COMP 204 – Principles of Computer Networks

Week 4

FRANKLIN UNIVERSITY

Agenda

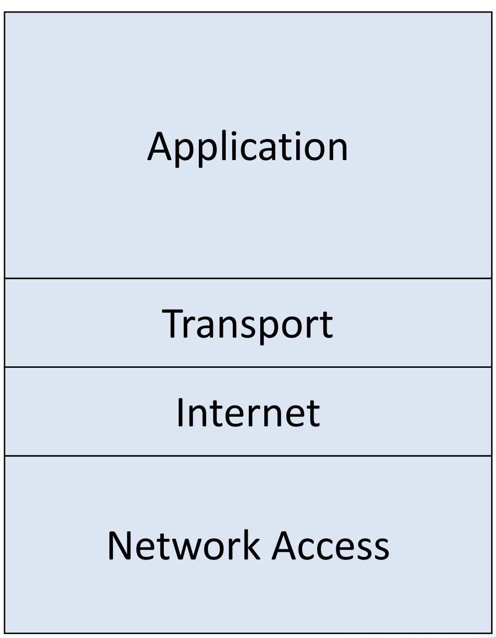
- Review this week's learning outcomes
- Presentation of this week's material
- Introduce homework problems
- Q & A session

FRANKLIN UNIVERSITY

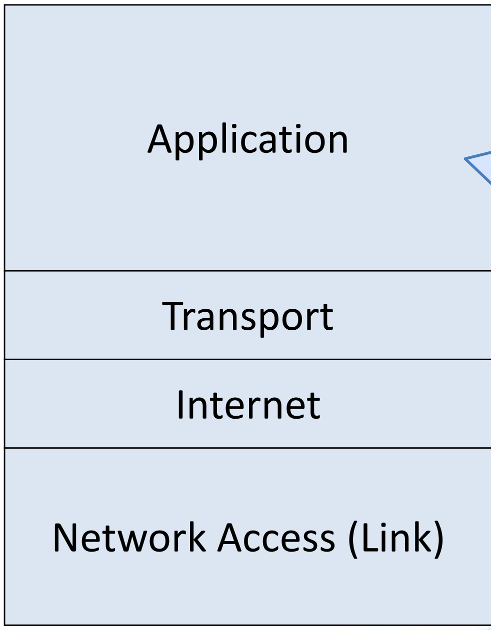
This Week's Outcomes

- Convert binary to decimal and decimal to binary to understand subnet masking.
- Apply bitwise operations to construct sub- and super-nets.
- Specify a strategy to dividing large networks into smaller versions (CIDR).
- Distinguish between public, private, and multicast address spaces (RFC1918)

Review – Application and Transport



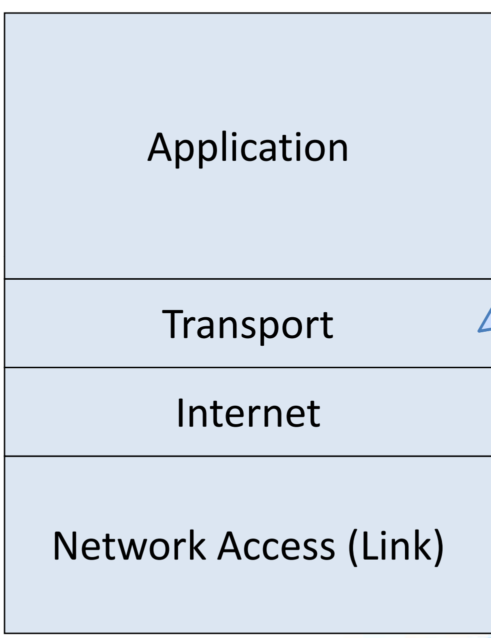
Review – Application Layer



OSI layers 5, 6, 7. User applications, services, and application layer protocols. “messages”

- Ex: browser, httpd, and HTTPD working together.
- App message -> app protocol -> transport layer.

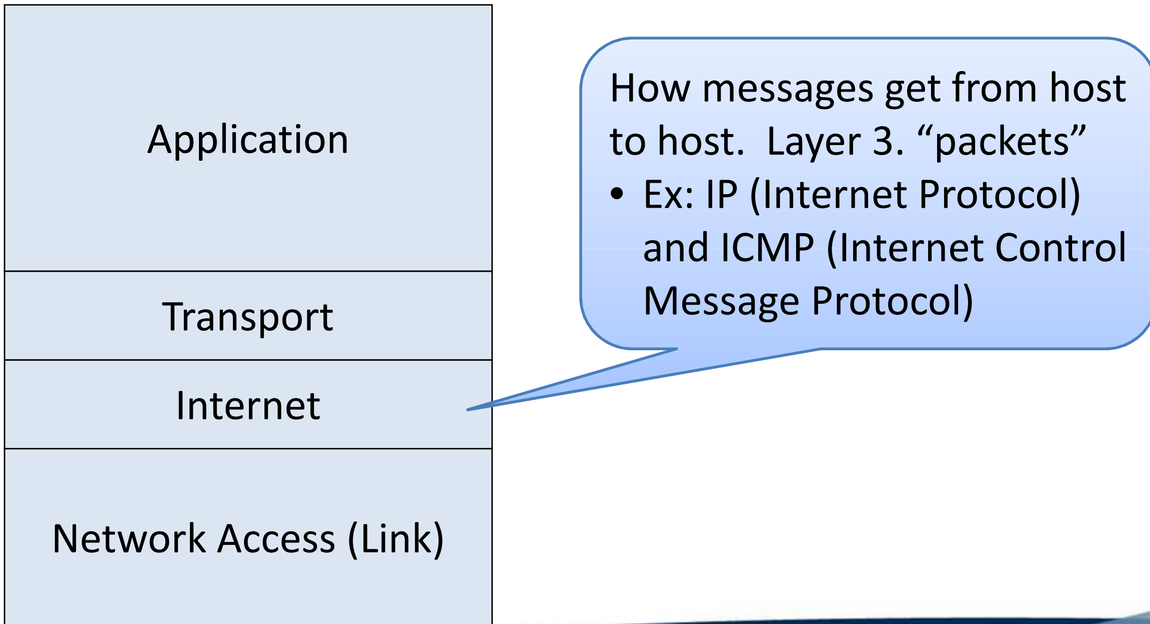
Review – Transport Layer



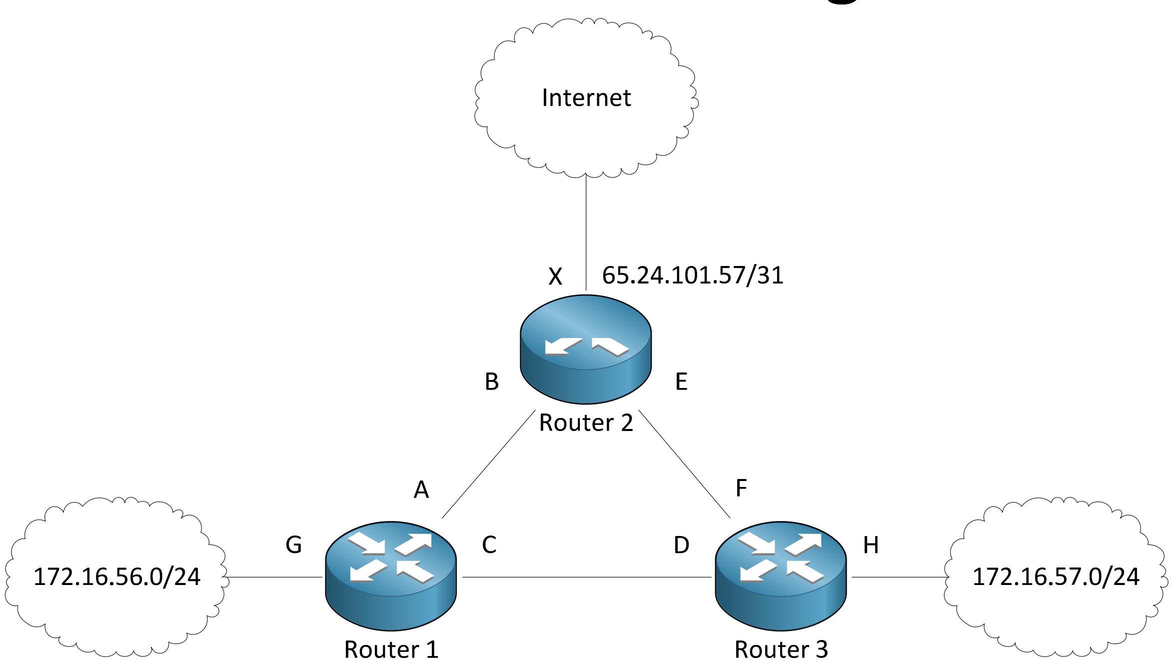
OSI layer 4. Typical examples are UDP and TCP. “segments”

- Port – specifies target service/app listening for messages
- UDP – “connectionless”
- TCP – “connection oriented”
- Header differences
- Handshaking in TCP

Review – Internet Layer

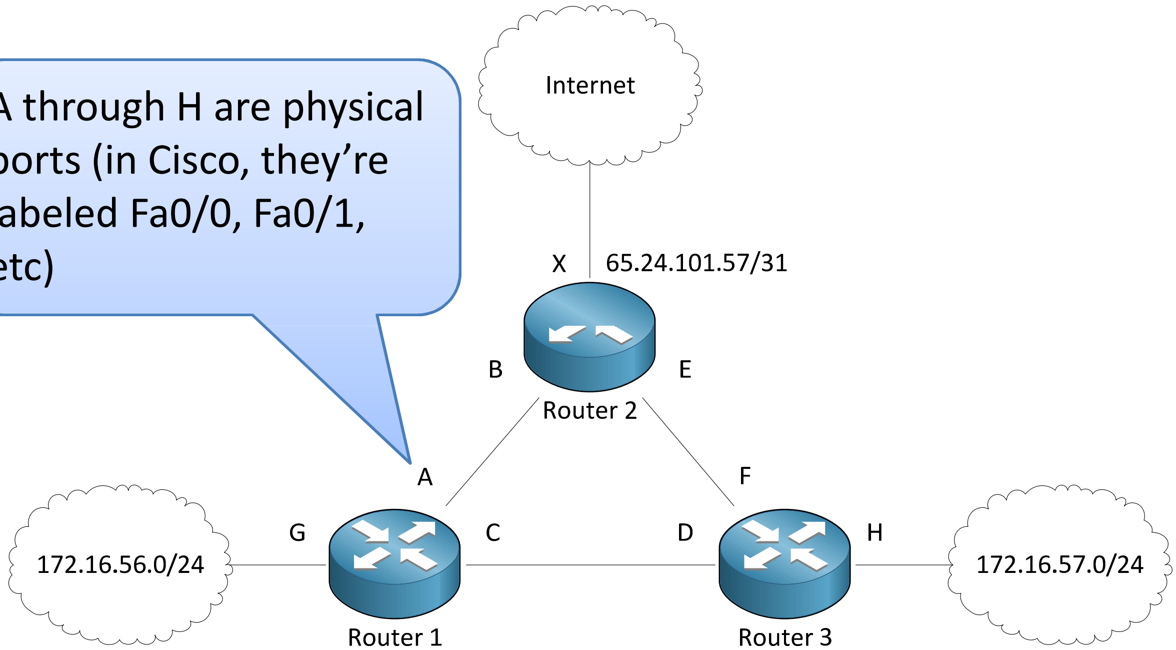


Review – Routing



Review – Routing

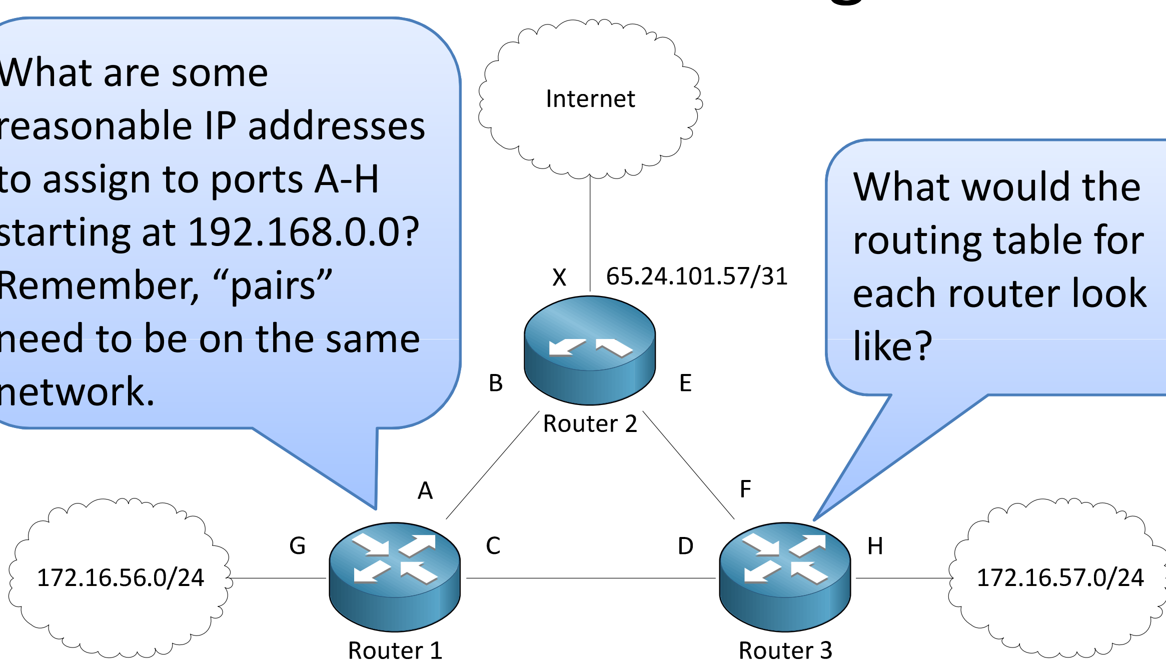
A through H are physical ports (in Cisco, they're labeled Fa0/0, Fa0/1, etc)



Review – Routing

What are some reasonable IP addresses to assign to ports A-H starting at 192.168.0.0? Remember, "pairs" need to be on the same network.

What would the routing table for each router look like?



Review – Routing

Port	IP address / VLSM
A	192.168.0.0/31
B	192.168.0.1/31
C	192.168.0.2/31
D	192.168.0.3/31
E	192.168.0.4/31
F	192.168.0.5/31
G	172.16.56.254
H	172.16.57.254

A, B: Must be on the same network as each other

C, D: Must be on the same network as each other

E, F: Must be on the same network as each other

G, H: Must be on the same network as the hosts to which it directly delivers.

Review – Routing

- Router 1 routing table

Port	Destination Network	Gateway
C	172.16.57.0/24	192.168.0.3
A	172.16.57.0/24	192.168.0.1
G	172.16.56.0/24	172.16.56.254
A	0.0.0.0/0	192.168.0.1
C	0.0.0.0/0	192.168.0.3

Routing "metric," decides between these, lower number is favored.

Could say "direct delivery," instead.

Review – Routing

- Router 2 routing table

Port	Destination Network	Gateway
E	172.16.57.0/24	192.168.0.5
B	172.16.57.0/24	192.168.0.0
B	172.16.56.0/24	192.168.0.0
E	172.16.56.0/24	192.168.0.5
X	0.0.0.0/0	65.24.101.56

Routing "metric," decides between these, lower number is favored.

How do I know this number at all?

Review – Routing

- Router 3 routing table

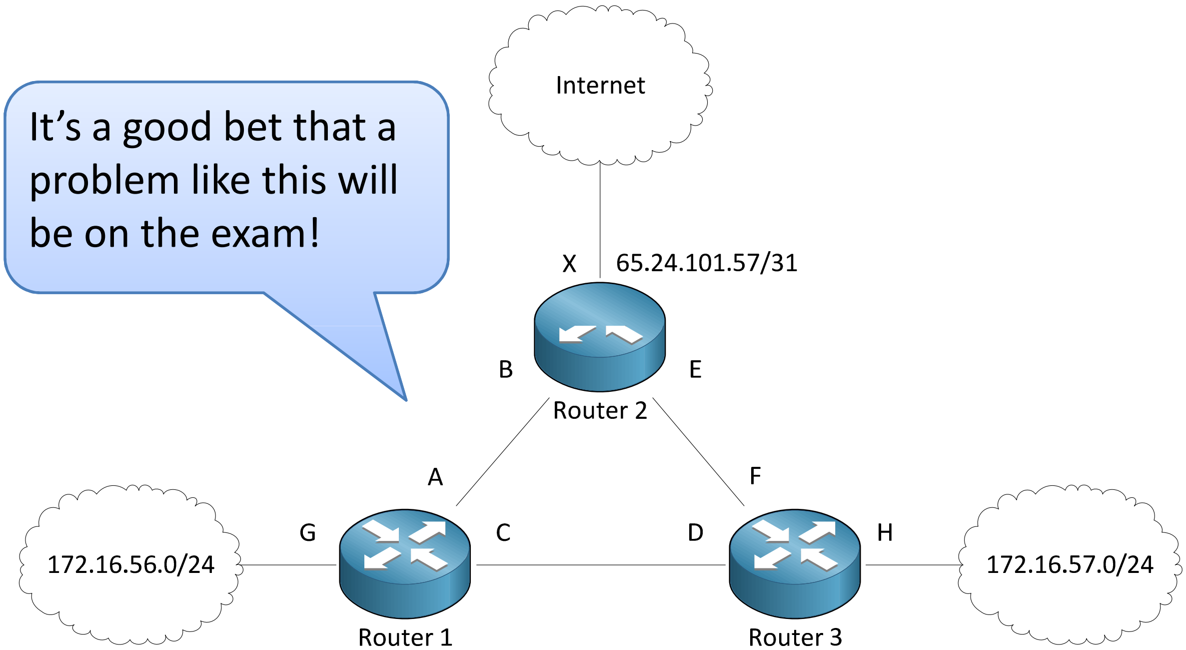
Port	Destination Network	Gateway
D	172.16.56.0/24	192.168.0.2
F	172.16.56.0/24	192.168.0.4
H	172.16.57.0/24	172.16.57.254
F	0.0.0.0/0	192.168.0.4
D	0.0.0.0/0	192.168.0.2

Routing "metric," decides between these, lower number is favored.

Could say "direct delivery," instead.

Review – Routing

It's a good bet that a problem like this will be on the exam!



Chapter 6

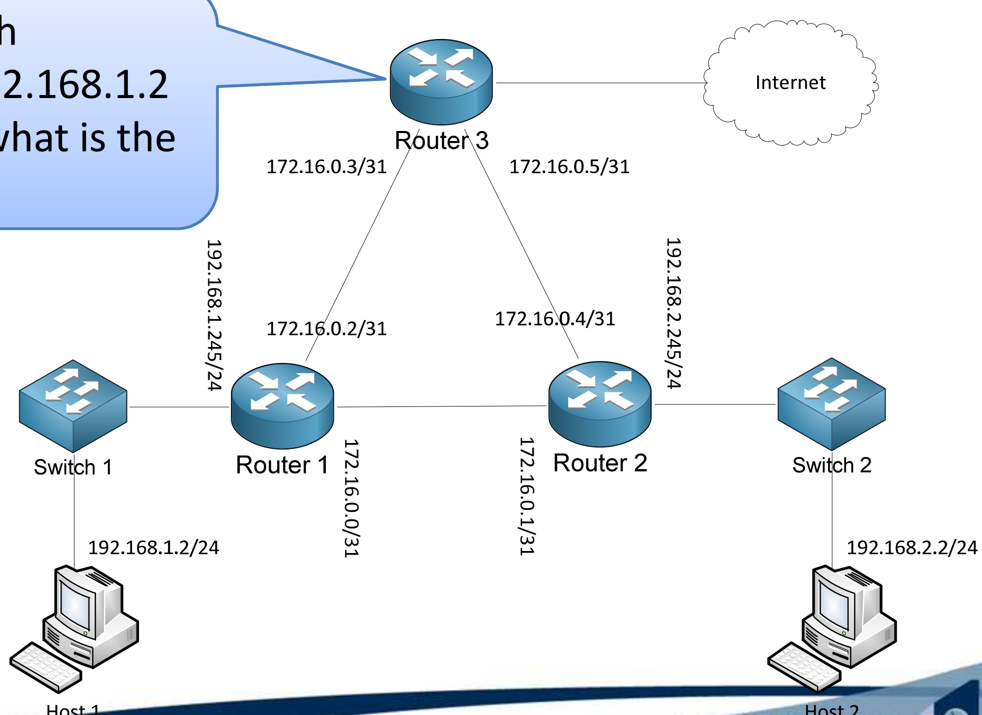
- Dividing large networks into smaller networks.
- Assigning IP addresses.

Network Addressing

- Recall routing:
  - Look at the network portion of the IP address.
    - If the network is locally connected (i.e. directly adjacent to the router), then deliver directly to the host.
    - If there is a routing entry for the network, forward to the next hop entry in the routing table
    - Otherwise, deliver to the default next hop.

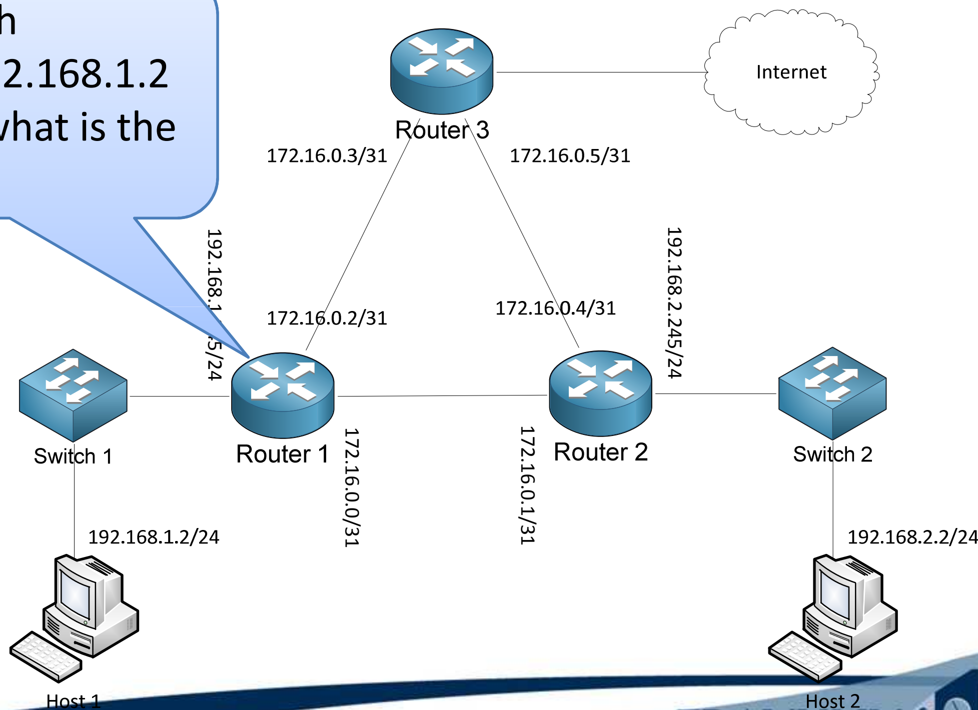
Network Addressing

If a packet with destination 192.168.1.2 arrives here, what is the next hop?



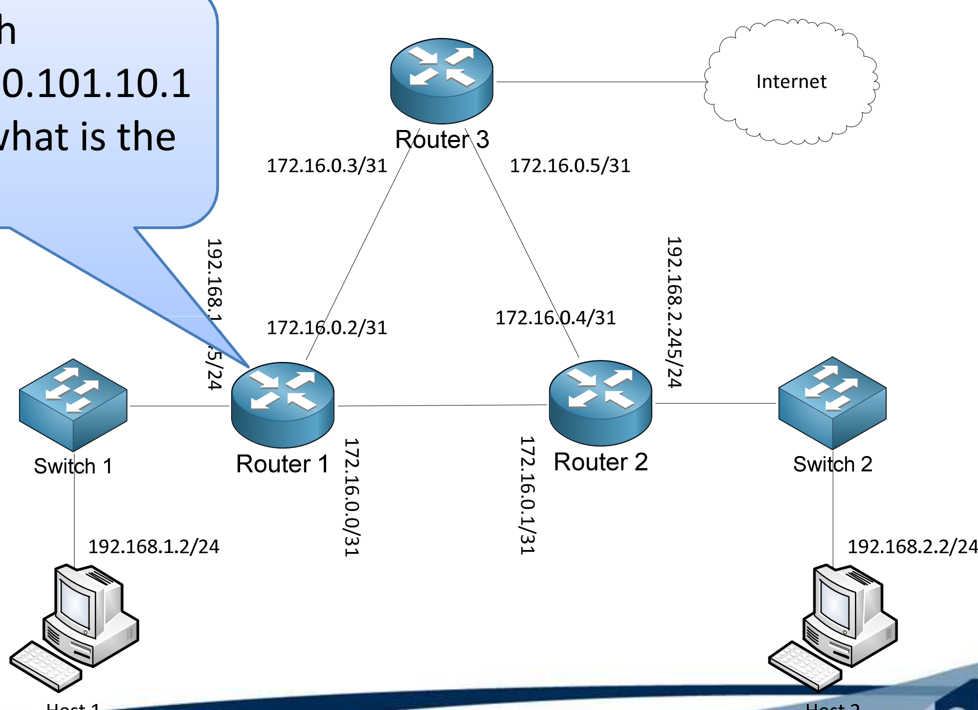
Network Addressing

If a packet with destination 192.168.1.2 arrives here, what is the next hop?



Network Addressing

If a packet with destination 130.101.10.1 arrives here, what is the next hop?



Network Addressing

- Recall routing:
  - Look at the **network portion** of the IP address.
    - If the network is lo ly connected (i.e. directly adjacent to the router), th eliver directly to the host.
    - If there is a ro ntry for the network, forward to outing table
    - lefault next hop.

What is the “network portion” of the IP address? And just what the heck are these /24 and /31 notations anyhow?

Network & Host Parts

31 30 29 28 27 26 25 24	23 22 21 20 19 18 17 16	15 14 13 12 11 10 09 08	07 06 05 04 03 02 01 00
11000000	10101000	00000010	10011101
192	168	2	157

- Break the address up into “octets” (groupings of 8 bits, or 1 byte).
- Some portion of this string of binary numbers will be the “network” identifier and some portion will be the “host” identifier within the network.

Network & Host Parts

31–24	23–16	15–08	07–00
11000000	10101000	00000010	10011101
192	168	2	157

- It's easy when the separation falls on a 8-bit boundary (like above). The blue portion is the "network" and the red portion is the "host."
  - The above written 192.168.2.157/24, indicating that the most-significant 24 bits are the network and the least significant 8 bits are the host.

Network & Host Parts

31–24	23–16	15–08	07–00
11000000	10101000	00000010	10011101
192	168	2	157

- If the IP address is 192.168.2.157/24, how many hosts can be on this network?

Network & Host Parts

31 30 29 28 27 26 25 24	23 22 21 20 19 18 17 16	15 14 13 12 11 10 09 08	07 06 05 04 03 02 01 00
11000000	10101000	00000010	10011101
192	168	2	157

- If the IP address is 192.168.2.157/24, how many hosts can be on this network?
  - Answer: 8 host bits, 2^8 = 256 (0 through 255)
    - Except 2 addresses are reserved. When the host bits are all 0s, it is the "network address" and when the host bits are all 1s, it is the broadcast address.
    - So, really, it's 254, numbered 1 - 254.

Network & Host Parts

31 30 29 28 27 26 25 24	23 22 21 20 19 18 17 16	15 14 13 12 11 10 09 08	07 06 05 04 03 02 01 00
11000000	10101000	00000010	10011101
192	168	2	157

- If the IP address is 192.168.2.157/27, how many hosts can be on this network?

Network & Host Parts

31 30 29 28 27 26 25 24	23 22 21 20 19 18 17 16	15 14 13 12 11 10 09 08	07 06 05 04 03 02 01 00
11000000	10101000	00000010	10011101
192	168	2	157

- If the IP address is 192.168.2.157/27, how many hosts can be on this network?
  - Answer: 5 host bits, $2^5 - 2 = 30$.
    - Numbered 192.168.2.129 through 192.168.2.158.
    - 192.168.2.128 is the network address
    - 192.168.2.159 is the broadcast address

Network & Host Parts

31 30 29 28 27 26 25 24	23 22 21 20 19 18 17 16	15 14 13 12 11 10 09 08	07 06 05 04 03 02 01 00
11000000	10101000	00000010	10011101
192	168	2	157

- If the IP address is 192.168.2.157/20, how many hosts can be on this network?

Network & Host Parts

31 30 29 28 27 26 25 24	23 22 21 20 19 18 17 16	15 14 13 12 11 10 09 08	07 06 05 04 03 02 01 00
11000000	10101000	00000010	10011101
192	168	2	157

- If the IP address is 192.168.2.157/20, how many hosts can be on this network?
  - Answer: 12 host bits, $2^{12} - 2 = 4094$.
    - Numbered 192.168.0.1 through 192.168.15.254.
    - 192.168.0.0/20 is the network address
    - 192.168.15.255/20 is the broadcast address

Network & Host Parts

- The /XX, notation is called VLSM or CIDR
  - VLSM: variable length subnet mask
  - CIDR: classless inter-domain routing
- Sometimes the network/host is written using a *netmask.*
  - A netmask is a pattern of all 1's followed by all zeros. The netmask is "anded" with an IP address to determine the network/host division

Network & Host Parts

- Ex: “/24” is equivalent to a netmask of 255.255.255.0. Why?

Network & Host Parts

- Ex: “/24” is equivalent to a netmask of 255.255.255.0. Why?

31 30 29 28 27 26 25 24	23 22 21 20 19 18 17 16	15 14 13 12 11 10 09 08	07 06 05 04 03 02 01 00
11111111	11111111	11111111	00000000
255	255	255	0

Network & Host Parts

- Ex: "/24" is equivalent to a netmask of 255.255.255.0. Why?

31 30 29 28 27 26 25 24	23 22 21 20 19 18 17 16	15 14 13 12 11 10 09 08	07 06 05 04 03 02 01 00
11111111	11111111	11111111	00000000
255	255	255	0

- The IP address of a host is ANDed with the netmask to strip off the host portion and leave only the network portion.

Network & Host Parts

- What is the netmask equivalent for /20?

Network & Host Parts

- What is the netmask equivalent for /20?

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
255								255								240								0							

Network & Host Parts

- Is 192.168.208.5/20 on the same network as 192.168.249.137/20?

Network & Host Parts

- Is 192.168.208.5/20 on the same network as 192.168.249.137/20?

31–24	23–16	15–08	07–00
11000000	10101000	11010000	00000101
192	168	208	5

31–24	23–16	15–08	07–00
11000000	10101000	11111001	10001001
192	168	249	137

Network & Host Parts

- Is 192.168.208.5/20 on the same network as 192.168.219.43/20?

Network & Host Parts

- Is 192.168.208.5/20 on the same network as 192.168.219.43/20?

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
1	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	0	1
192								168								208								5							

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	09	08	07	06	05	04	03	02	01	00
1	1	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	1	0	1	1	0	1	1	0	0	1	0	1	0	1	1
192								168								219								43							

FRANKLIN UNIVERSITY

Network & Host Parts

- Classful addresses
  - Older style addressing schema where all netmasks came in octets too.
    - Class A: 0.0.0.0/8 through 127.255.255.255/8
      - 128 networks of 16,777,216 hosts
    - Class B: 128.0.0.0/16 through 191.255.255.255/16
      - 16,384 networks of 65,536 hosts
    - Class C: 192.0.0.0/24 through 239.255.255.255/24
      - 2,097,152 networks of 256 hosts

FRANKLIN UNIVERSITY

Network & Host Parts

- Classful addresses
  - Older style addressing schema where all netmasks came in octets too.
    - Class A: 0.0.0.0/8 through 127.255.255.255/8
      - 128 networks of 16,777,216 hosts
    - Class B: 128.0.0.0/16 through 191.255.255.255/16
      - 16,384 networks of 65,536 hosts
    - Class C: 192.0.0.0/24 through 239.255.255.255/24
      - 2,097,152 networks of 256 hosts

Not Used Today

FRANKLIN UNIVERSITY

Reserved addresses

- Already mentioned two reserved host addresses on each network:
  - Host part all 0s: network address
  - Host part all 1s: directed broadcast address
- IP 255.255.255.255 is *limited* broadcast address. Used to get an IP address via DHCP.
- All broadcast packets have TTL set to 1 (non-routable)

FRANKLIN UNIVERSITY

Reserved addresses

- Class D: Multicast addresses
  - 224.0.0.0 through 239.255.255.255
- Class E: Reserved
  - 240.0.0.0 through 255.255.255.255
- Loopback
  - 127.0.0.0/8 (127.0.0.0 through 127.255.255.255) always refers to "localhost." Allows apps on the same machine to communicate w/o routing.

Private IP Addresses

- Not enough IP addresses to cover all the devices connected to the Internet.
  - Private IP address ranges are reserved for internal networks (usually hidden behind NAT)
    - 10.0.0.0/8 (10.0.0.0 through 10.255.255.255)
    - 172.16.0.0/12 (172.16.0.0 to 172.31.255.255)
    - 192.168.0.0/16 (192.168.0.0 to 192.168.255.255)
  - Defined by RFC 1918

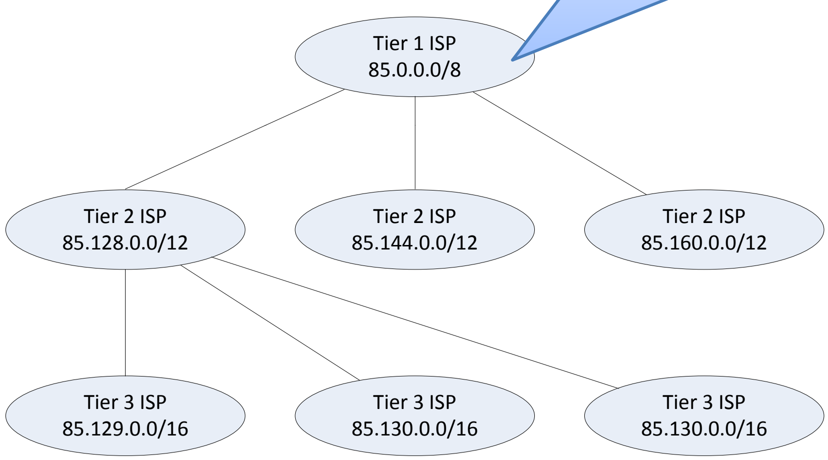
Dividing Address Spaces

- Tier 1, 2 and 3 ISPs
  - Tier 1 ISPs own large sections of the IP address range, which they “sublet” to Tier 2 ISPs using VLSM/CIDR (IANA assigns these and runs root DNS servers)
  - Tier 2 ISPs then section off chunks to Tier 3 ISPs (also using VLSM/CIDR)
  - Tier 3 ISPs often assign just a single IP address to an organization. These organizations hide RFC1919 networks behind NAT.

Dividing Address Spaces

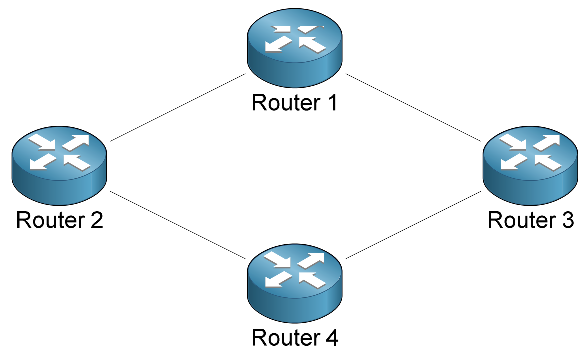
- Example of subdividing

See page 220 and following on how to subnet a subnet.



RFC 3021

- Using 31-Bit Prefixes on IPv4 Point-to-Point Links
  - It turns out that the following is a really common router layout:



FRANKLIN UNIVERSITY

RFC 3021

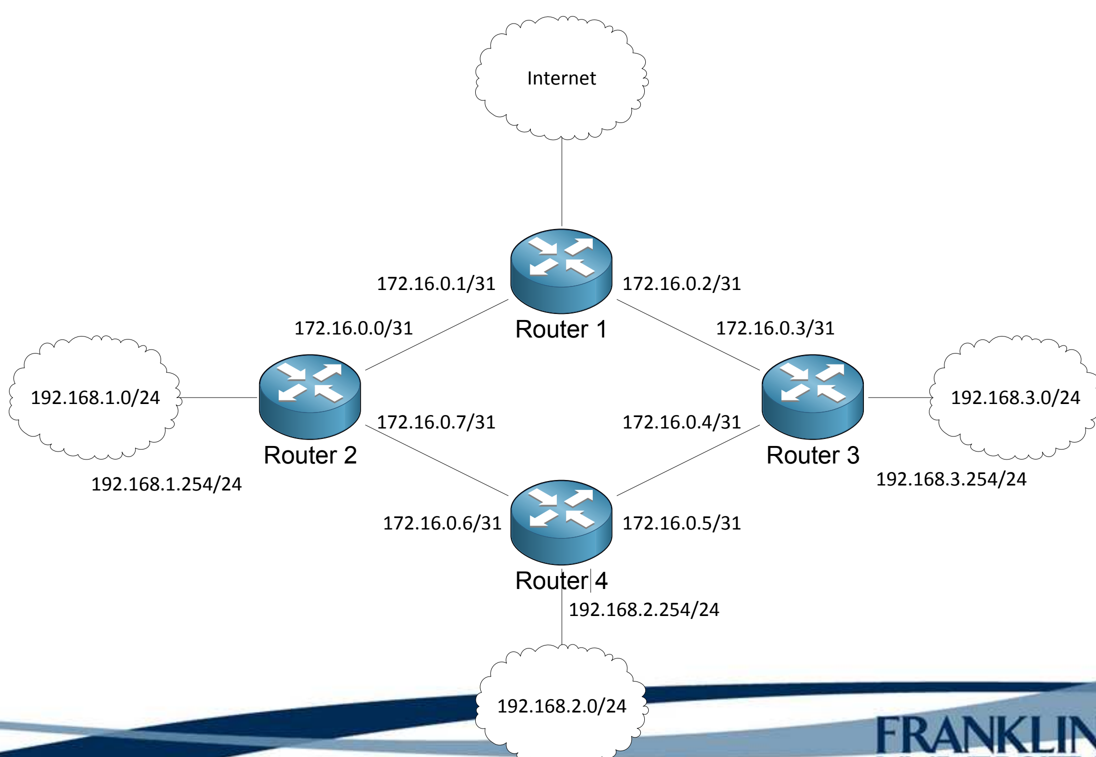
- Using 31-Bit Prefixes on IPv4 Point-to-Point Links
  - Routers have many point-to-point links to other routers. Each interface on a router needs its own IP address. If we reserve the “network” and “broadcast” addresses, then we need a VLSM of /30 (2 reserved + 2 interfaces)

FRANKLIN UNIVERSITY

RFC 3021

- Using 31-Bit Prefixes on IPv4 Point-to-Point Links
  - But this wastes half the IP addresses for router meshes in “reserved” addresses.
  - RFC 3021 says that for point-to-point links, using a /31 VLSM is okay. So we get those back.

RFC 3021



How to subnet

- Given a limited range of contiguous IP addresses, how do you break it up into separate networks with different numbers of hosts?
  - Identify the number of needed networks
  - Count the number of hosts on each (leaving some room to grow)
  - Sort the list descending by host count
  - Begin dividing up the address space.

FRANKLIN UNIVERSITY

How to subnet

- Ex: need 5 networks of 12, 55, 4, 62, and 100 hosts each.
  - 100: next power of 2 is 128. Has room.
  - 62: next power of 2 is 64. Needs room.
  - 55: next power of 2 is 64. Has room.
  - 12: next power of 2 is 16. Needs room.
  - 4: is a power of 2. Needs room.

FRANKLIN UNIVERSITY

How to subnet

- Ex: need 5 networks of 12, 55, 4, 62, and 100 hosts each.
  - 128 hosts, needs 7 bits
  - 128 hosts, needs 7 bits
  - 64 hosts, needs 6 bits
  - 32 hosts, needs 5 bits
  - 16 hosts, needs 4 bits

How to subnet

- Ex: need 5 networks of 12, 55, 4, 62, and 100 hosts each.
  - 128 hosts, needs 7 bits
  - 128 hosts, needs 7 bits
  - 64 hosts, needs 6 bits
  - 32 hosts, needs 5 bits
  - 16 hosts, needs 4 bits

Divide up the 10.0.0.0/8 network efficiently here.

How to subnet

- First network
  - 128 hosts, needs 7 bits
    - Network address 10.0.0.0
    - Broadcast address 10.0.0.127
    - Therefore 10.0.0.0/25
    - 126 hosts (10.0.0.1 through 10.0.0.126)

With 7 bits needed, that's a /25 VLSM

How to subnet

- Second network – starts after the first!
  - 128 hosts, needs 7 bits
    - Network address 10.0.0.128
    - Broadcast address 10.0.0.255
    - Therefore 10.0.0.128/25
    - 126 hosts (10.0.0.129 through 10.0.0.254)

With 7 bits needed, that's a /25 VLSM

How to subnet

- Third network – starts after the second!
  - 64 hosts, needs 6 bits
    - Network address 10.0.1.0
    - Broadcast address 10.0.1.63
    - Therefore 10.0.1.0/26
    - 62 hosts (10.0.1.1 through 10.0.1.62)

With 6 bits needed, that's a /26 VLSM

How to subnet

- Fourth network – starts after the third!
  - 32 hosts, needs 5 bits
    - Network address 10.0.1.64
    - Broadcast address 10.0.1.95
    - Therefore 10.0.1.64/27
    - 30 hosts (10.0.1.65 through 10.0.1.94)

With 5 bits needed, that's a /27 VLSM

How to subnet

- Fifth network – starts after the fourth!
  - 16 hosts, needs 4 bits
    - Network address 10.0.1.96
    - Broadcast address 10.0.1.111
    - Therefore 10.0.1.96/28
    - 14 hosts (10.0.1.97 through 10.0.1.110)

With 4 bits needed, that's a /28 VLSM

How to subnet

- Nice table representation

Orig Sz	Subnet	Net Addr	Bcast Addr	First host	Last host
100	10.0.0.0/25	10.0.0.0	10.0.0.127	10.0.0.1	10.0.0.126
62	10.0.0.128/25	10.0.0.128	10.0.0.255	10.0.0.129	10.0.0.254
55	10.0.1.0/26	10.0.1.0	10.0.1.63	10.0.1.1	10.0.1.62
12	10.0.1.64/27	10.0.1.64	10.0.1.95	10.0.1.65	10.0.1.94
4	10.0.1.96/28	10.0.1.96	10.0.1.111	10.0.1.97	10.0.1.110

How to subnet

- Nice table representation

Orig Sz	Subnet	Net Addr	Bcast Addr	First host	Last host
100	10.0.0.0/25	10.0.0.0	10.0.0.127	10.0.0.1	10.0.0.126
62	10.0.0.128/25	10.0.0.128	10.0.0.255	10.0.0.129	10.0.0.254
55	10.0.1.0/26	10.0.1.0	10.0.1.63	10.0.1.1	10.0.1.62
12	10.0.1.64/27	10.0.1.64	10.0.1.95	10.0.1.65	10.0.1.94
4	10.0.1.96/28	10.0.1.96	10.0.1.111	10.0.1.97	10.0.1.110

It's a good bet that a problem like this will be on the exam!

FRANKLIN UNIVERSITY

This Week's Outcomes

- Convert binary to decimal and decimal to binary to understand subnet masking. ✓
- Apply bitwise operations to construct sub- and super-nets. ✓
- Specify a strategy to dividing large networks into smaller versions (CIDR). ✓
- Distinguish between public, private, and multicast address spaces (RFC1918) ✓

FRANKLIN UNIVERSITY

Self Quiz

- A network admin needs to create a network that supports 16 hosts. What kind of netmask will work here?
- What does RFC1918 specify? What good does it do for network admins?
- Why did IANA move away from classful addresses to classless addresses?

FRANKLIN UNIVERSITY

Self Quiz

- A RFC 3021 compliant point-to-point router connection has IP address and VLSM 192.168.12.57/31.
  - Write the *netmask* in dotted decimal
  - What is the IP address and *netmask* of the other end of the connection?

FRANKLIN UNIVERSITY

Self Quiz

- A network admin needs to create 4 networks corresponding to 4 different cities. The cities have 35, 22, 19, and 10 hosts respectively. Draw a network diagram with IP address schemas drawn from 192.168.0.0/16 that will support this network with minimal wasted IP addresses.

FRANKLIN UNIVERSITY

Due this week

- Homework 3
- Participation 4

FRANKLIN UNIVERSITY

Next week

- Chapter 7 and 8 – Link layer and physical layer. How bits get from interface to interface.

Q & A

- Questions, comments, concerns?