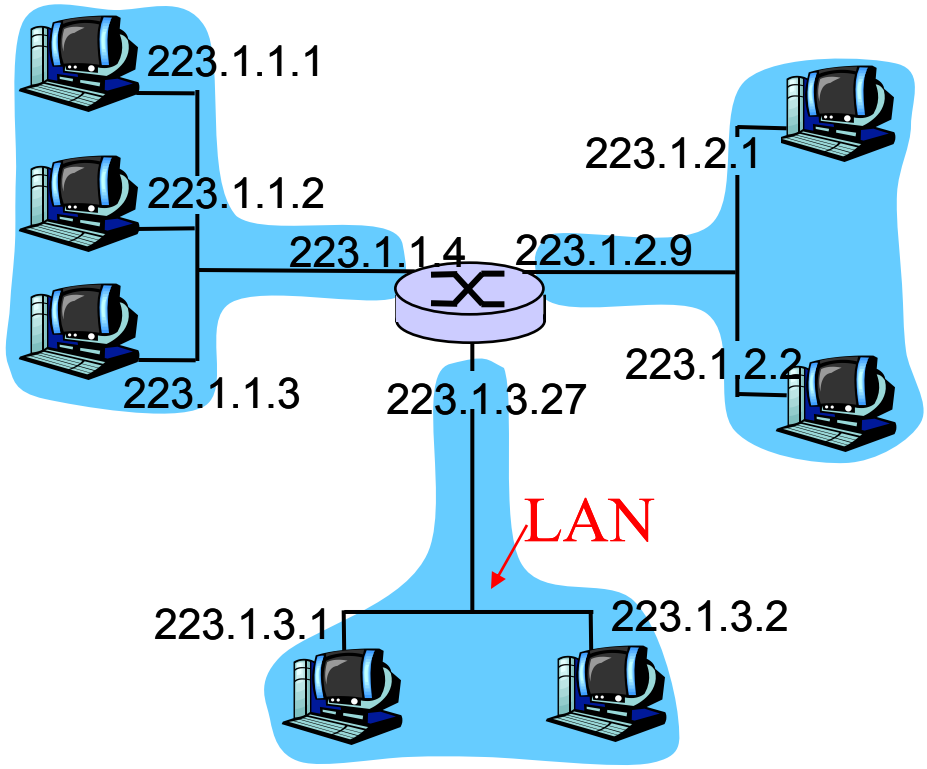
SYBEX

Subnetting Basics

- **Benefits of subnetting include:**
  - Reduced network traffic
  - Optimized network performance
  - Simplified management
  - Facilitated spanning of large geographical distances.

Subnets

- IP address:
  - subnet part (high order bits)
  - host part (low order bits)
- *What's a subnet ?*
  - device interfaces with same subnet part of IP address
  - can physically reach each other without intervening router

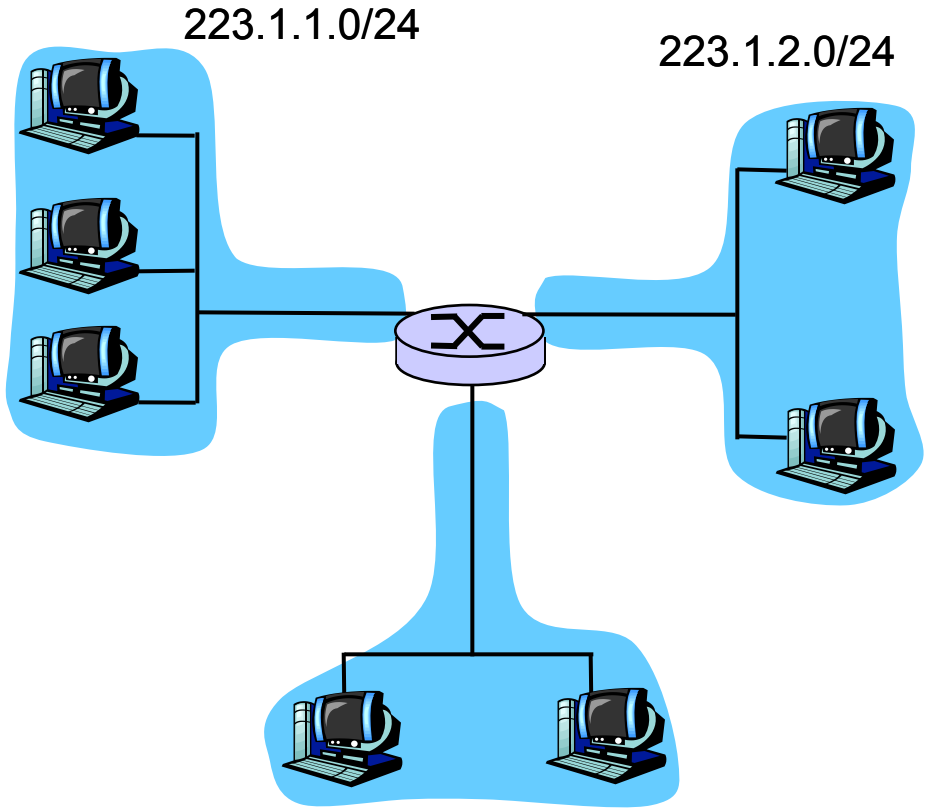


network consisting of 3 subnets

Subnets

Recipe

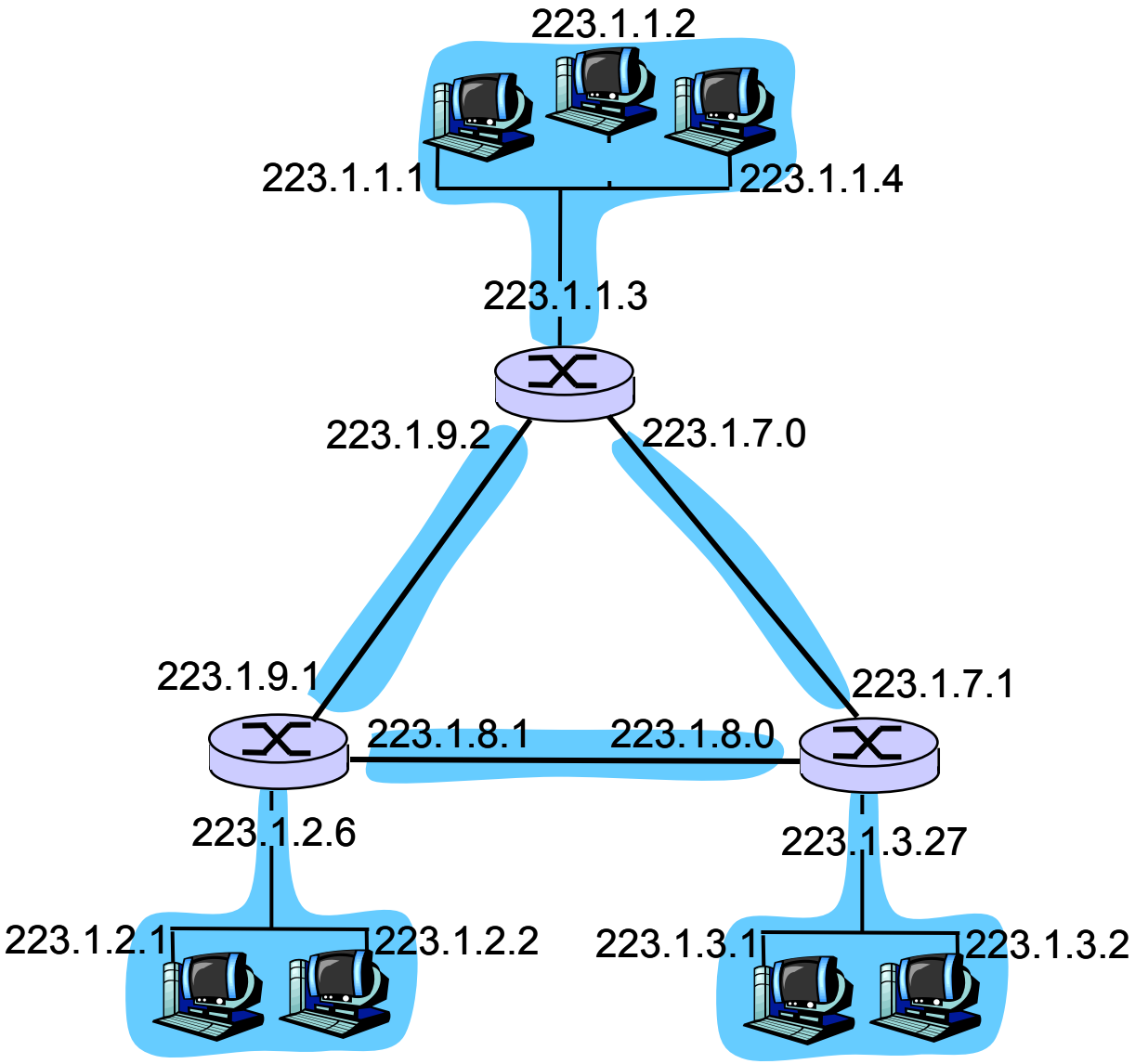
- To determine the subnets, detach each interface from its host or router, creating islands of isolated networks. Each isolated network is called a subnet.



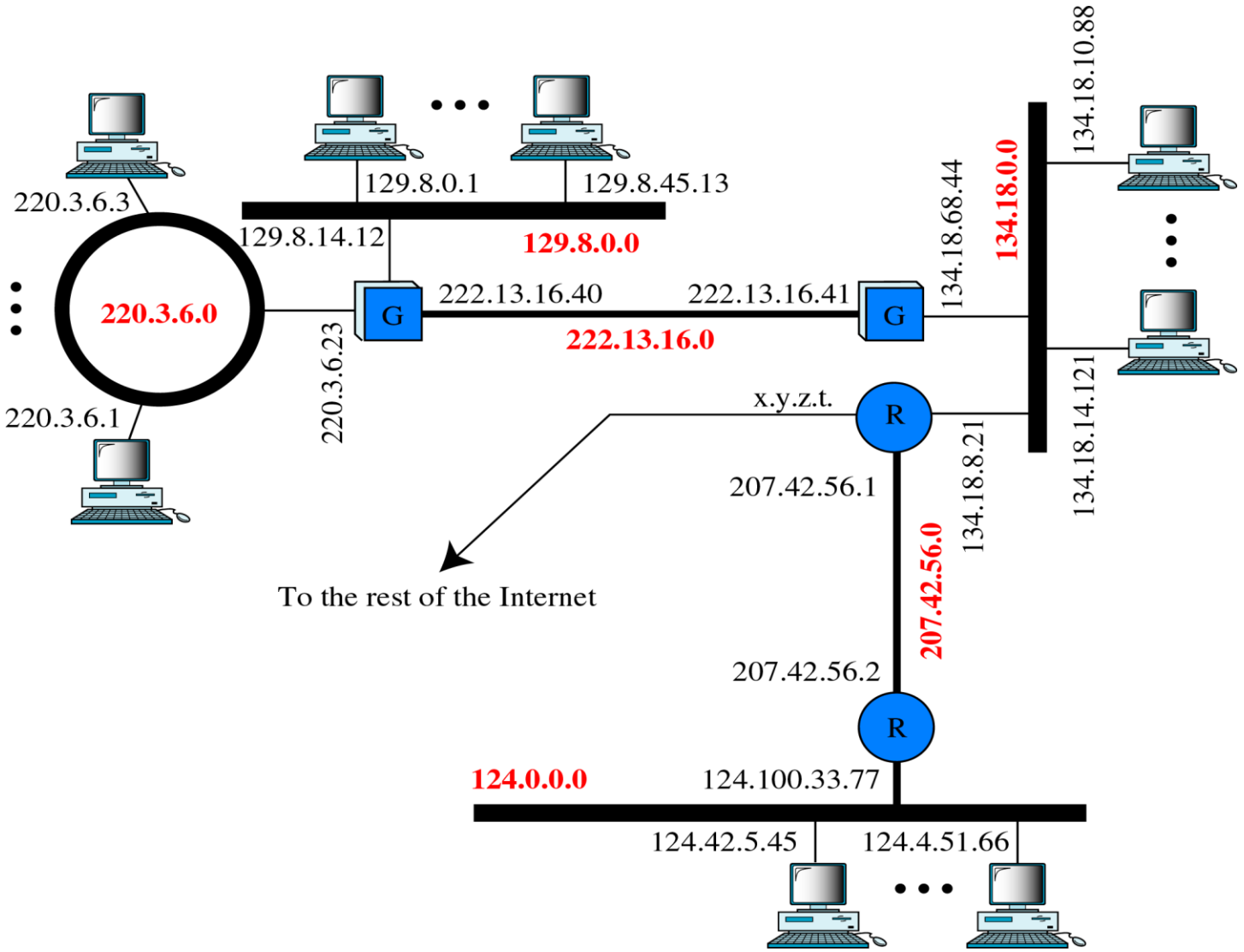
Subnet mask: /24

Subnets

How many?



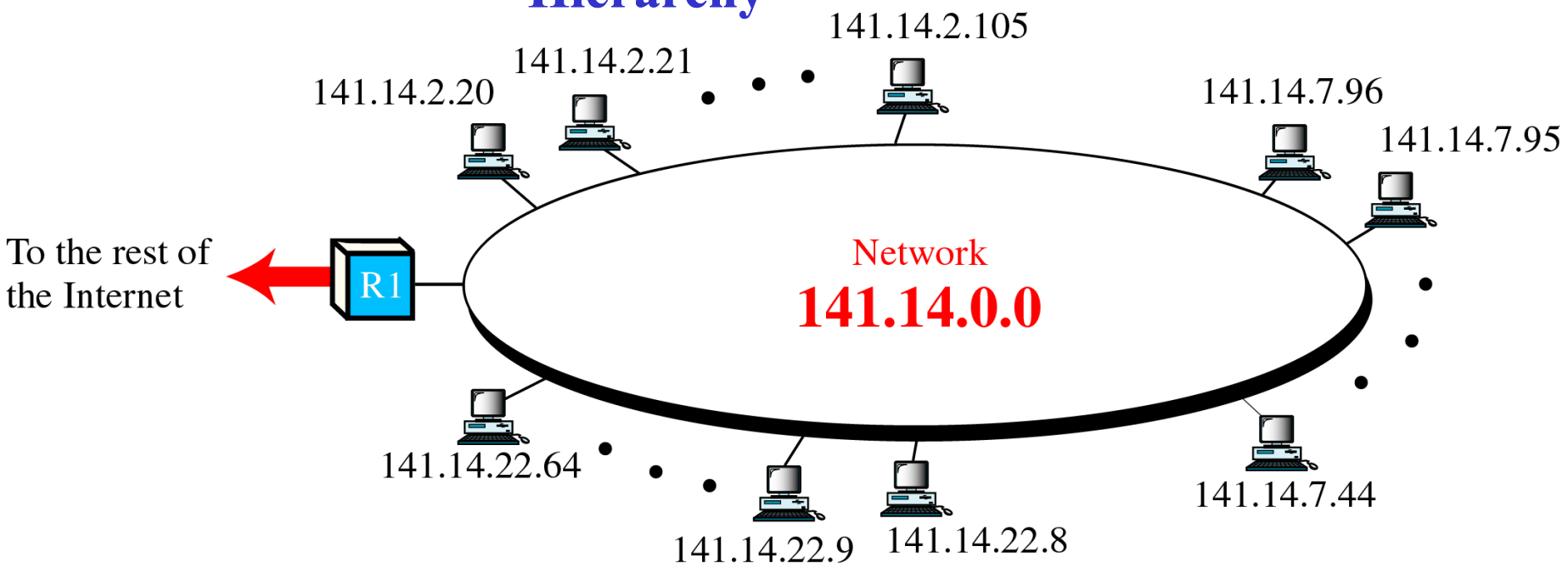
A Sample Internet



- An internet address specifies both the network to which a host belongs (netid) and the host itself (hostid).
- The figure shows a portion of the Internet made up of LANs (3 Ethernet and a Token Ring)
- Routers are indicated by circles containing Rs.
- Gateways are indicated by boxes containing Gs. Each has a separate address for each of its connected networks.
- The figure also shows the network addresses in color.
- A network address is the netid with the hostid part set to 0s.
- The network addresses in the figure are
  - 129.8.0.0 (B)
  - 124.0.0.0 (A)
  - 134.18.0.0 (B)
  - 220.3.6.0 (C)

Subneting

A Network with Two Levels of Hierarchy

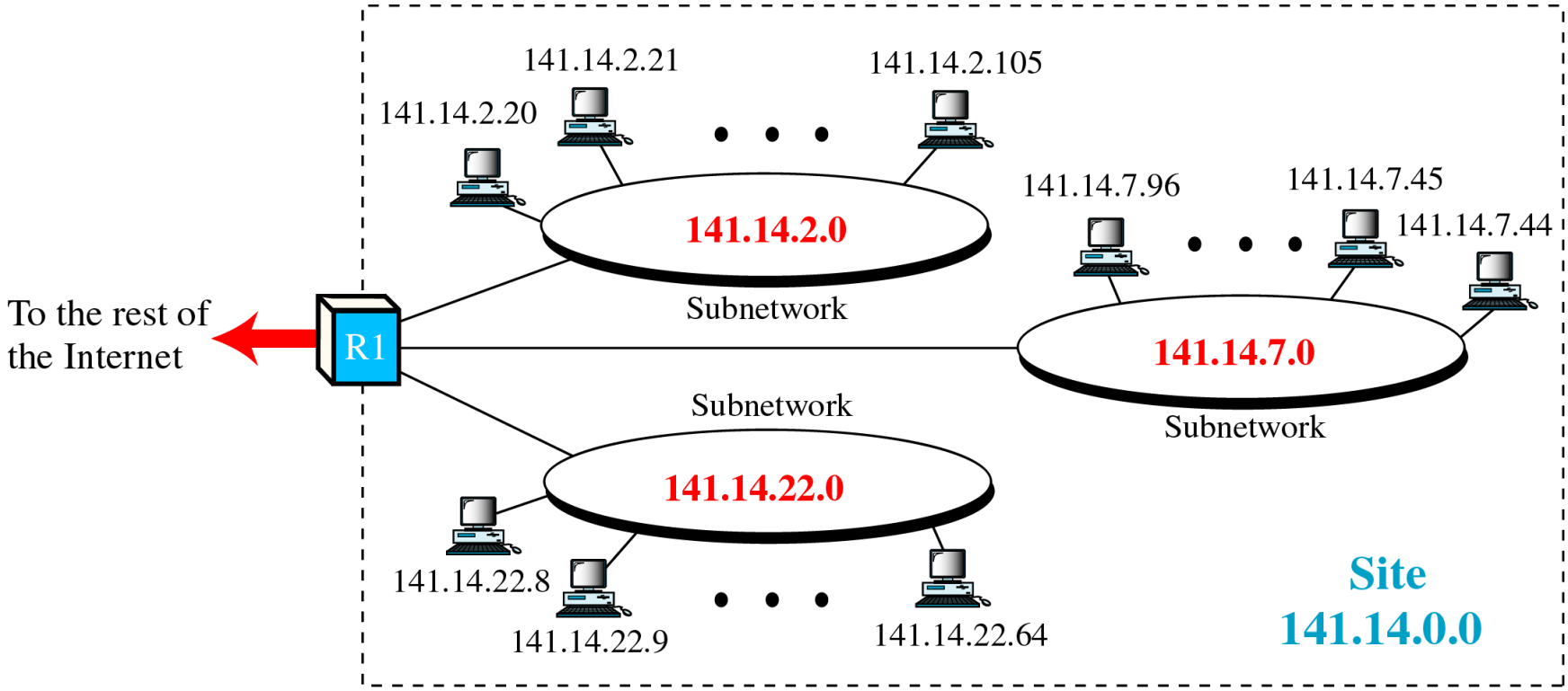


Subneting

- Without subnetting, IP address with 2-level of hierarchy (consist of netid and hostid) is not enuff
- Consider the org. which has 2-level of hierarchy cannot have more than one physical network
- With this scheme, the org. is limited to two levels of hierarchy. The hosts cannot be organized into groups, and all of the hosts are at the same level. The org. has one network with many hosts.
- One solution to this problem is **subnetting**, the further division of a network into smaller networks called subnetworks. It shows a network which is divided into 3-subnetworks.

Subneting

A Network with Three Levels of Hierarchy



- The rest of the Internet is not aware that the network is divided into 3 physical subnetworks: the three subnetworks still appear as a single network to the rest of Internet. E.g. A packet destined for host 141.14.2.21 still reaches router R1. The destination address of the IP datagram is still a class B address
- When the packet arrives at router R1, the interpretation of the IP address changes
  - R1 knows the network 141.12 is physically divided into three subnetworks
  - Two last octets define two things:
    - subnetid (2) and hostid (21)

How To Create Subnets

Take bits from the host portion of the IP address and reserve the to divine the subnet address.

1. Determine the number of required network IDs:
   - One for each subnet
   - One for each wide area network connection
2. Determine the number of required host IDs per subnet:
   - One for each TCP/IP host
   - One for each router interface
3. Based on the above requirement, create the following:
   - One subnet mask for your entire network
   - A unique subnet ID for each physical segment
   - A range of host IDs for each subnet

SYBEX

Understanding the Powers of 2

Understanding the Powers of 2

Powers of 2 are important to understand and memorize for use with IP subnetting. To review powers of 2, remember that when you see a number with another number to its upper right (called an exponent), this means you should multiply the number by itself as many times as the upper number specifies. For example, 2^3 is $2 \times 2 \times 2$, which equals 8. Here's a list of powers of 2 you should commit to memory:

$2^1 = 2$	$2^3 = 8$	$2^5 = 32$	$2^7 = 128$
$2^2 = 4$	$2^4 = 16$	$2^6 = 64$	$2^8 = 256$

Subnet Masks

- Used to define which part of the host address will be used as the subnet address.
- A 32-bit value that allows the recipient of IP packets to distinguish the network ID portion of the IP address from the host ID portion.

Default Subnet Masks

Class	Format	Default Subnet Mask
A	*network.node.node.node*	255.0.0.0
B	*network.network.node.node*	255.255.0.0
C	*network.network.network.node*	255.255.255.0

Classless Inter-Domain Routing (CIDR)

Used to allocate an amount of IP address space to a given entity (company, home, customer, etc).

Example: 192.168.10.32/28

The slash notation (/) means how many bits are turned on (1s) and tells you what your subnet mask is.

http://www.ietf.org/rfc/rfc1519.txt

IP Addresses – Classless Inter-Domain Routing, CIDR (RFC 1519)

- Initially, Internet backbone routing tables did not use masks: netid was derived from the IP address class.
- When the number of networks in Internet started growing exponentially, routing tables size started exploding.
- In order to reduce routing tables size, CIDR proposed a "rational" geographical-based distribution of IP addresses to be able to "summarize routes", and use masks instead of classes.
- Summarization example:

200.1.10.0/24
200.1.11.0/24 → 200.1.10.0/23

CIDR Values

Subnet Mask	CIDR Value
255.0.0.0	/8
255.128.0.0	/9
255.192.0.0	/10
255.224.0.0	/11
255.240.0.0	/12
255.248.0.0	/13
255.252.0.0	/14
255.254.0.0	/15
255.255.0.0	/16
255.255.128.0	/17
255.255.192.0	/18
255.255.224.0	/19
255.255.240.0	/20
255.255.248.0	/21

Subnet Mask	CIDR Value
255.255.252.0	/22
255.255.254.0	/23
255.255.255.0	/24
255.255.255.128	/25
255.255.255.192	/26
255.255.255.224	/27
255.255.255.240	/28
255.255.255.248	/29
255.255.255.252	/30

Subnetting Class C Addresses

In a Class C address, only 8 bits are available for defining the hosts. Remember that subnet bits start at the left and go to the right, without skipping bits. This means that the only Class C subnet masks can be the following:

Binary	Decimal	CIDR
10000000	= 128	/25
11000000	= 192	/26
11100000	= 224	/27
11110000	= 240	/28
11111000	= 248	/29
11111100	= 252	/30

Class C 192 mask examples

Subnet	Host	Meaning
00	000000 = 0	The network (do this first)
00	000001 = 1	The first valid host
00	111110 = 62	The last valid host
00	111111 = 63	The broadcast address (do this second)

Subnet	Host	Meaning
01	000000 = 64	The network
01	000001 = 65	The first valid host
01	111110 = 126	The last valid host
01	111111 = 127	The broadcast address

Class C 192 mask examples

Subnet	Host	Meaning
10	000000 = 128	The subnet address
10	000001 = 129	The first valid host
10	111110 = 190	The last valid host
10	111111 = 191	The broadcast address

Subnet	Host	Meaning
11	000000 = 192	The subnet address
11	000001 = 193	The first valid host
11	111110 = 254	The last valid host
11	111111 = 255	The broadcast address

Subnetting Class C Addresses – Fast Method

Answer Five Simple Questions:

- How many subnets does the chosen subnet mask produce?
- How many valid hosts per subnet are available?
- What are the valid subnets?
- What's the broadcast address of each subnet?
- What are the valid hosts in each subnet?

SYBEX

How Many Subnets?

2^X = number of subnets.

- X is the number of masked bits, or the 1s.
- For example, in 11000000, the number of ones gives us 2^2 subnets. In this example there are 4 subnets.

How Many Hosts Per Subnet?

2^y-2 = number of hosts per subnet.

- Y is the number of unmasked bits, or the 0s.
- For example, in 11000000, the number of zeros gives us 2^6-2 hosts. In this example, there are 62 hosts per subnet.

SYBEX

What Are The Valid Subnets?

- **256-subnet mask = block size, or base number.**
- **For example 256-192=64. 64 is the first subnet. The next subnet would be the base number plus itself or 64+64=128, (the second subnet).**
  - 64:subnet-01
  - 128: subnet-10,
  - 192: subnet-11,
  - 00: subnet-00

What's The Broadcast Address For Each Subnet?

- The broadcast address is all host bits turned on, which is the number immediately preceding the next subnet.

What Are The Valid Hosts?

- Valid hosts are the number between the subnets, omitting all 0s and all 1s.

Quiz_01

How many hosts and subnets are possible if you have an IP class B of 172.16.0.0/16 with a subnet mask of 255.255.254.0?

- A. 510 subnets and 126 hosts
- B. 512 subnets and 128 hosts
- C. 126 subnets and 512 hosts
- D. 128 subnets and 510 hosts

SYBEX

Quiz_01_answer

How many hosts and subnets are possible if you have an IP class B of 172.16.0.0/16 with a subnet mask of 255.255.254.0?

- A. 510 subnets and 126 hosts
- B. 512 subnets and 128 hosts
- C. 126 subnets and 512 hosts
- D. 128 subnets and 510 hosts

- **Answer: D**

Quiz_02

If a host on a network has the address 172.16.45.14/30, what is the address of the subnetwork to which this host belongs?

- A. 172.16.45.0
- B. 172.16.45.4
- C. 172.16.45.8
- D. 172.16.45.12
- E. 172.16.45.18

Quiz_02_answer

If a host on a network has the address 172.16.45.14/30, what is the address of the sub-network to which this host belongs?

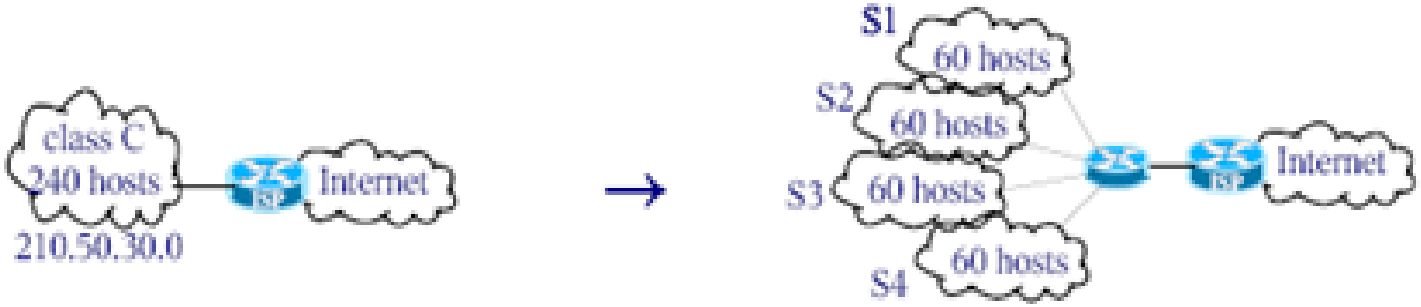
- A. 172.16.45.0
- B. 172.16.45.4
- C. 172.16.45.8
- D. 172.16.45.12
- E. 172.16.45.18

- **Answer: D**
  - The last octet in binary form is 00001110. Only 6 bits of this octet belong to the subnet mask. Hence, the sub-network is 172.16.45.12.

Quiz_03

IP Addresses – Subnetting Example

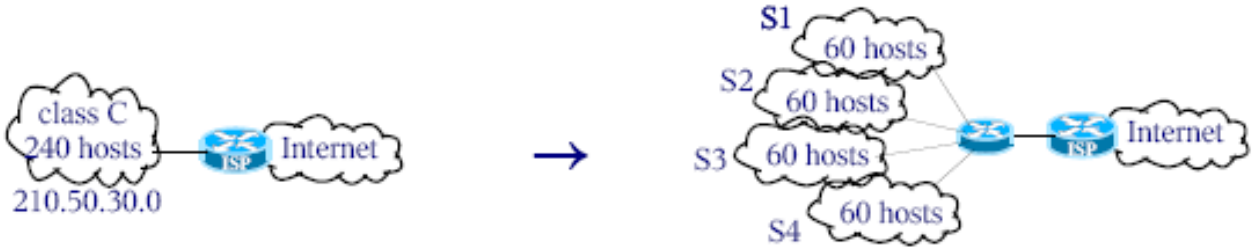
- We want to subnet the address 210.50.30.0/24 in 4 subnets



Quiz_03_answer

IP Addresses – Subnetting Example

- We want to subnet the address 210.50.30.0/24 in 4 subnets



B = 210.50.30

subnet	subnetid	IP net. addr.	range	broadcast	available
S1	00	B.0/26	B.0 ~ B.63	B.63	$2^6 - 2 = 62$
S2	01	B.64/26	B.64 ~ B.127	B.127	$2^6 - 2 = 62$
S3	10	B.128/26	B.128 ~ B.191	B.191	$2^6 - 2 = 62$
S4	11	B.192/26	B.192 ~ B.255	B.255	$2^6 - 2 = 62$

IP addressing demo

- **Windows**
  - ipconfig, route, etc
- **Linux**
  - ifconfig, route, etc
- **Packet sniffer and protocol analyzer**
  - wireshark

SYBEX

IP addressing: the last word...

Q: How does an ISP get block of addresses?

A: ICANN: Internet Corporation for Assigned Names and Numbers

- allocates addresses
- manages DNS
- assigns domain names, resolves disputes

- More Information
  - Cisco CCNA: Internet Protocols, Addressing, and Subnets

IP addresses: how to get one?

Q: How does *host* get IP address?

- hard-coded by system admin in a file
  - Wintel: control-panel->network->configuration->tcp/ip->properties
  - Linux/Unix:
    - /etc/rc.config
    - /etc/sysconfig/network-scripts/ifcfg-ethx
    - ifconfig
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "plug-and-play"

IP addresses: how to get one?

Q: How does *network* get subnet part of IP addr?

A: gets allocated portion of its provider ISP's address space

ISP's block	11001000 00010111 00010000	00000000	200.23.16.0/20
Organization 0	11001000 00010111 00010000	00000000	200.23.16.0/23
Organization 1	11001000 00010111 00010010	00000000	200.23.18.0/23
Organization 2	11001000 00010111 00010100	00000000	200.23.20.0/23
...	.....	....	....
Organization 7	11001000 00010111 00011110	00000000	200.23.30.0/23