CS 3251- Computer Networks 1: IP

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Lecture 12

9/26/13

Announcements

- I start every class with announcements.
  - That's why being here is important - things change!
- Project 2 - Due on 10/8/13
  - Some parts are intentionally ambiguous.
  - There is a lot of design and engineering work that needs to be done on this - *get started now.*
- Midterm - 10/22 - In Class

Last Time

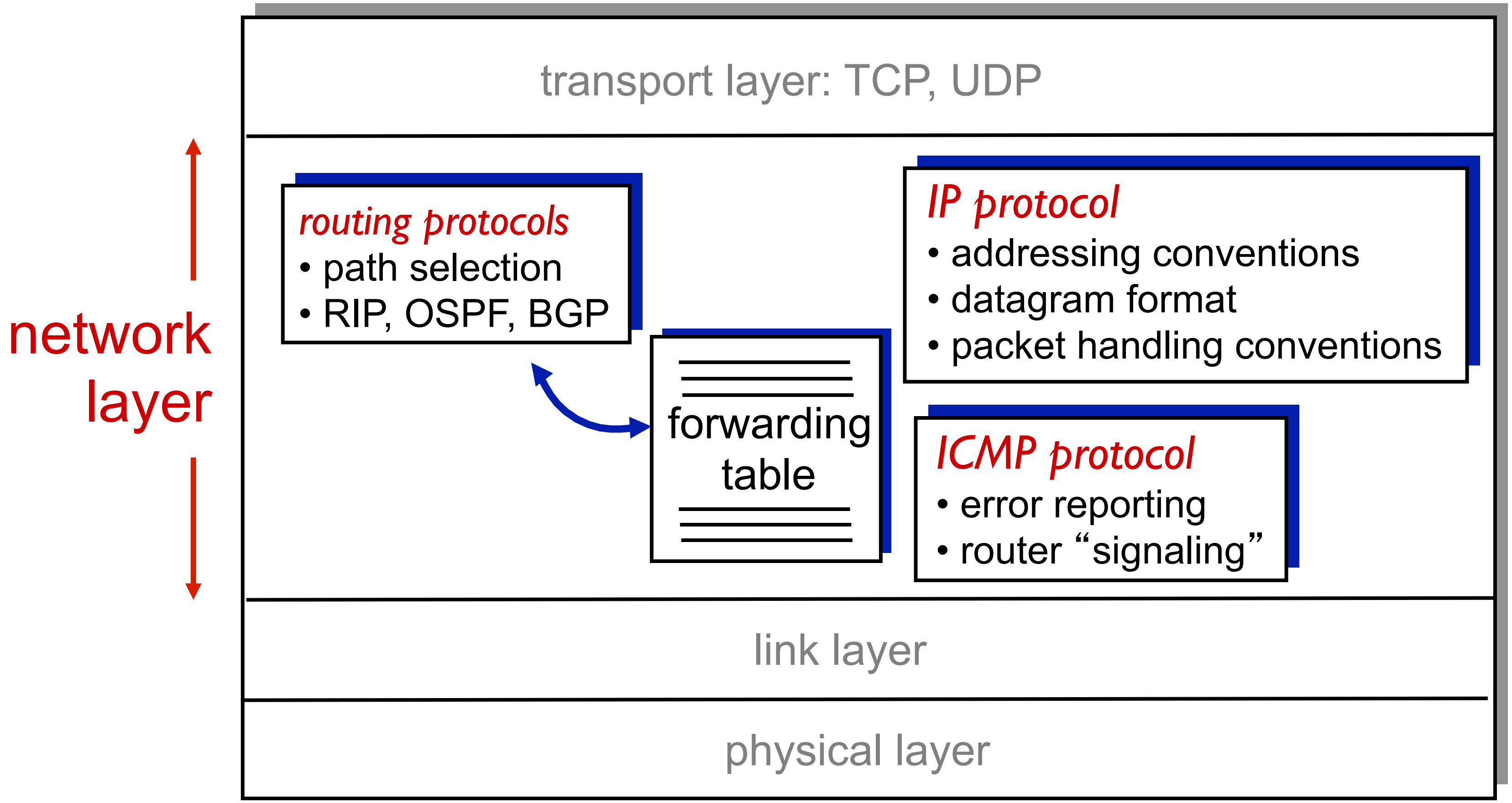
- What is forwarding? Routing?
- What's the difference between TCP and VC networks?
- What is longest prefix matching? How does it work?
- How do modern routers differ from first generation devices?

Chapter 4: Network Layer

- 4. 1 Introduction
- 4.2 Virtual circuit and datagram networks
- 4.3 What's inside a router
- 4.4 IP: Internet Protocol
  - Datagram format
  - IPv4 addressing
  - ICMP
  - IPv6
- 4.5 Routing algorithms
  - Link state
  - Distance Vector
  - Hierarchical routing
- 4.6 Routing in the Internet
  - RIP
  - OSPF
  - BGP
- 4.7 Broadcast and multicast routing

The Internet Network layer

Host, router network layer functions:



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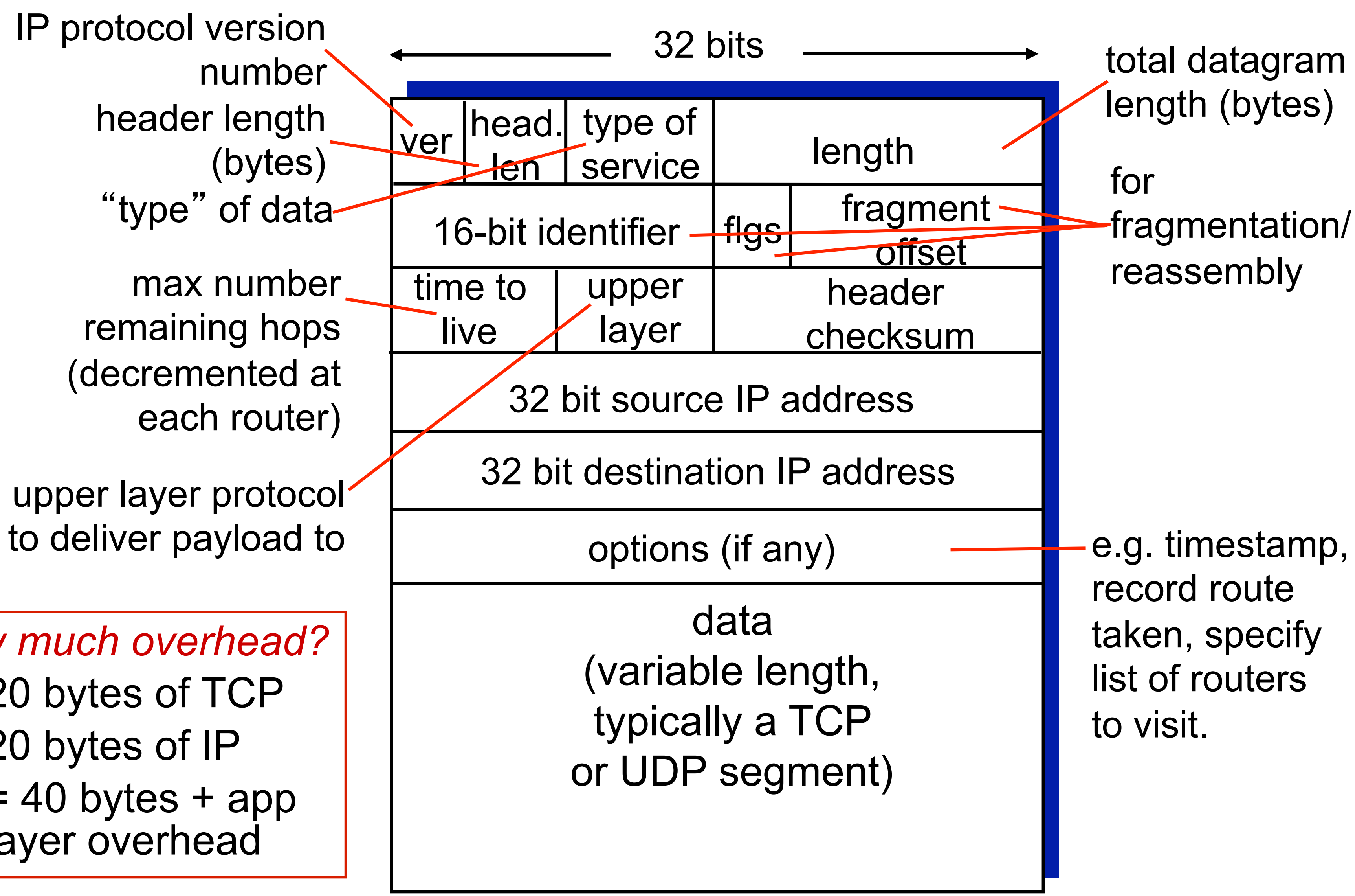
IP datagram format

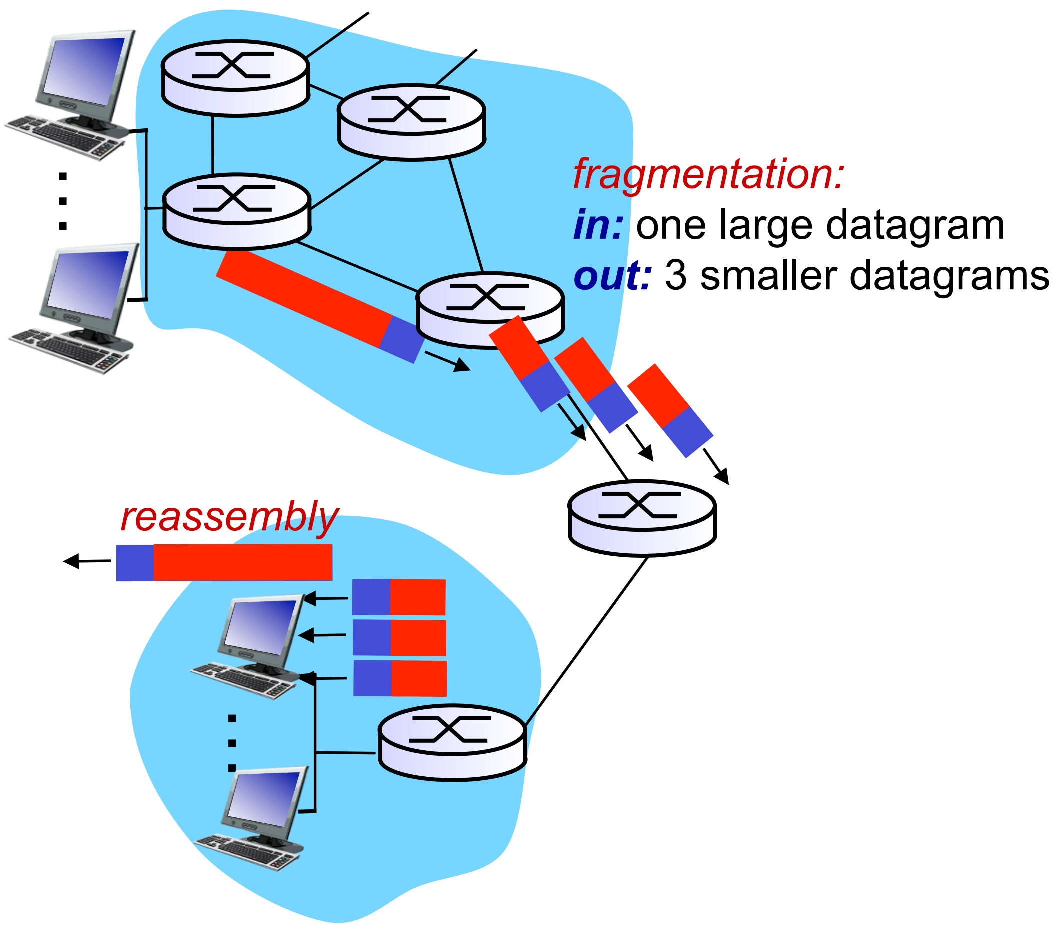


how much overhead?

- 20 bytes of TCP
- 20 bytes of IP
- = 40 bytes + app layer overhead

IP Fragmentation & Reassembly

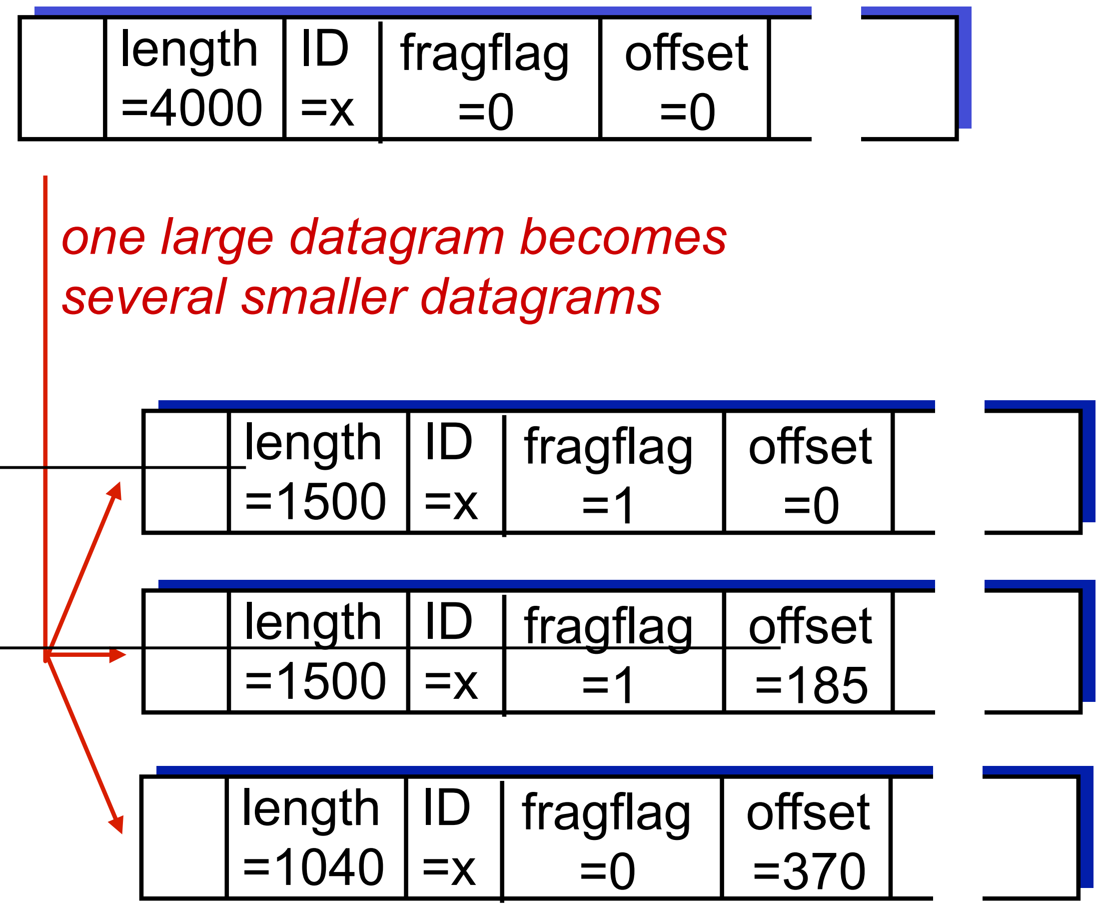
- network links have MTU (max.transfer size) - largest possible link-level frame.
  - different link types, different MTUs
- large IP datagram divided ("fragmented") within net
  - one datagram becomes several datagrams
  - "reassembled" only at final destination
  - IP header bits used to identify, order related fragments



IP Fragmentation and Reassembly

example:

- 4000 byte datagram
- MTU = 1500 bytes



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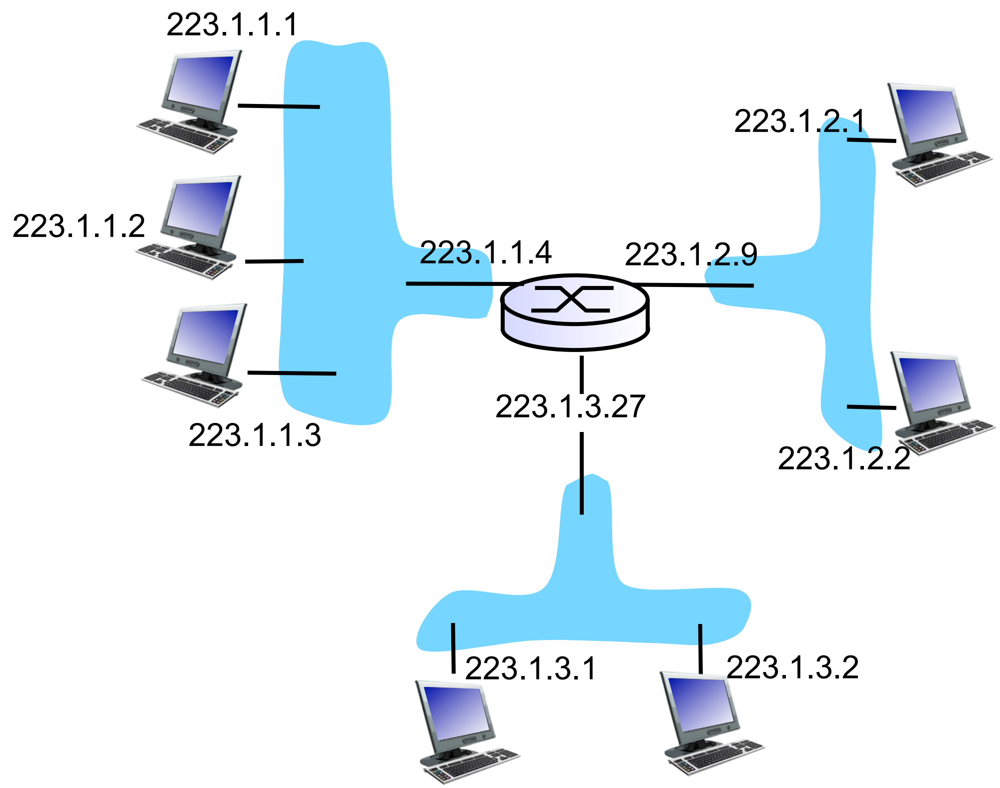
IP Addressing: Introduction

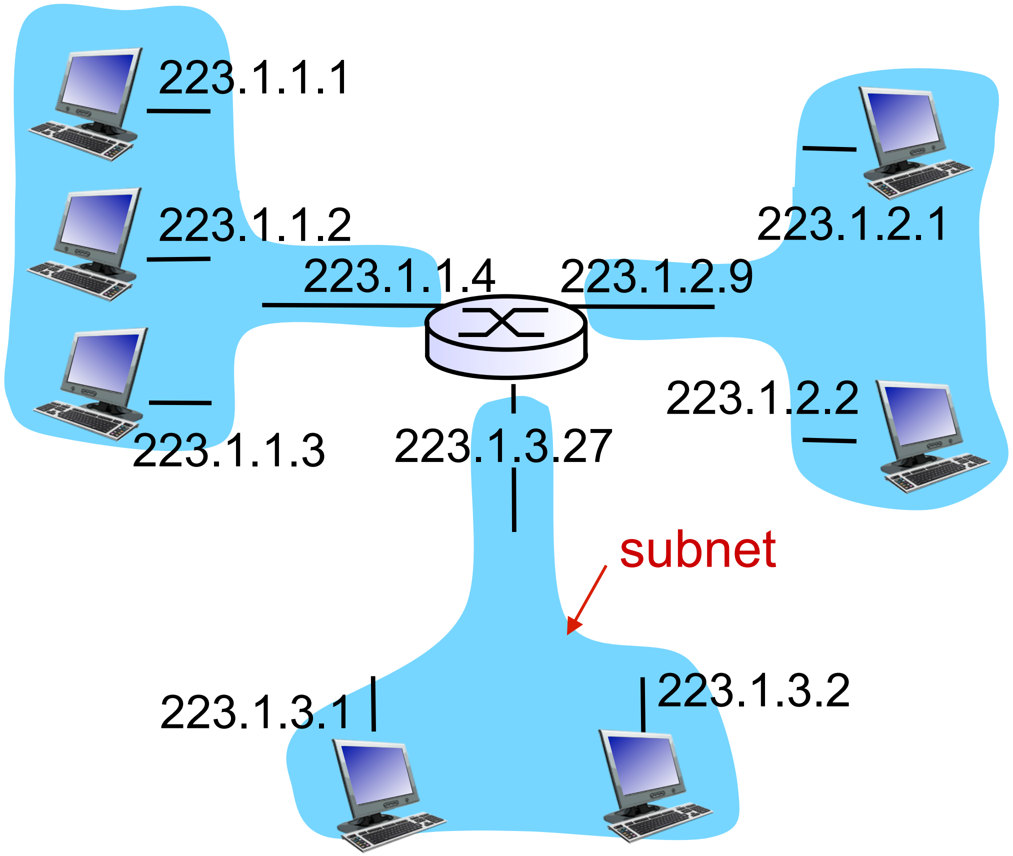
- IP address: 32-bit identifier for host, router *interface*
- interface: connection between host/router and physical link
  - routers typically have multiple interfaces
  - host typically has one interface
- IP addresses associated with *each* interface



223.1.1.1 = $\underbrace{11011111}_{223}\ \underbrace{00000001}_{1}\ \underbrace{00000001}_{1}\ \underbrace{00000001}_{1}$

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

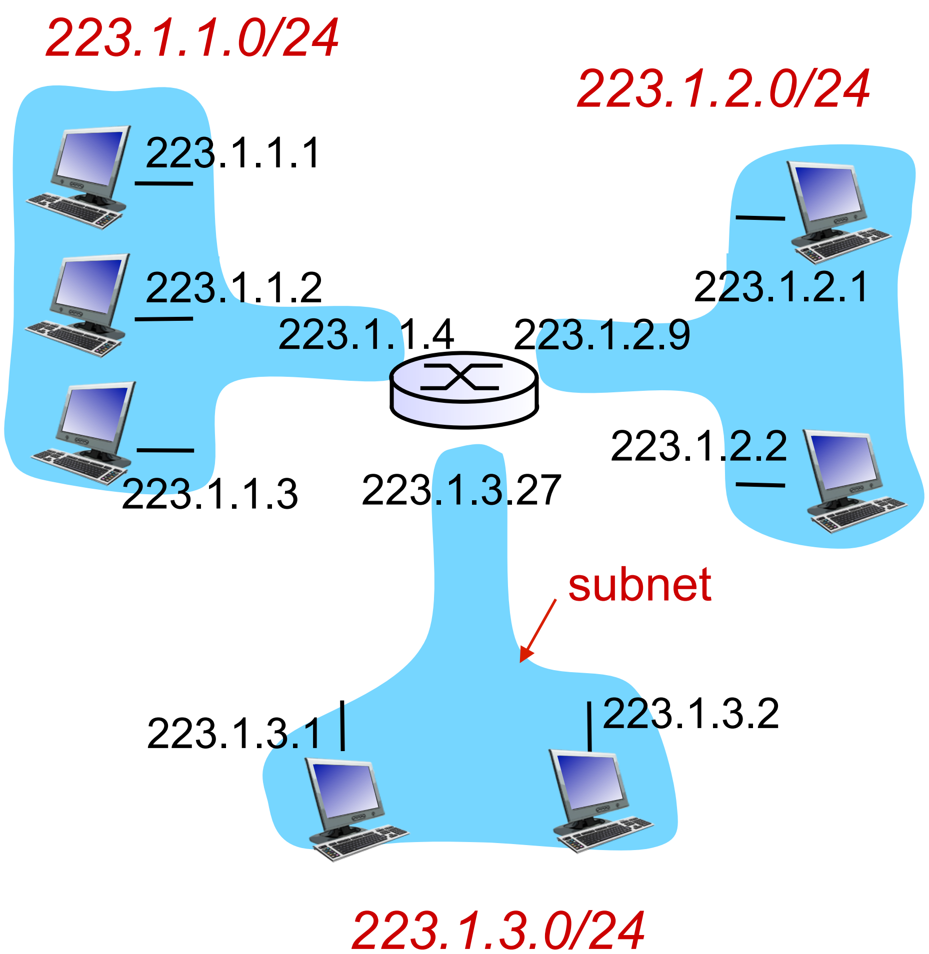


network consisting of 3 subnets

Subnets

Recipe

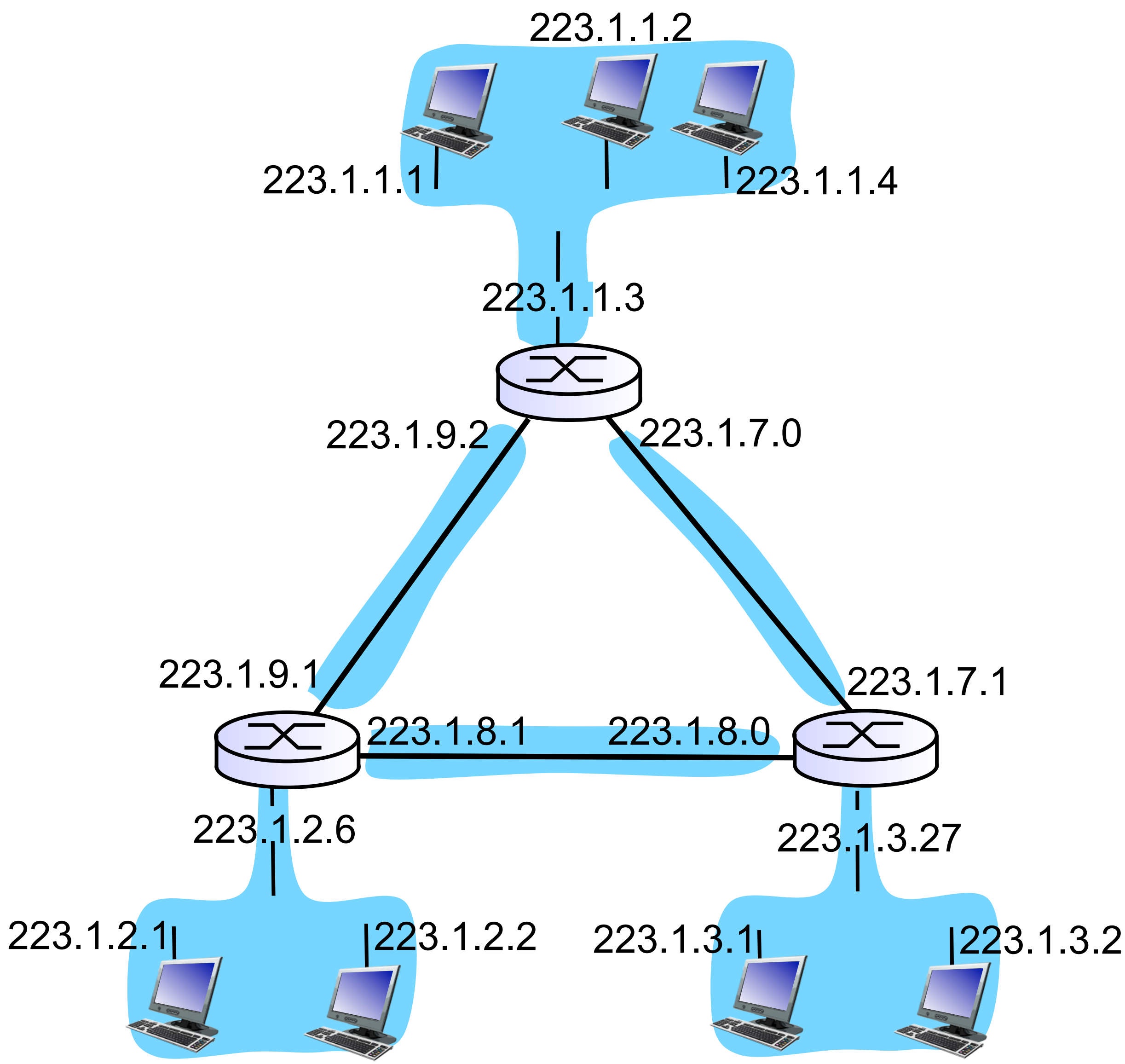
- To determine the subnets, detach each interface from its host or router, creating islands of isolated networks.
- Each isolated network is called a subnet.



Subnet mask: /24

Subnets

How many?



IP addressing: CIDR

CIDR: Classless InterDomain Routing

- subnet portion of address of arbitrary length
- address format: a.b.c.d/x, where x is # bits in subnet portion of address

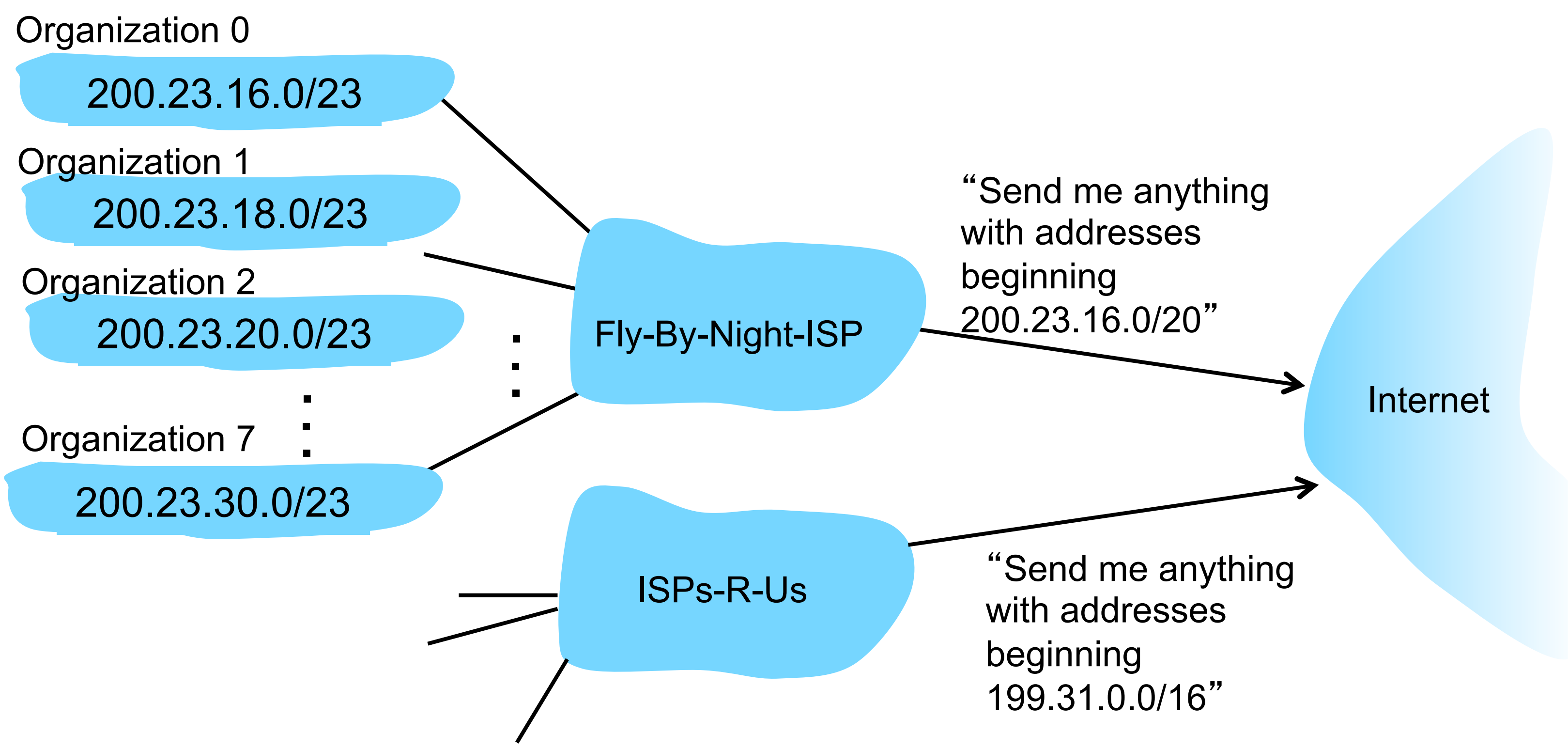
subnet part | host part

11001000 00010111 00010000 00000000

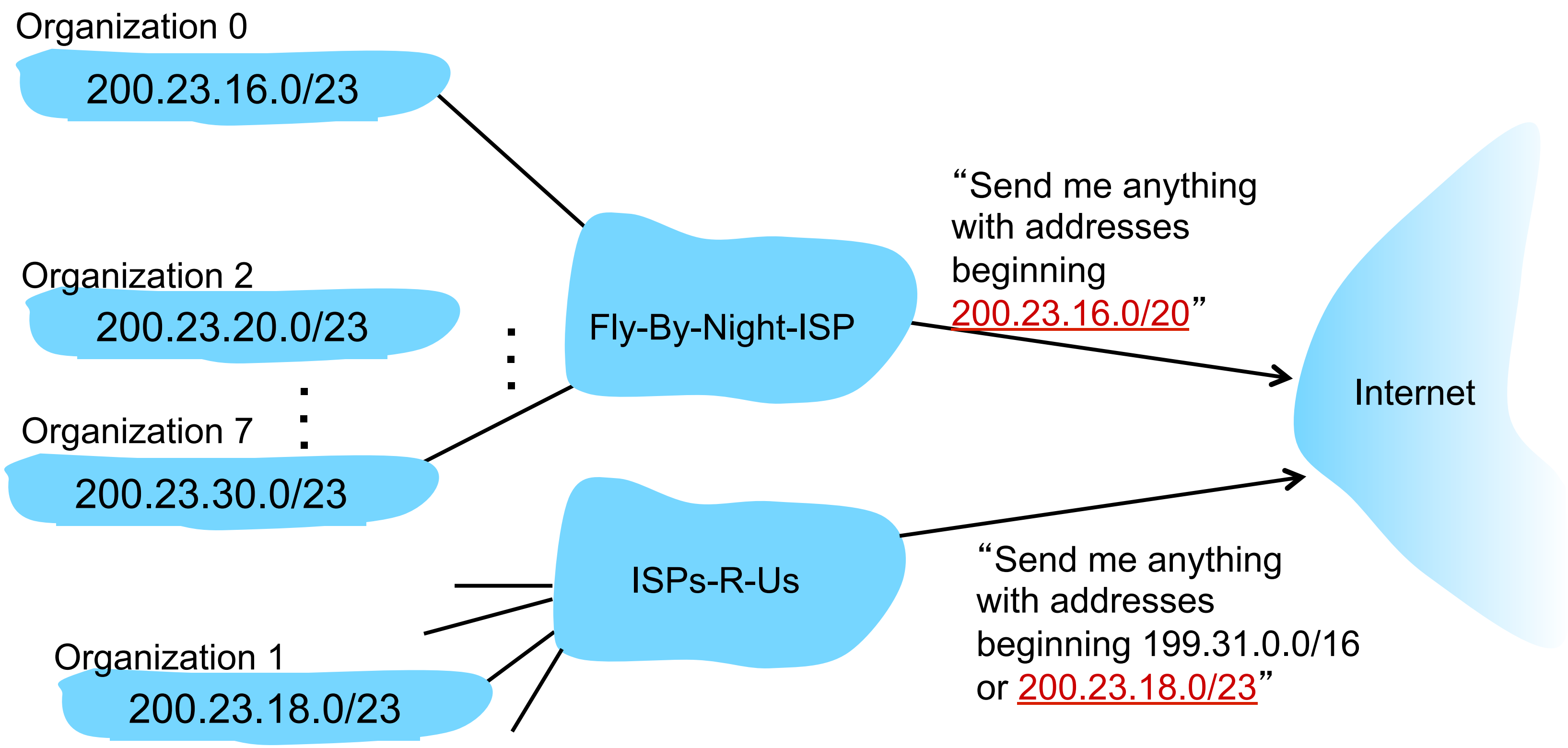
200.23.16.0/23

Hierarchical addressing: route aggregation

Hierarchical addressing allows efficient advertisement of routing information:



ISPs-R-Us has a more specific route to Organization 1



IP addresses: how to get one?

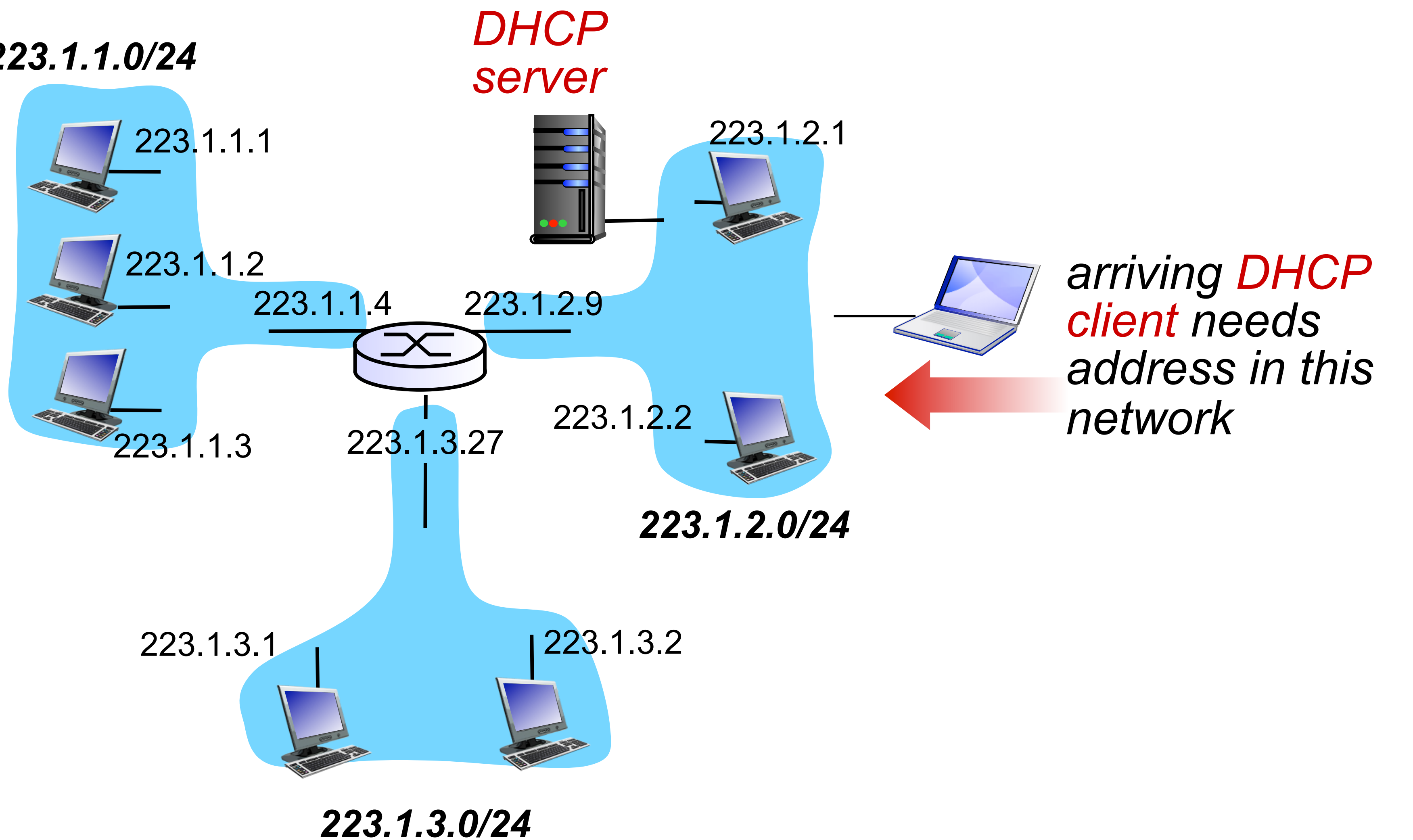
Q: How does a host get an IP address?

- hard-coded by system admin in a file
  - Windows: control-panel->network->configuration->tcp/ip->properties
  - UNIX: /etc/rc.config
- DHCP: Dynamic Host Configuration Protocol: dynamically get address from as server
  - "plug-and-play"

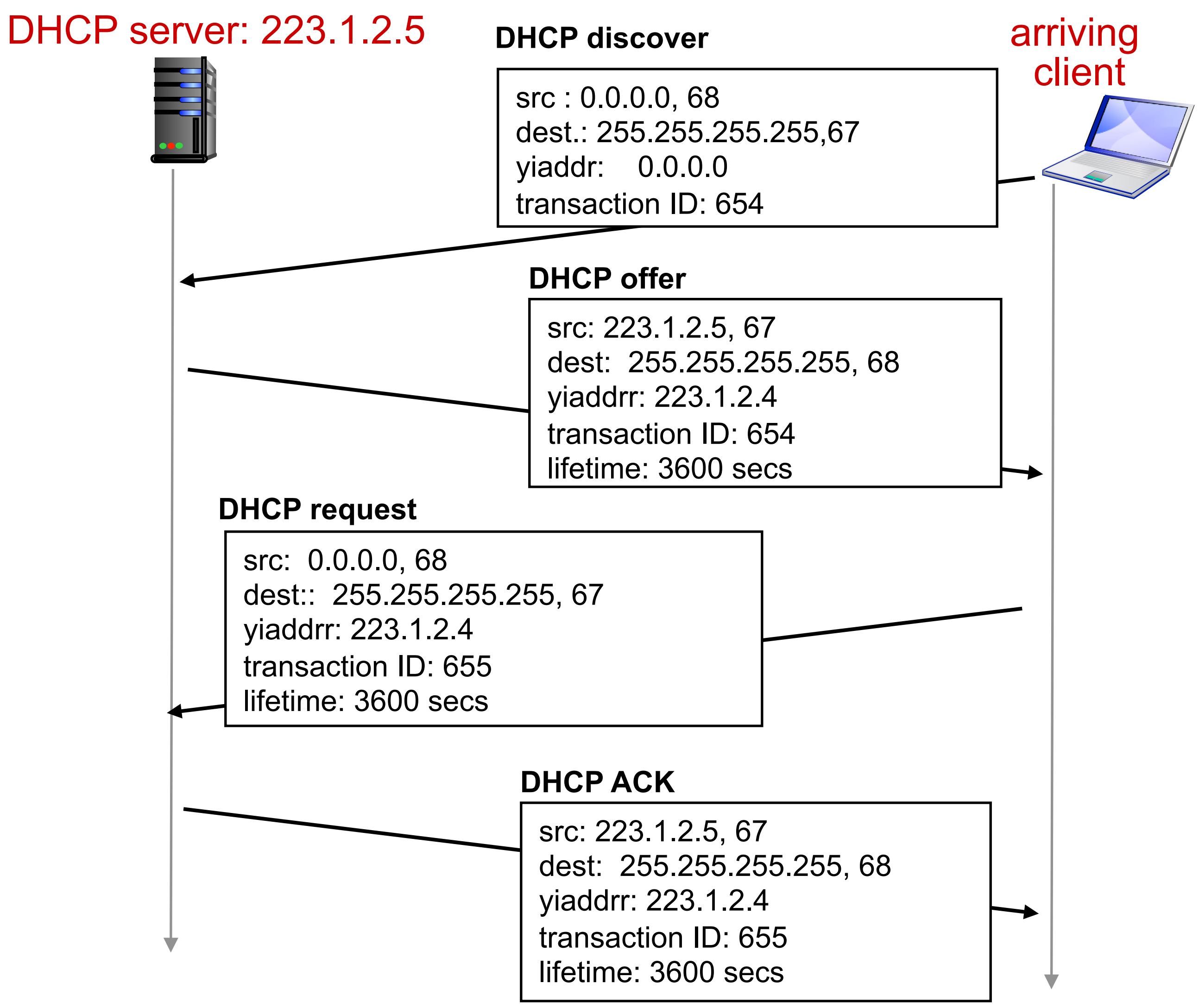
DHCP: Dynamic Host Configuration Protocol

- 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 an "on")
  - Support for mobile users who want to join network (more shortly)
- DHCP overview:
  - host broadcasts "DHCP discover" msg
  - DHCP server responds with "DHCP offer" msg
  - host requests IP address: "DHCP request" msg
  - DHCP server sends address: "DHCP ack" msg

DHCP client-server scenario



DHCP client-server scenario



DHCP: More than Just 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)

IP addresses: how to get one?

Q: How does a network get the 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

IP addressing: the last word...

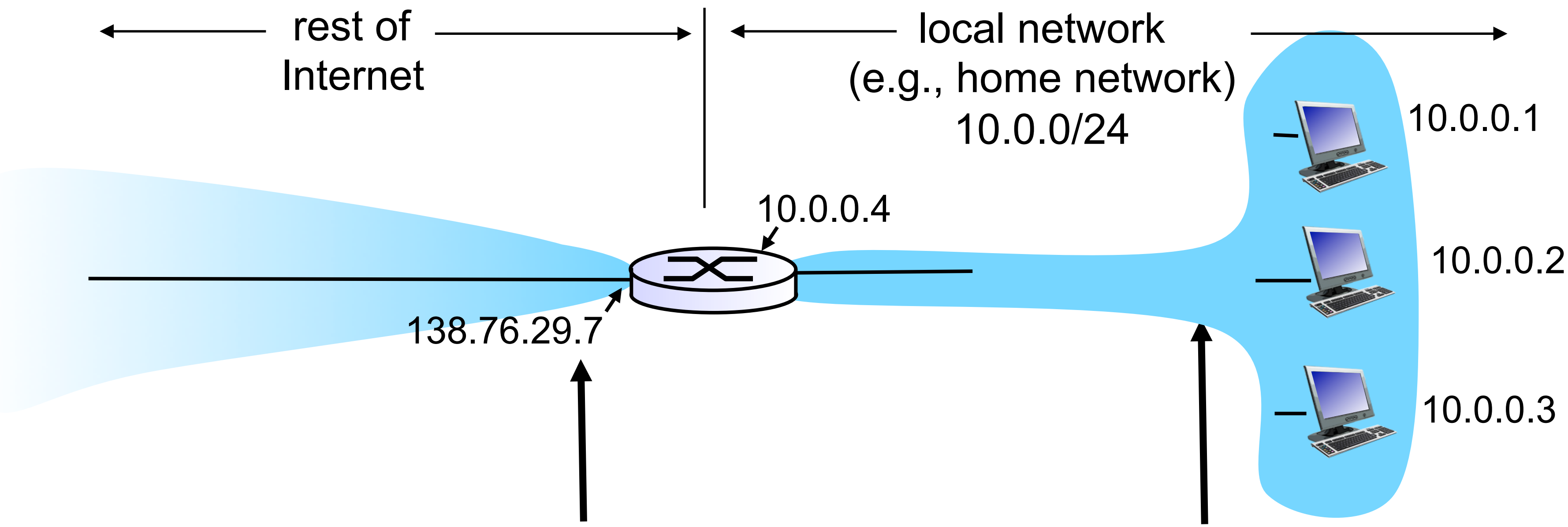
Q: How does an ISP get block of addresses?

A: ICANN: Internet Corporation for Assigned Names and Numbers

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

ICANN
The Internet Corporation for Assigned Names and Numbers

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 world is concerned:
  - range of addresses not needed from ISP: just one IP address 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:

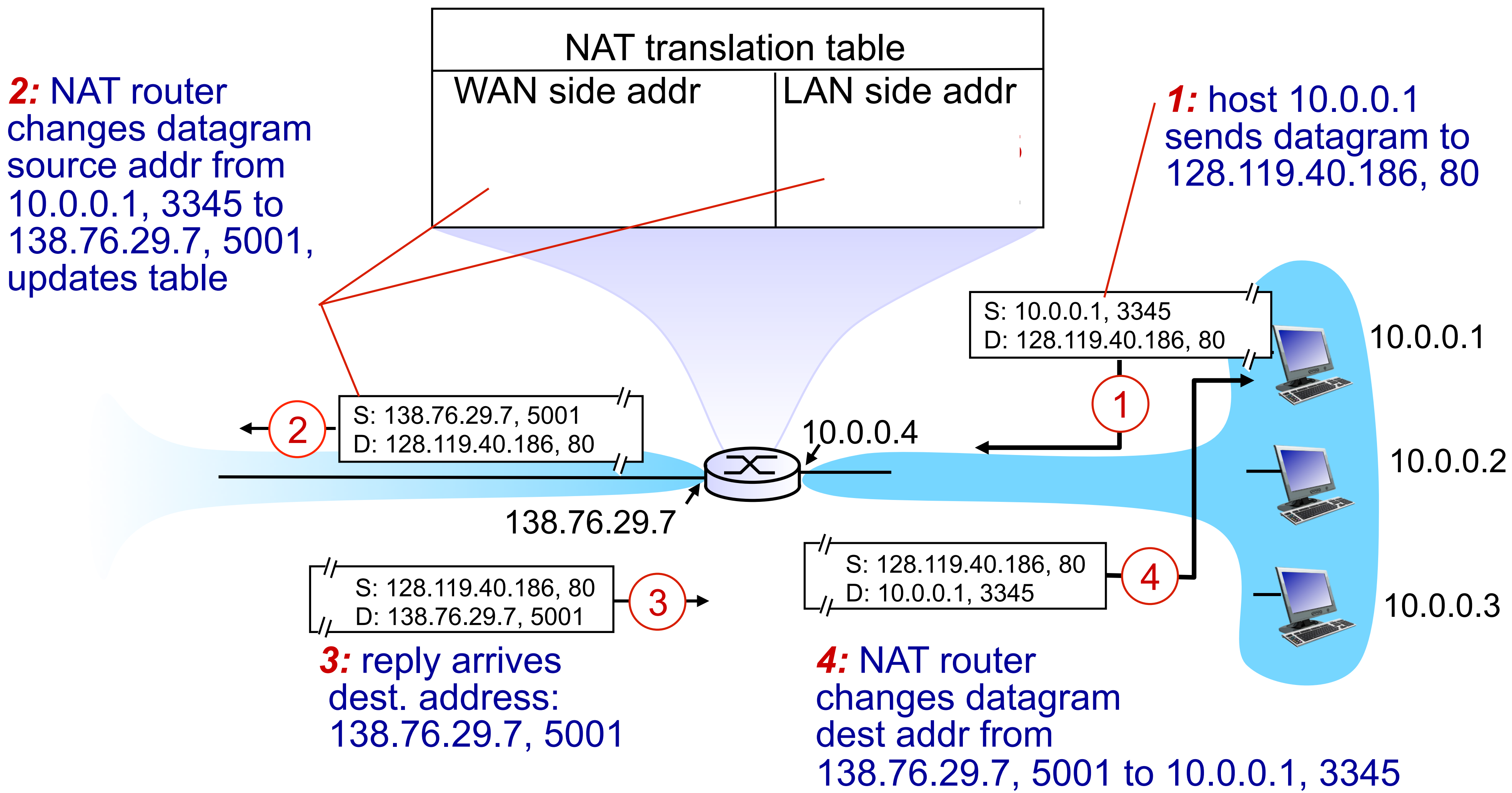
- outgoing datagrams: replace (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)

  . . . 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

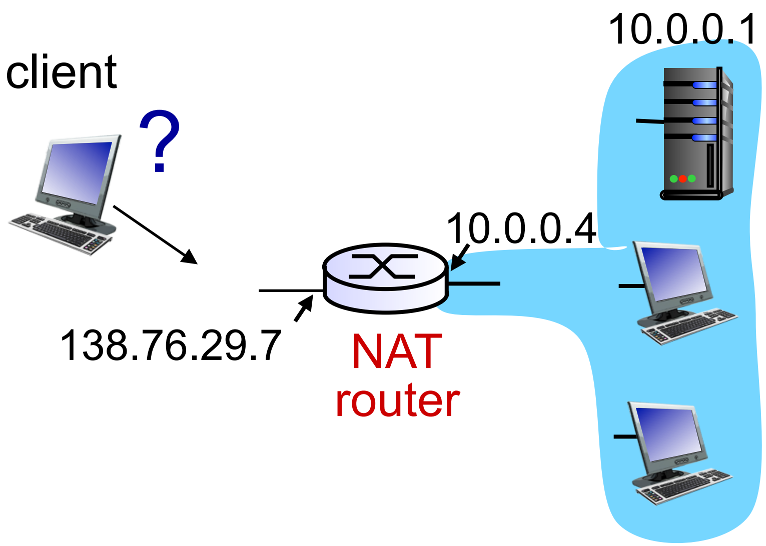


NAT: Network Address Translation

- 16-bit port-number field:
  - 60,000 simultaneous connections with a single LAN-side address!
- NAT is controversial:
  - routers should only process up to layer 3
  - violates end-to-end argument
    - NAT possibility must be taken into account by app designers, eg, P2P applications
  - address shortage should instead be solved by IPv6
    - Anything happen recently to make you argue against this?

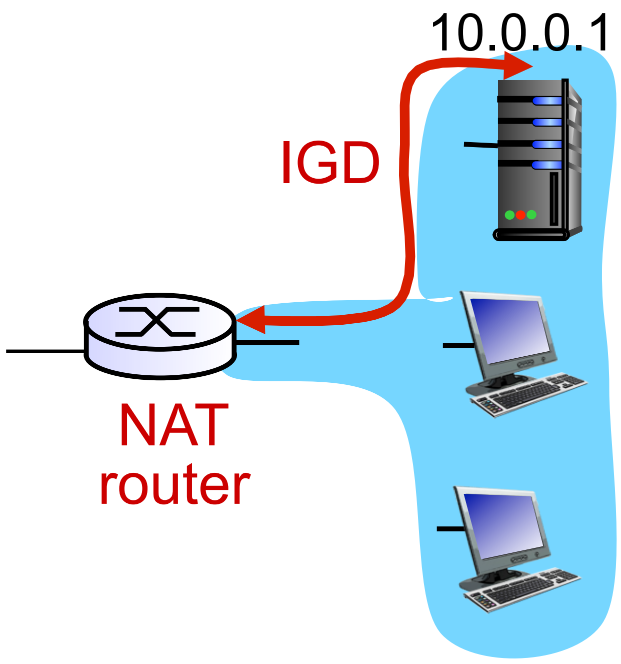
NAT traversal problem

- client wants to connect to server with address 10.0.0.1
  - server address 10.0.0.1 local to LAN (client can't use it as destination addr)
  - only one externally visible NATted address: 138.76.29.7
- Solution 1: statically configure NAT to forward incoming connection requests at given port to server
  - e.g., (123.76.29.7, port 2500) always forwarded to 10.0.0.1 port 25000



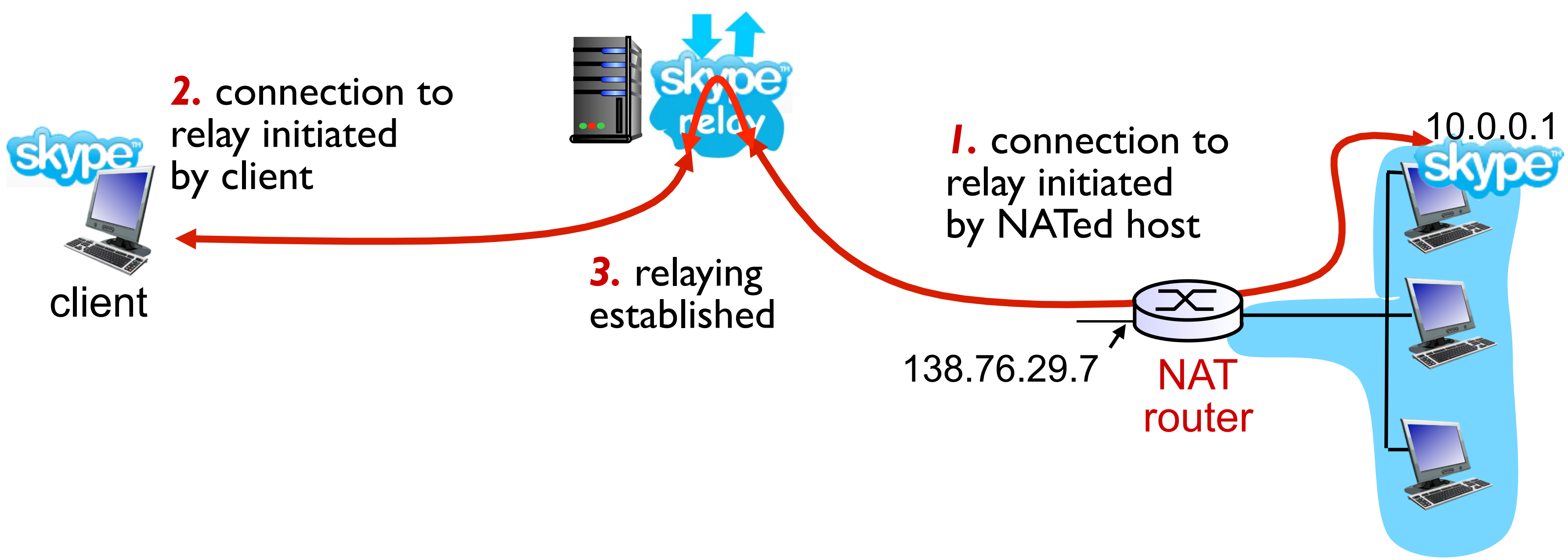
NAT traversal problem

- Solution 2: Universal Plug and Play (UPnP) Internet Gateway Device (IGD) Protocol. Allows NATted host to:
  - learn public IP address (138.76.29.7)
  - add/remove port mappings (with lease times)
- i.e., automate static NAT port map configuration



NAT traversal problem

- Solution 3: relaying (used in Skype)
  - NATed client establishes connection to relay
  - External client connects to relay
  - relay bridges packets between to connections



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ICMP: Internet Control Message Protocol

- used by hosts & routers to communicate network-level information
  - error reporting: unreachable host, network, port, protocol
  - echo request/reply (used by ping)
- network-layer "above" IP:
  - ICMP msgs carried in IP datagrams
- ICMP message: type, code plus first 8 bytes of IP datagram causing error

Type	Code	description
0	0	echo reply (ping)
3	0	dest. network unreachable
3	1	dest host unreachable
3	2	dest protocol unreachable
3	3	dest port unreachable
3	6	dest network unknown
3	7	dest host unknown
4	0	source quench (congestion control - not used)
8	0	echo request (ping)
9	0	route advertisement
10	0	router discovery
11	0	TTL expired
12	0	bad IP header

Traceroute and ICMP

- Source sends series of UDP segments to dest
  - First has TTL =1
  - Second has TTL=2, etc.
  - Unlikely port number
- When nth datagram arrives to nth router:
  - Router discards datagram
  - And sends to source an ICMP message (type 11, code 0)
  - Message includes name of router& IP address

- When ICMP message arrives, source calculates RTT
- Traceroute does this 3 times

Stopping criterion

- UDP segment eventually arrives at destination host
- Destination returns ICMP "host unreachable" packet (type 3, code 3)
- When source gets this ICMP, stops.

Smurf Attack

- ICMP Messages can be used in a classic "amplification" attack.
- An ICMP "ping" is sent to the broadcast address in a subnet (255.255.255.255) or network (192.168.1.255).
- All hosts receiving this message would automatically respond, thereby clogging the network.
  - Only took one message to initiate.

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IPv6

- Initial motivation: 32-bit address space soon to be completely allocated.
- Additional motivation:
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS

IPv6 datagram format:

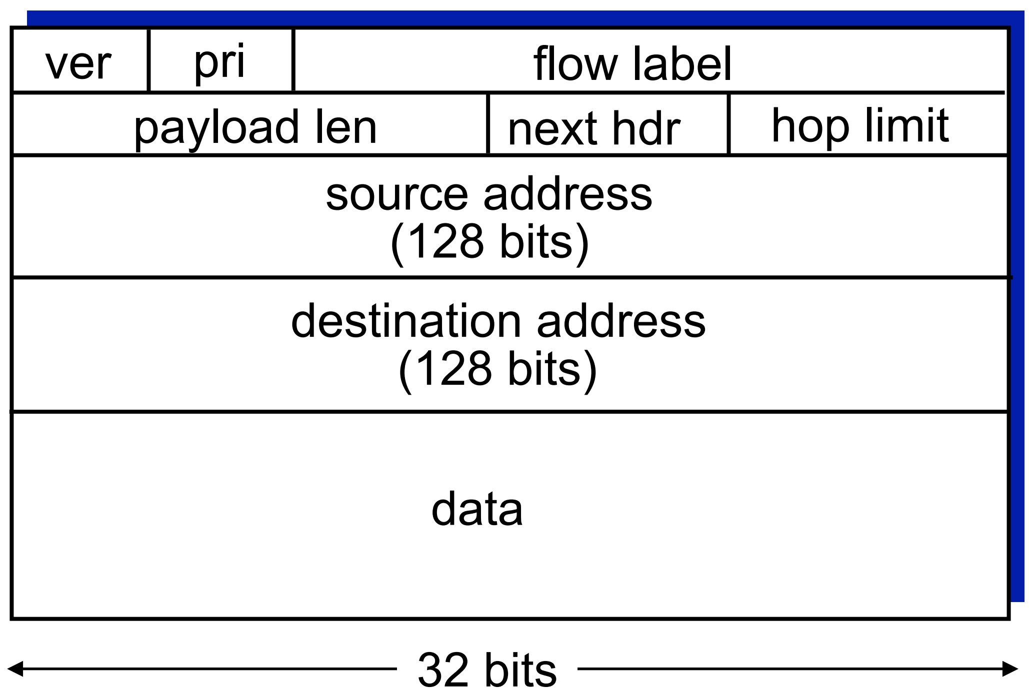
  - fixed-length 40 byte header
  - no fragmentation allowed

IPv6 Header (Cont)

Priority: identify priority among datagrams in flow

Flow Label: identify datagrams in same "flow."
(concept of "flow" not well defined).

Next header: identify upper layer protocol for data

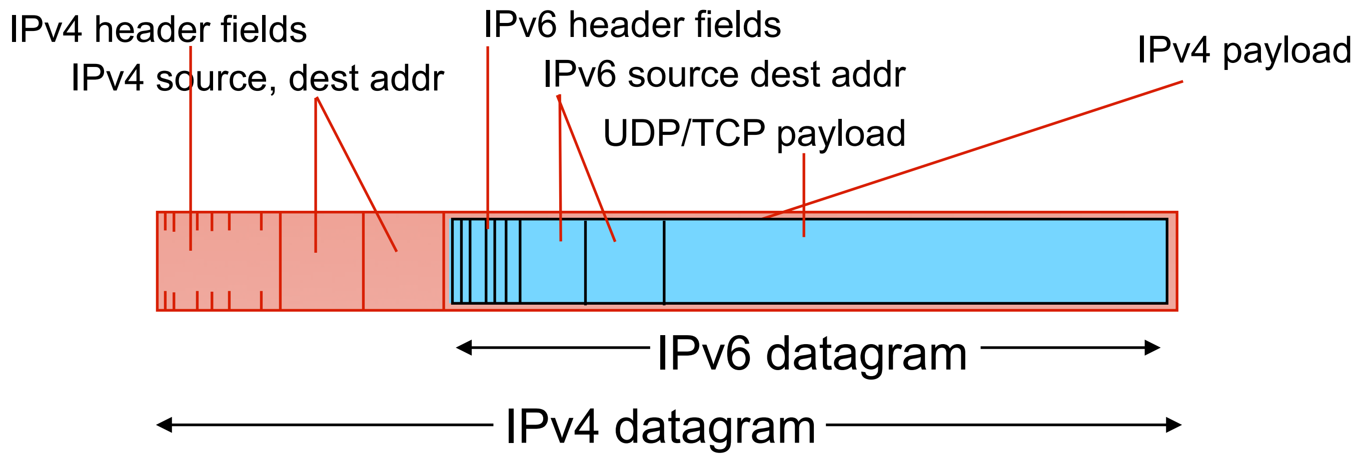


Other Changes from IPv4

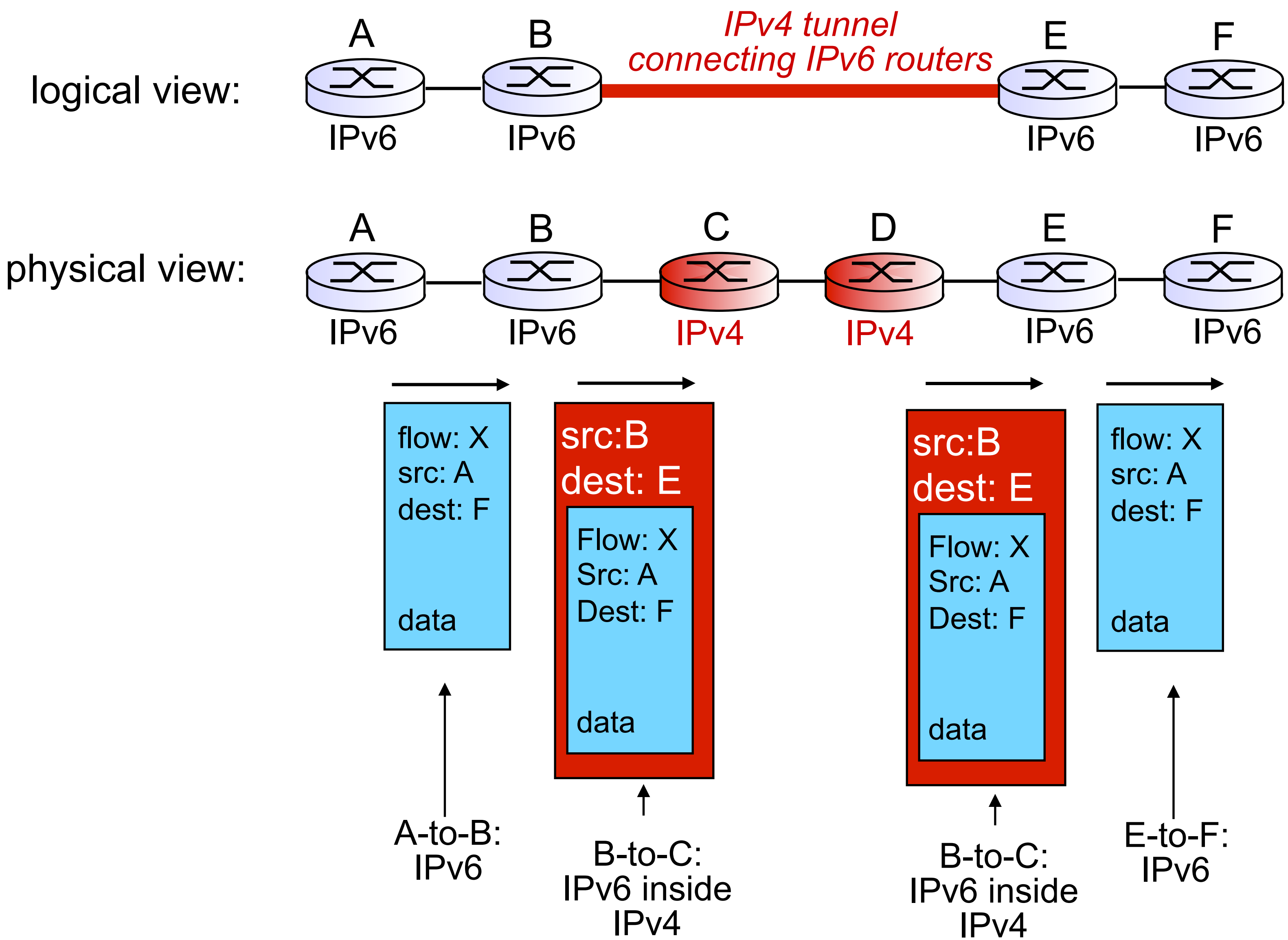
- Checksum: removed entirely to reduce processing time at each hop
- Options: allowed, but outside of header, indicated by "Next Header" field
- ICMPv6: new version of ICMP
    - additional message types, e.g. "Packet Too Big"
    - multicast group management functions

Transition From IPv4 To IPv6

- Not all routers can be upgraded simultaneous
  - no "flag days"
  - How will the network operate with mixed IPv4 and IPv6 routers?
- Tunneling: IPv6 carried as payload in IPv4 datagram among IPv4 routers



Tunneling


logical view:
A
B
IPv4 tunnel connecting IPv6 routers
E
F
IPv6
IPv6
IPv6
IPv6
physical view:
A
B
C
D
E
F
IPv6
IPv6
IPv4
IPv4
IPv6
IPv6
flow: X
src: A
dest: F
data
src:B
dest: E
Flow: X
Src: A
Dest: F
data
src:B
dest: E
Flow: X
Src: A
Dest: F
data
flow: X
src: A
dest: F
data
A-to-B: IPv6
B-to-C: IPv6 inside IPv4
B-to-C: IPv6 inside IPv4
E-to-F: IPv6

Next Time

- Read Section 4.5
  - Routing algorithms - this is important stuff
- Check that course calendar?
  - Haven't started Homework 2 and Project 2? Good luck!