# Internet Protocols EBU5403
# The Network Layer

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| | Week 1 | Week 2 | Week 3 | Week 4 |
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# Network Layer (Data): outline

4.1 Overview of Network layer
- data plane
- control plane

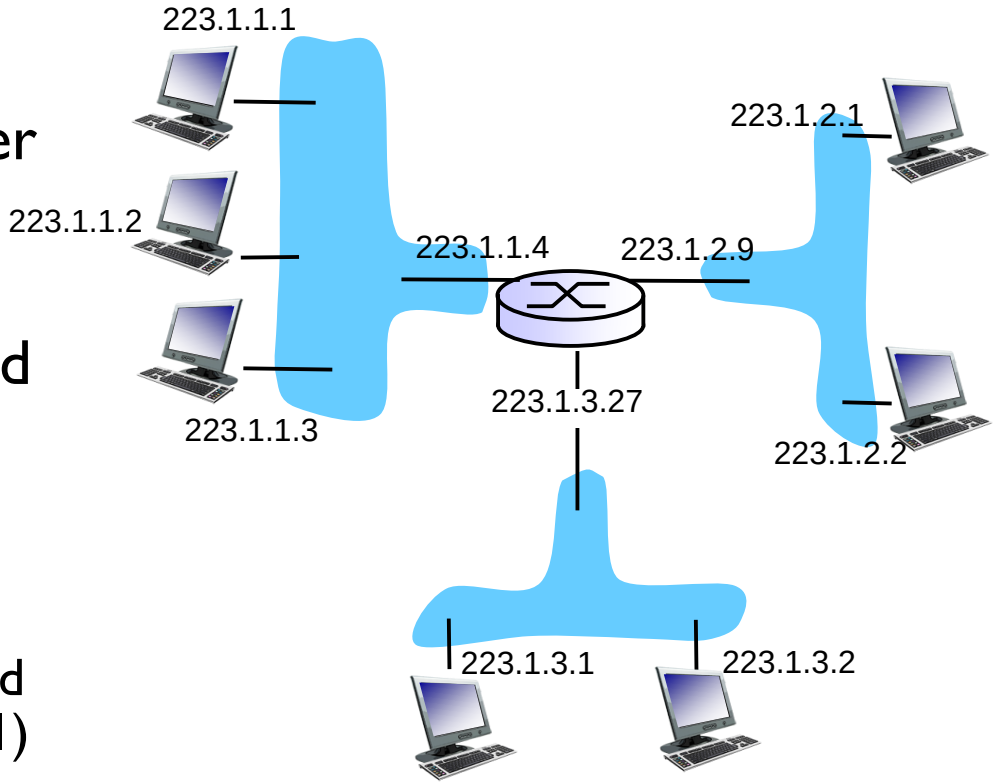
4.2 What's inside a router

4.3 IP: Internet Protocol
- datagram format
- fragmentation
- IPv4 addressing
- network address translation
- IPv6

4.4 Generalized Forward and SDN
- match
- action
- OpenFlow examples of match-plus-action in action

# IP addressing: introduction

- *IP address:* 32-bit identifier for host, router *interface*
- *interface:* connection between host/router and physical link
  - routers typically have multiple interfaces
  - host typically has one or two interfaces (e.g., wired Ethernet, wireless 802.11)
- *IP addresses associated with each interface*



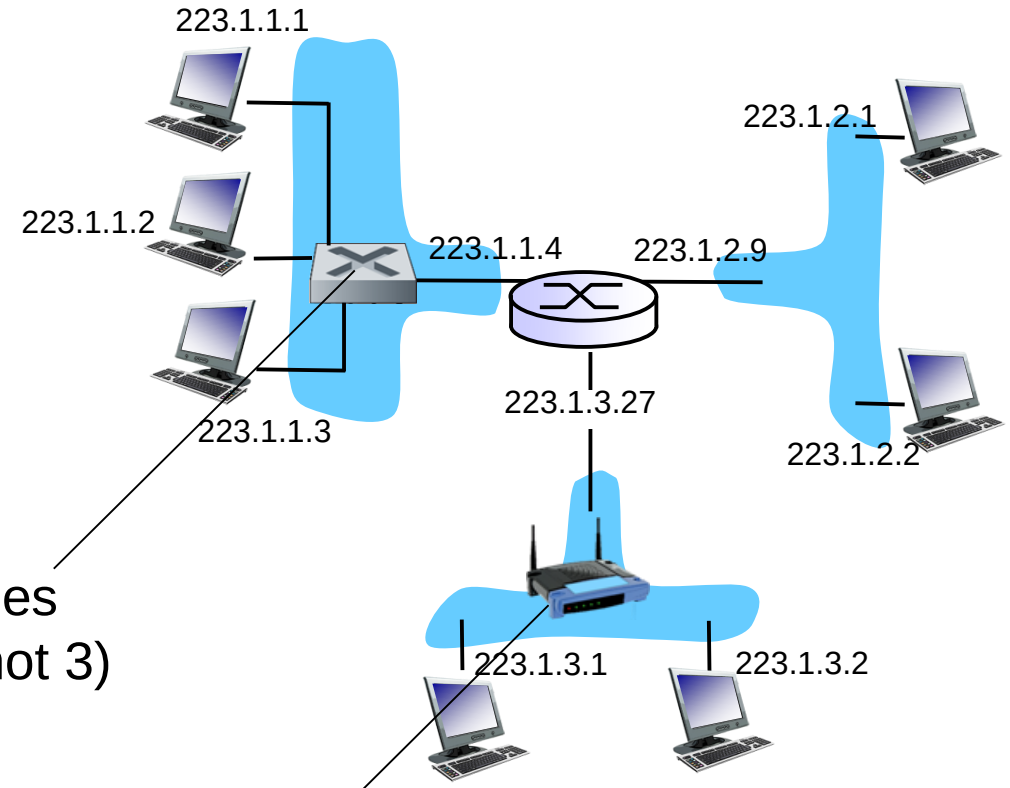

223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

# IP addressing: introduction

*Q: how are interfaces actually connected?*

*A: we'll learn about that in later lectures.*

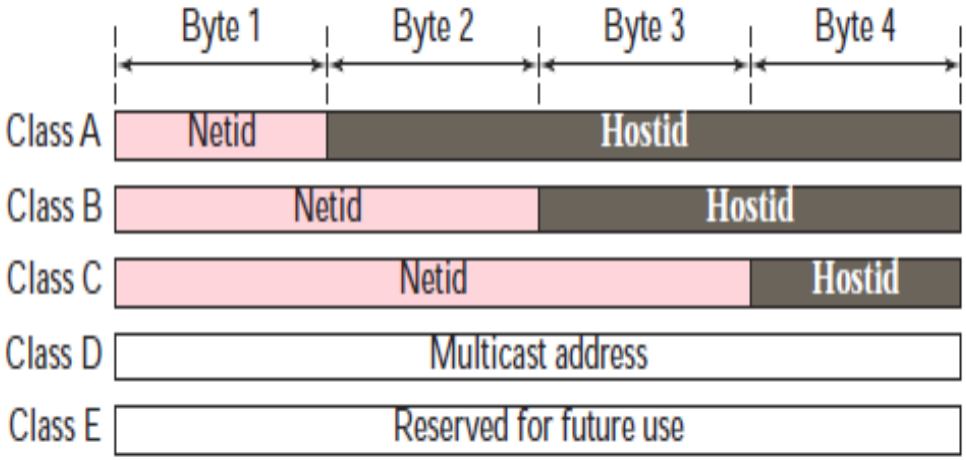



*A:* wired Ethernet interfaces connected by Ethernet switches (remember switches layer 2 not 3)

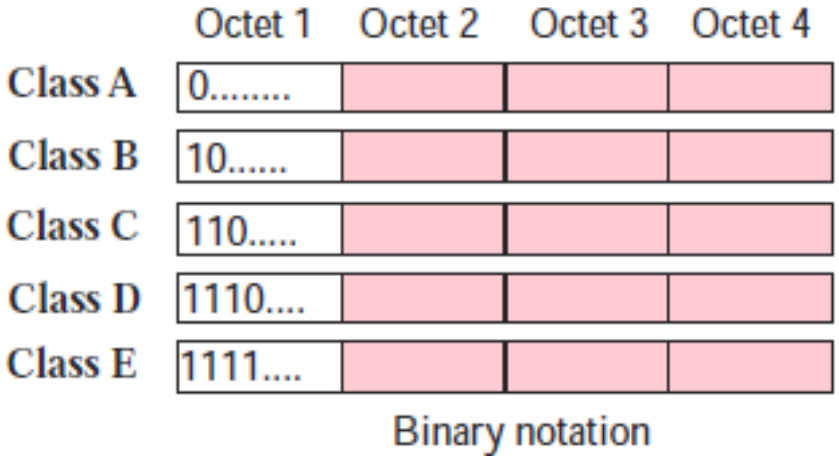
*For now:* don't need to worry about how one interface is connected to another (with no intervening router)

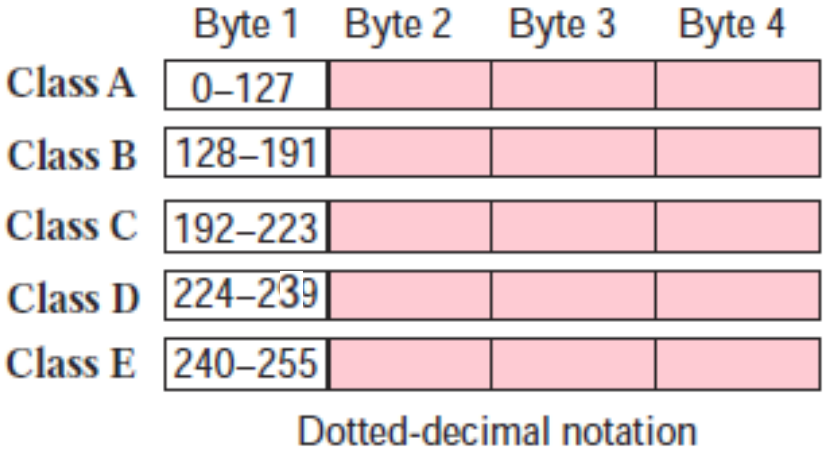
*A:* wireless WiFi interfaces connected by WiFi base station

# Classful IP addressing




- In classful addressing, the IP address space is divided into five classes: A, B, C, D, E.
- Starting number, n (first byte), shows whether Class A, B or C
  - **Class A**: n < 128 (up to 16m hosts)
  - **Class B**: 128 ≤ n < 192 (up to 65K hosts)
  - **Class C**: 192 ≤ n < 224 (up to 254 hosts)



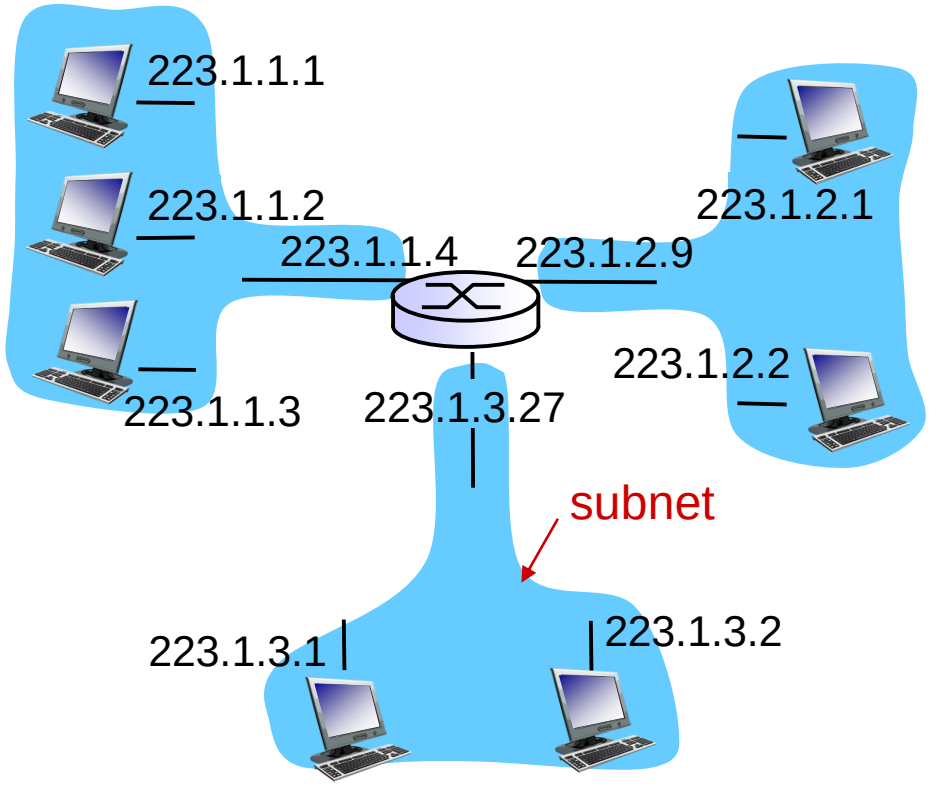
# Addresses for private networks

| *Class* | *Netids* | *Blocks* |
|---|---|---|
| A | 10.0.0 | 1 |
| B | 172.16 to 172.31 | 16 |
| C | 192.168.0 to 192.168.255 | 256 |

These addresses are "special" and not used on the general Internet. You use them to set up test networks or networks of machines not accessible from outside.

# 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

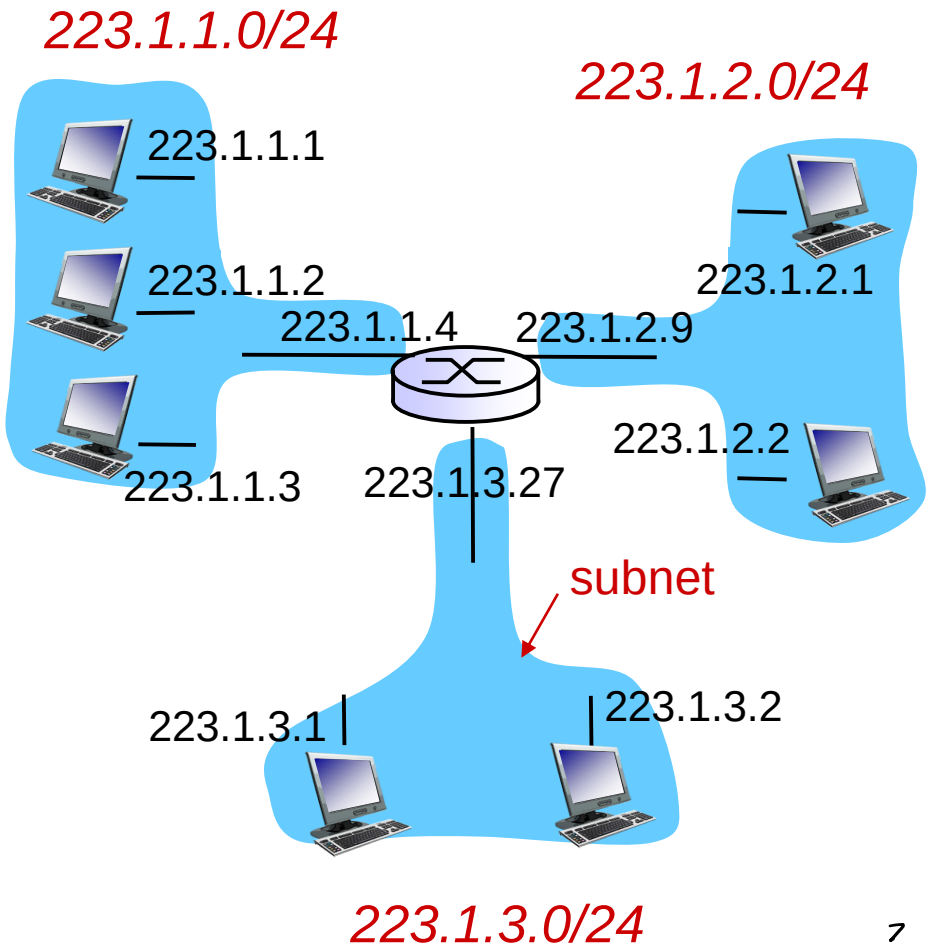



network consisting of 3 subnets

# Subnets

*recipe*

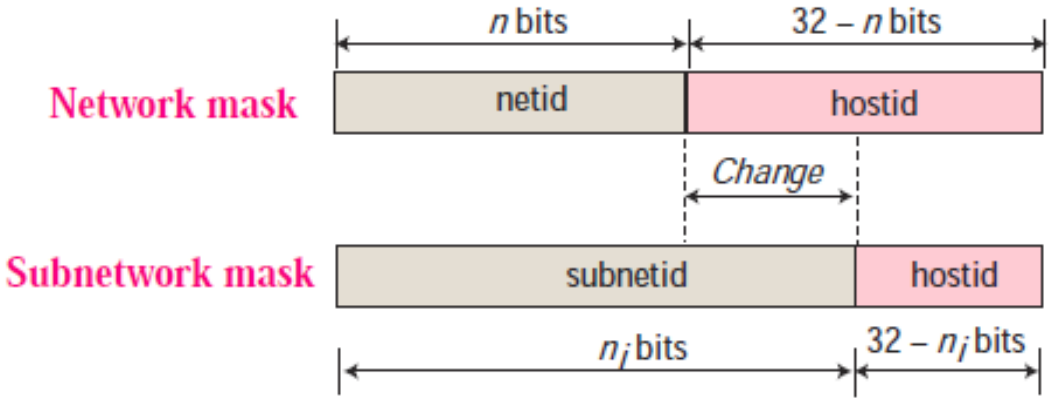
- to determine the subnets, detach each interface from its host or router, creating islands of isolated networks
- each isolated network is called a *subnet*
- *subnet mask (or slash notation) number of bits taken to identify network*
  - */8 size of old class A*
  - */16 size of class B*
  - */24 size of class C*




subnet mask: /24

# Network mask and subnetwork mask

- Subnetting increases length of **netid** and decreases length of **hostid**




- To divide a network to ***s*** number of subnetworks, each of equal numbers of hosts, the **subnetid** for each subnetwork can be calculated as

$$n_{\text{sub}} = n + \log_2 s$$

***n*** **-** length of netid, $n_{sub}$ **-** length of each subnetid, ***s*** – number of subnets

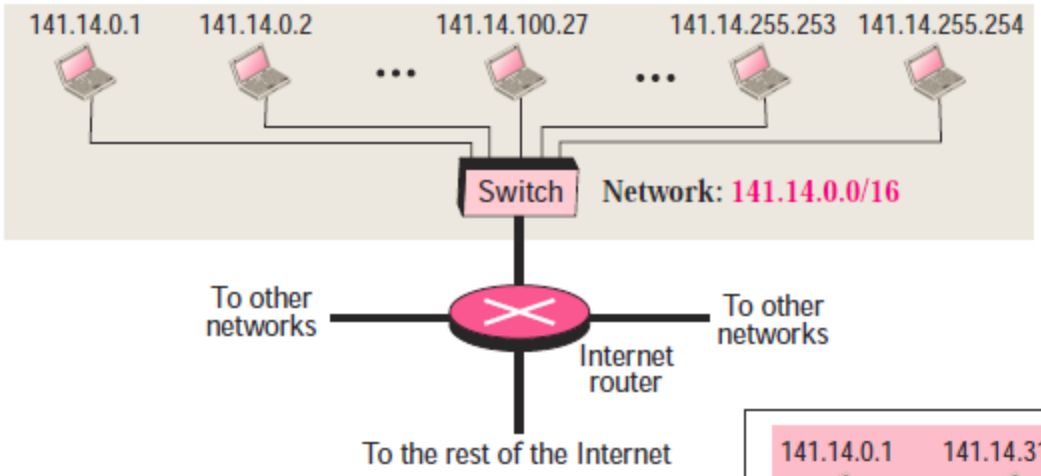
# Three-Level Addressing: Subnetting

- The idea of splitting a block to smaller blocks is referred to as subnetting.
- In subnetting, a network is divided into several smaller subnetworks (subnets) with each subnetwork having its own subnetwork address.

**Why subnetting ?**

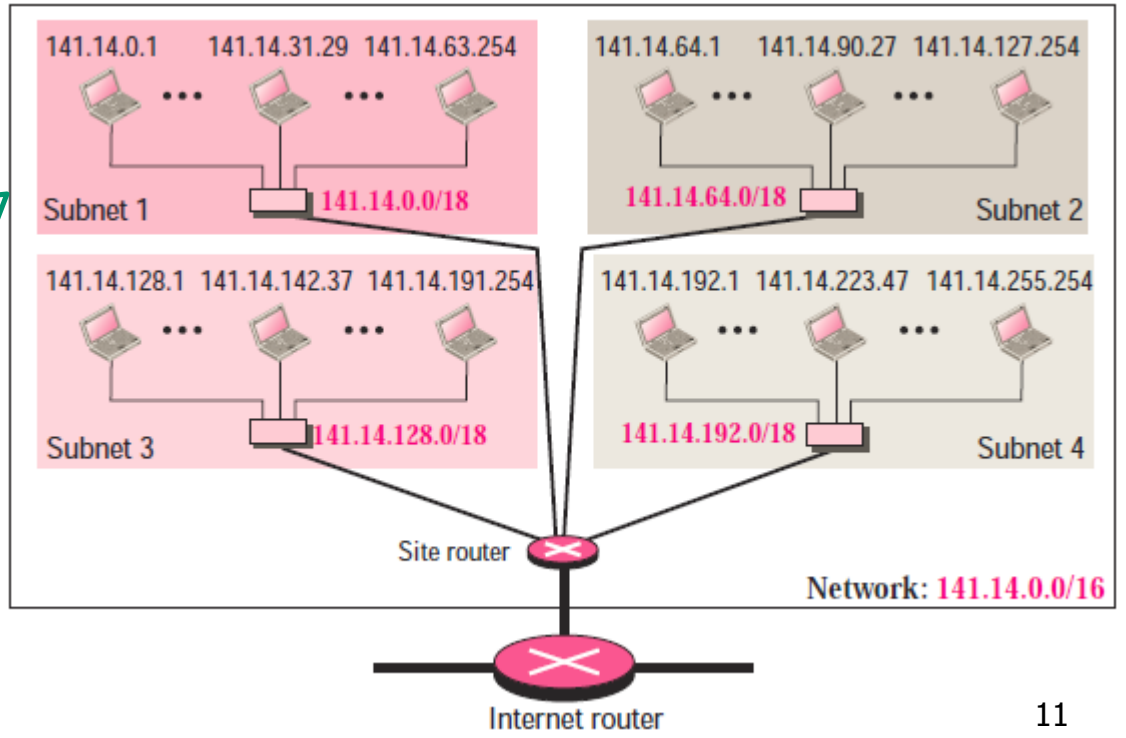
- an organization that was granted a large block of IP addresses (a long time ago this would be class A, class B etc)
- wants to divide this into smaller blocks of addresses that are individual networks.
- Or perhaps organization wants to sell some of its IP addresses off.

# A subnetting example




- A network using class B addresses before subnetting
- /16 to show the length of the netid (class B)

- a private site router is used to divide the network into four subnetworks.
- after subnetting, each subnetwork can now have almost $2^{14}$ hosts.
- /16 and /18 show the length of the netid and subnetids.

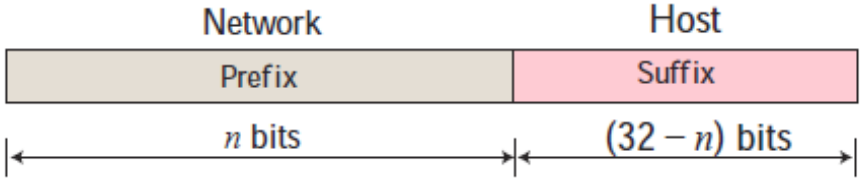


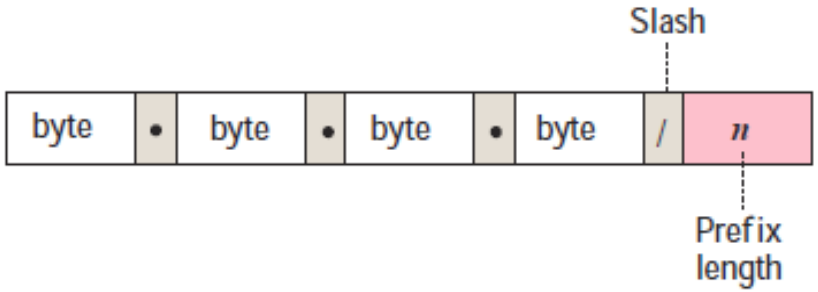
# Test your understanding

- Network address: 192.168.8.0/24
- Needs 6 subnets

# Classless addressing

- In classless addressing, variable-length blocks are assigned that belong to no class.
- In this architecture, the entire address space ($2^{32}$ addresses) is divided into blocks of different sizes.




- The slash notation is formally referred to as classless interdomain routing or CIDR (Classless InterDomain Routing) notation.

# Subnets and / notation

- Example 129.66.25.5/22

Host part 10 bits
(32 bits – 22 bits)

Network part (22 bits – because it is /22)

10000001.01000010.00011001.00000101

Network address is the address with all the host bits set to zero – address like any other but represents the network.

10000001.01000010.00011000.00000000

Network address: 129.66.24.0/22

The network address is also the first usable IP address in the block

Broadcast address (sends to everyone) is the address with all the host bits set to one.

10000001.01000010.00011011.11111111

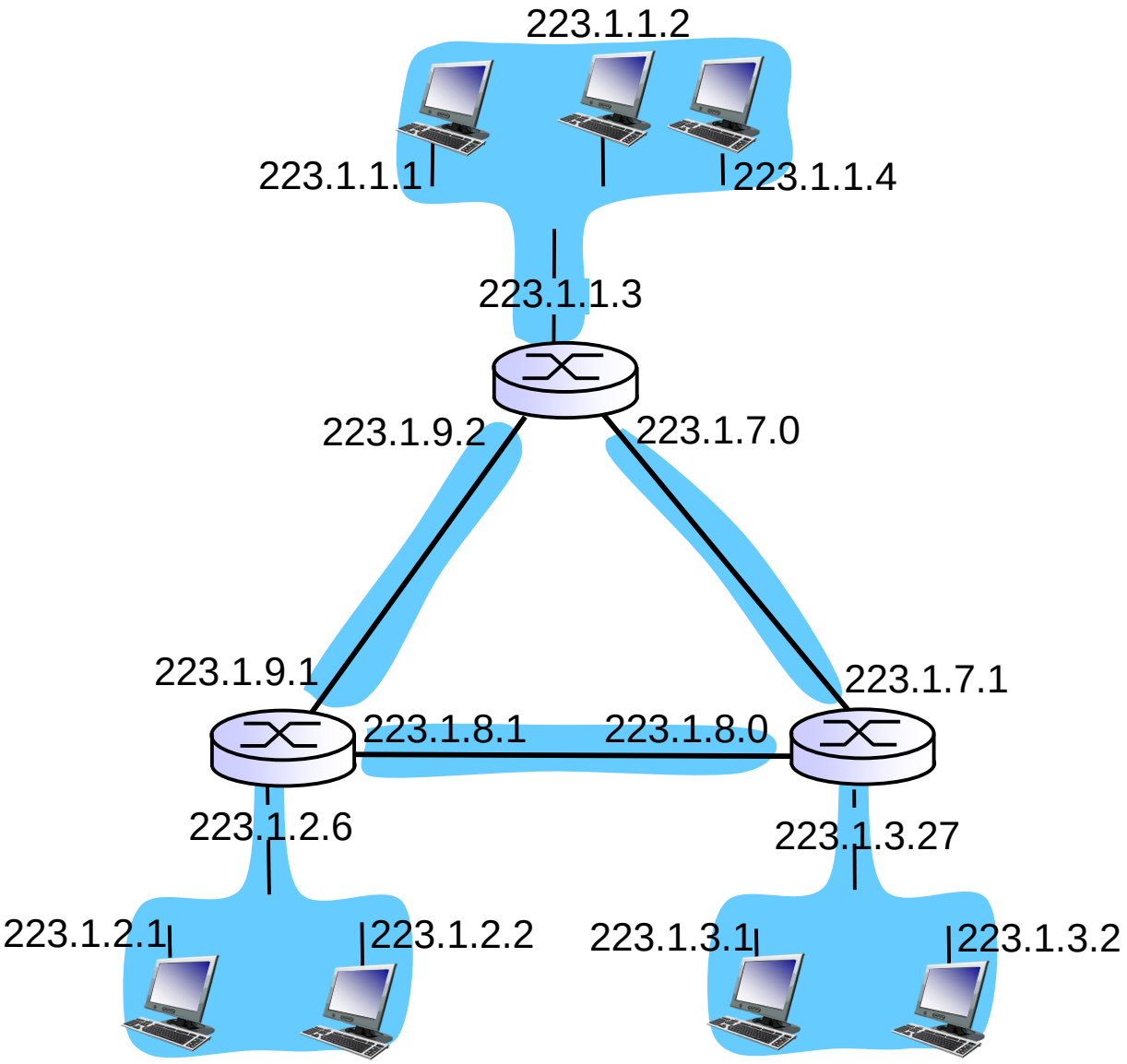
Broadcast address: 129.66.27.255/22

# Splitting IP address by slash notation

- For a /n address, the first n bits are the network address and the last 32-n bits are for the host.
- If the host parts are all 1s then this is the broadcast address – sent to all hosts on the network.
- Host has m = 32-n bits (e.g. /20 has m=12)
- Room for $2^m$ – 1 hosts (e.g. /20 has 4095)
- Example:
  - 140.120.84.24/20
  - Network address is 140.120.80.0/20
  - Broadcast address is 140.120.95.255/20
  - (95 is 01011111 255 is 11111111)
- /31 only has 1 host address
- /30 is smallest subnet we can have – 3 hosts
- /30 commonly used to connect just two routers (which must be on same subnet).

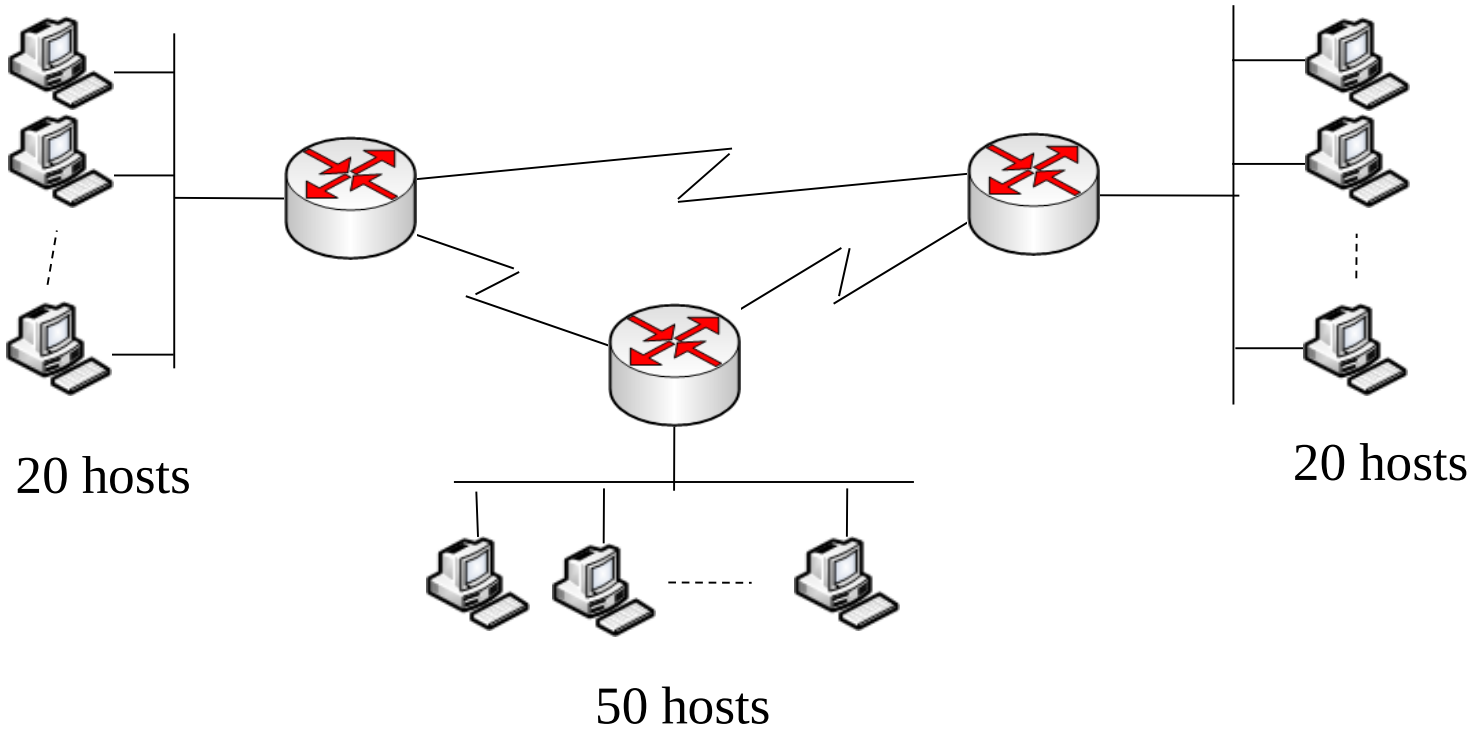
# Subnets

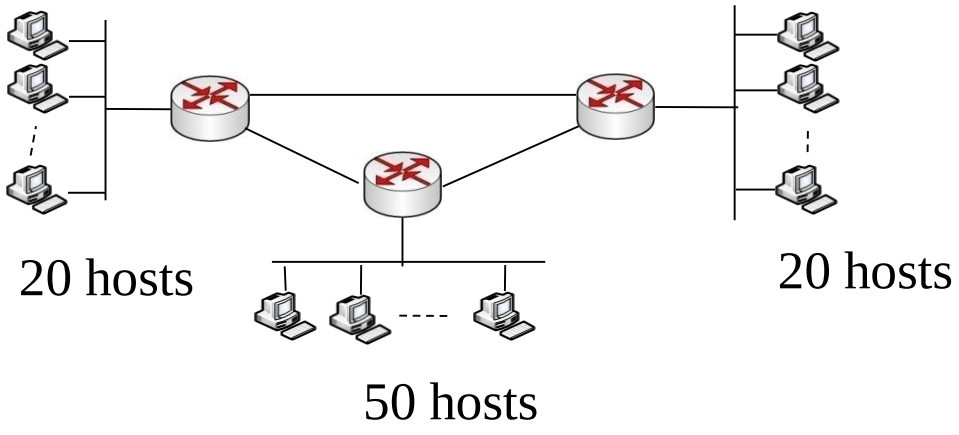
how many?



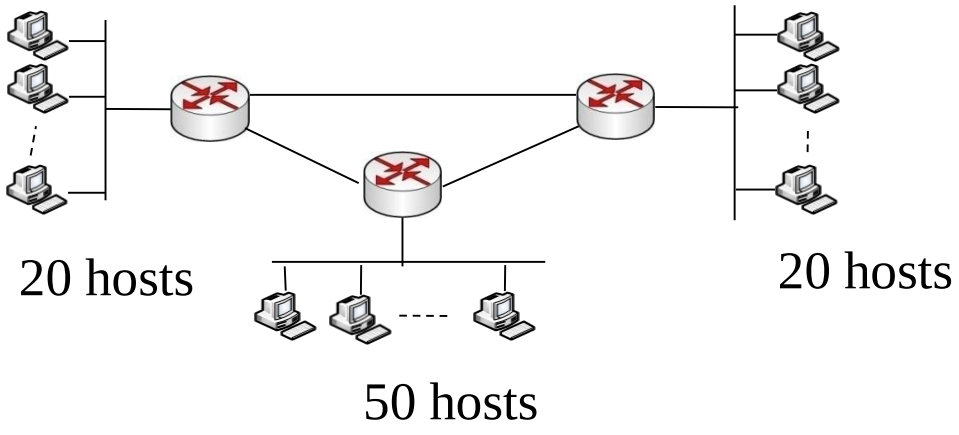
# VLSM (variable length subnet mask)

Subnet 192.168.1.0/24 to address this network by using the most efficient addressing possible.






192.168.1.0/24




192.168.1.0/24

- start with the largest subnet.
- Why start with the largest subnet? To avoid waste
- In real world, always leave room for growth
- /30 is commonly used for point-to-point WAN link/serial link between routers
- Only classless routing protocols support VLSM.

50= 00110010=6bits
Reserve 6 bits for hosts
Default subnet mask: 255.255.255.0/24=
11111111.11111111.11111111.00000000
New subnet mask;
255.255.254.0/26=111111111.11111111.11111111.11000000
Increment 64
192.168.1.0 - 192.168.1.63 (allocate to the largest subnet with 50 hosts: 192.168.1.0/26)
192.168.1.64 – 192.168.1.127
192.168.1.128 - …..
….

20=00010100 = 5 bits
Reserve 5 bits for hosts
Default subnet mask: 255.255.255.0/24 =
11111111.11111111.11111111.00000000
New subnet mask; 255.255.254.0/27=111111111.11111111.11111111.11100000
Increment 32
192.168.1.0 - 192.168.1.31 (already allocated)
192.168.1.32 – 192.168.1.63 (already allocated)
192.168.1.64 - 192.168.1.95 (allocate to the subnet with 20 hosts:
192.168.1.64/27)
192.168.1.96 – 192.168.1.127 (allocate to the other subnet with 20 hosts:
192.168.1.96/27)
192.168.1.128 - ….
…

2=00000010 = 2 bits
Reserve 2 bits for hosts
Default subnet mask: 255.255.255.0/24 =
11111111.11111111.11111111.00000000
New subnet mask;
255.255.254.0/30=111111111.11111111.11111111.11111100
Increment 4
192.168.1.0 - 192.168.1.3 (already allocated)
192.168.1.4 - 192.168.1.7
…..
192.168.1.128 -192.168.1.131 (allocated to link between routers:
192.168.1.128/30)
192.168.1.132 -192.168.1.135 (allocated to link between routers:
192.168.1.132/30)
192.168.1.136 -192.168.1.139 (allocated to link between routers:
192.168.1.136/30)

# DHCP: Dynamic Host Configuration Protocol

Q: How does a *host* get IP address?

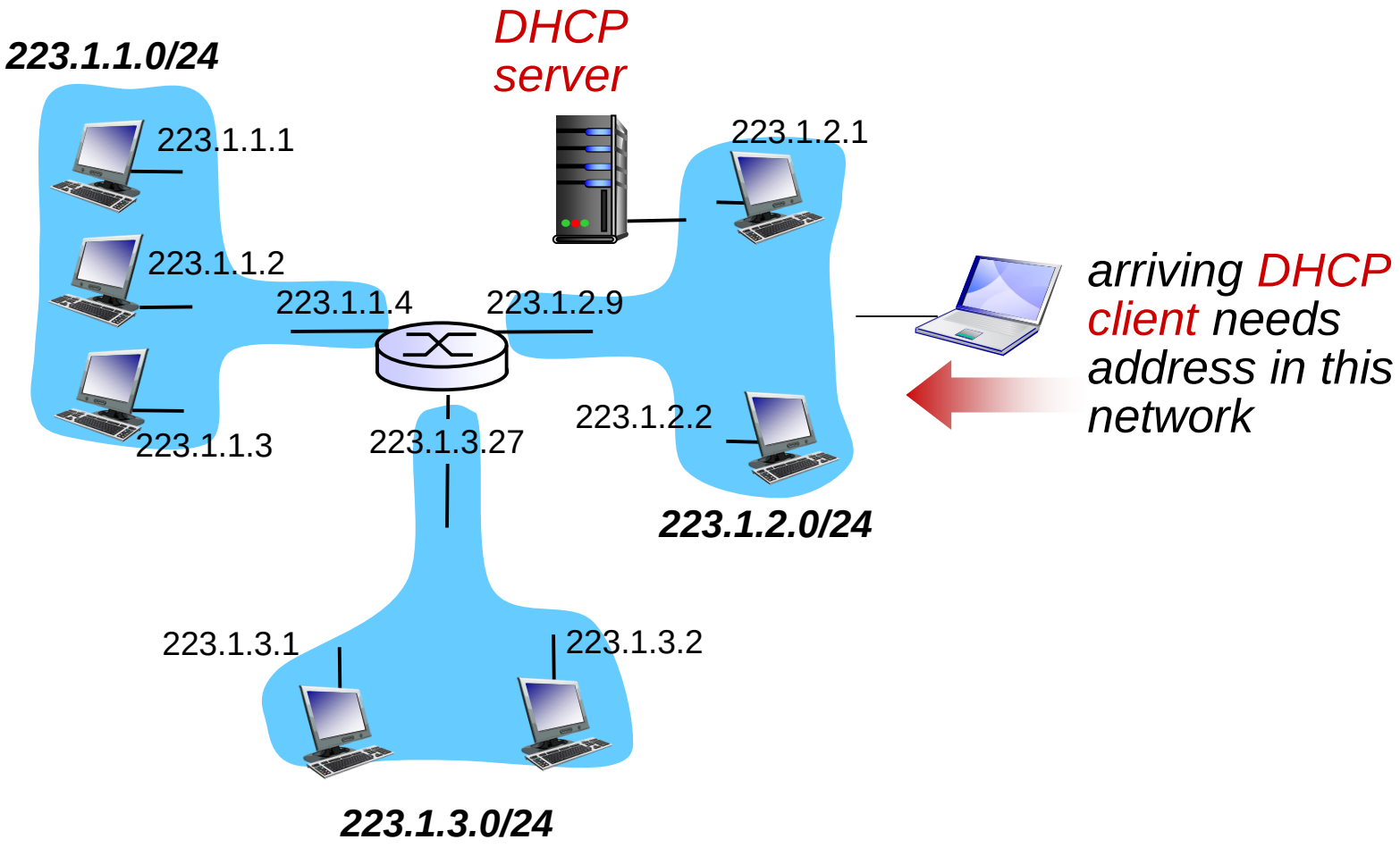
*goal:* allow host to *dynamically* obtain its IP address from network server when it joins network

- can renew its lease on address in use
- allows reuse of addresses (only hold address while connected/"on")
- support for mobile users who want to join network (more shortly)

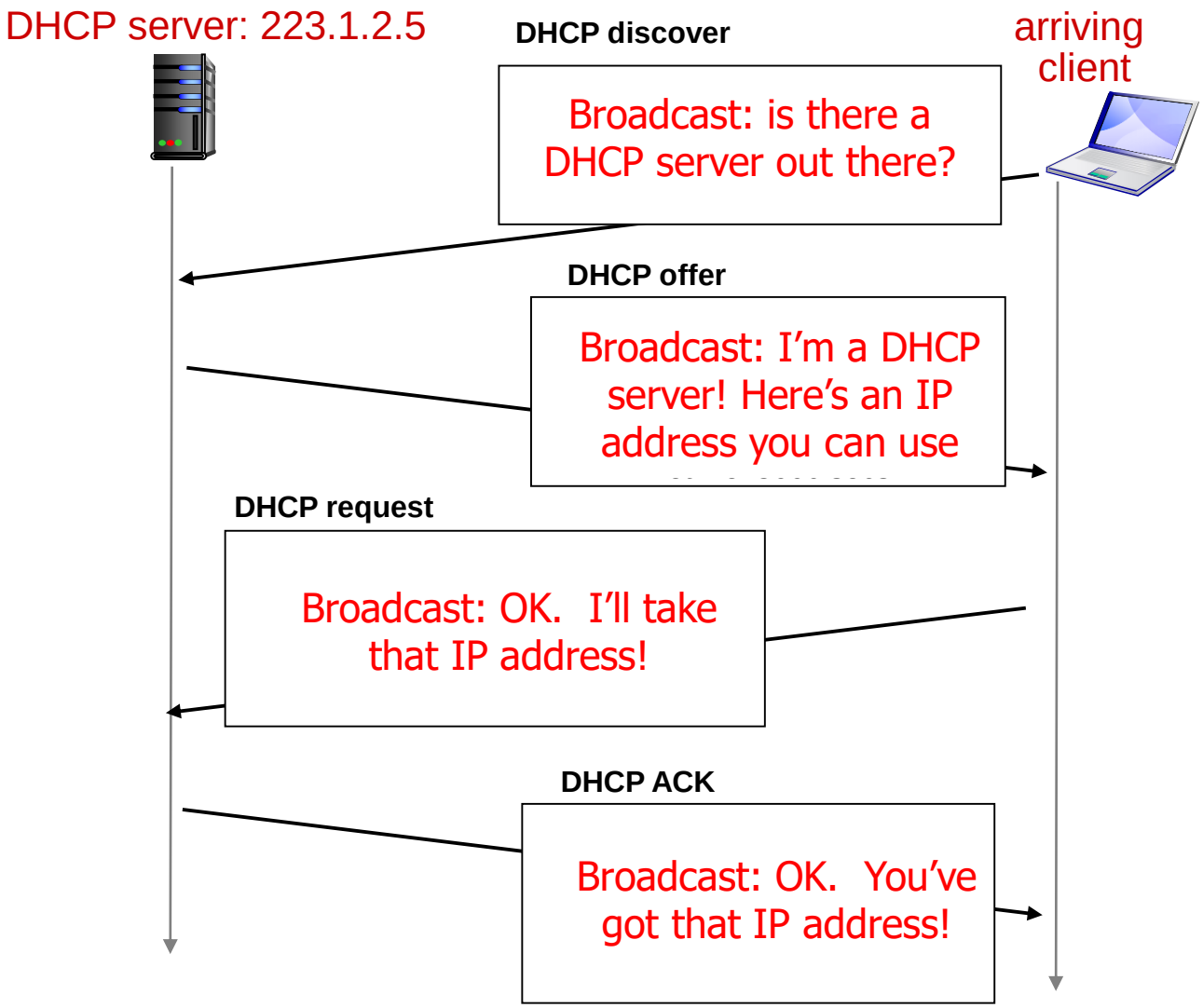
*DHCP overview:*

- host broadcasts "DHCP discover" msg [optional]
- DHCP server responds with "DHCP offer" msg [optional]
- host requests IP address: "DHCP request" msg
- DHCP server sends address: "DHCP ack" msg

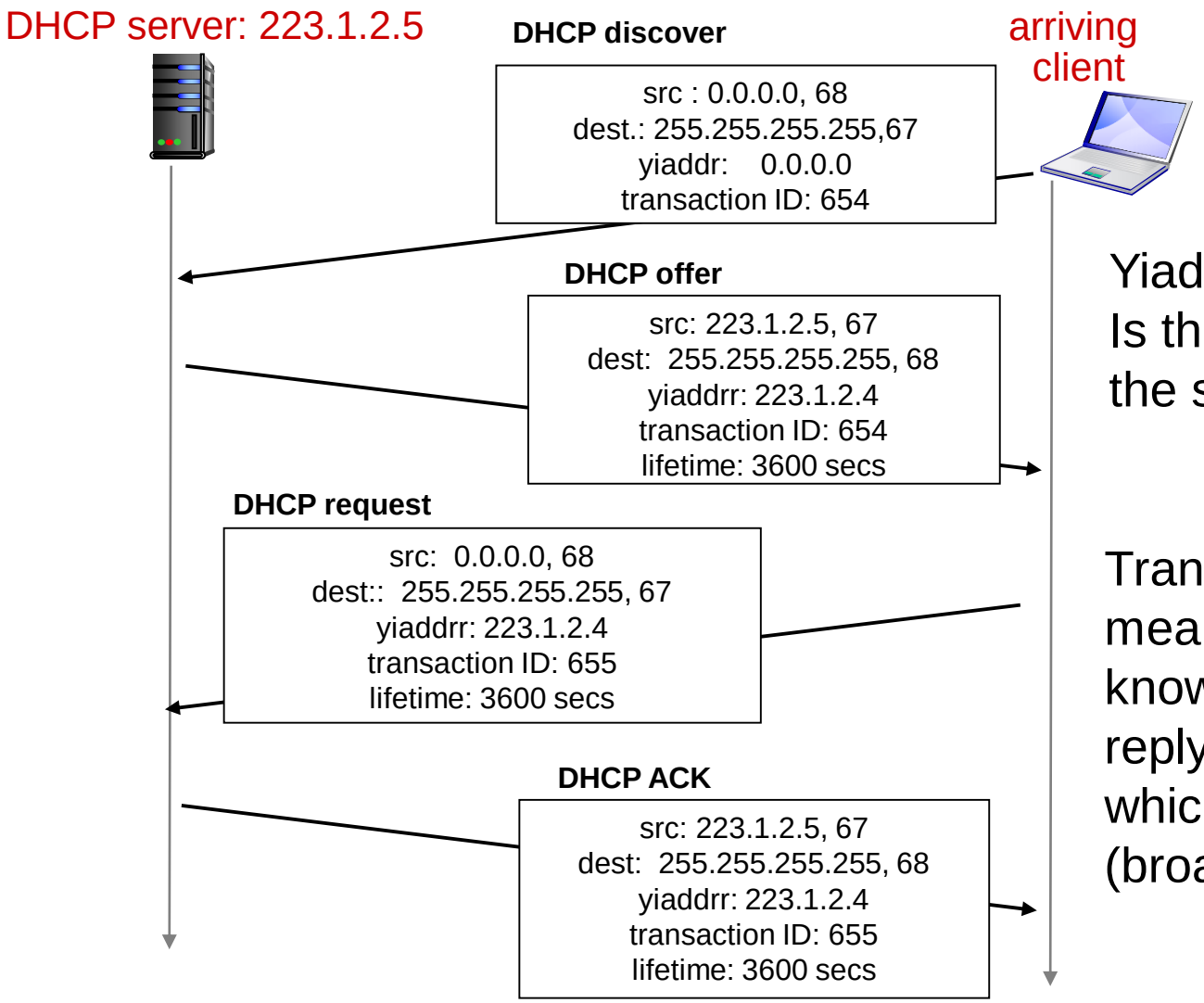
# DHCP client-server scenario



# DHCP client-server scenario



# DHCP client-server scenario




Yiaddrr
Is the IP address the server offers

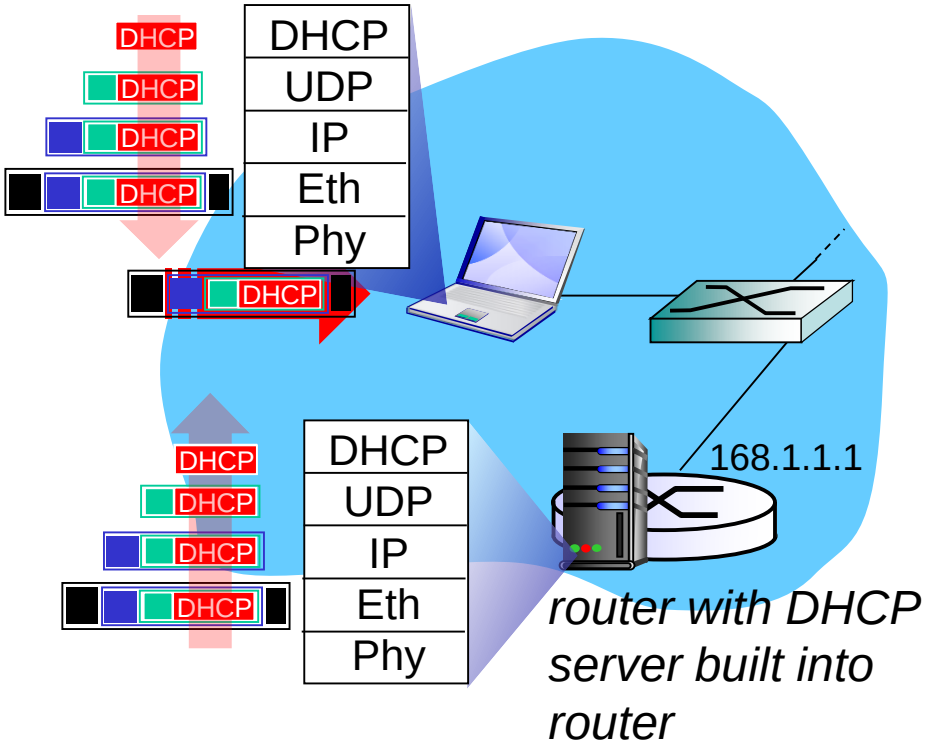
Transaction ID means client knows which reply goes with which request (broadcast)

# DHCP: more than IP addresses

DHCP can return more than just allocated IP address on subnet:

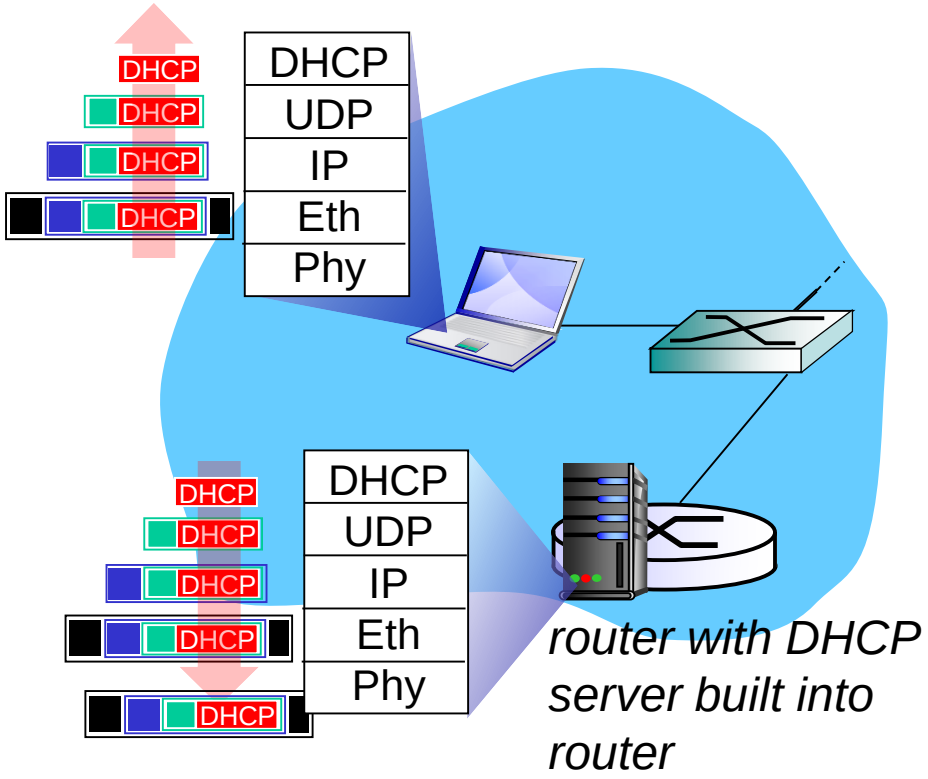
- address of first-hop router for client
- name and IP address of DNS sever
- network mask (indicating network versus host portion of address)

# DHCP: example




- connecting laptop needs its IP address, addr of first-hop router, addr of DNS server: use DHCP
- DHCP request encapsulated in UDP, encapsulated in IP, encapsulated in 802.1 Ethernet
- Ethernet frame broadcast (dest: FFFFFFFFFFFF) on LAN, received at router running DHCP server
- Ethernet demuxed to IP demuxed, UDP demuxed to DHCP

# DHCP: example




- DCP server formulates DHCP ACK containing client's IP address, IP address of first-hop router for client, name & IP address of DNS server
- encapsulation of DHCP server, frame forwarded to client, demuxing up to DHCP at client
- client now knows its IP address, name and IP address of DNS server, IP address of its first-hop router

# What have we learned?

- IPv4 addresses 4 dotted decimal numbers.
- The "slash" notation says which part of the IPv4 address is "network" and what is "host".
  - Example: 135.10.10.0/24 – first 24 bits are "network" that is 135.10.10.? all on same network
- Subnetting splits a network into several subnets.
- VLSM (variable length subnet mask) uses more than one mask for different subnets.
- We subnet most efficiently by picking the largest subnet first.
- DHCP (Dynamic Host Configuration Protocol) allows a host to get an IP address from the network it connects to.