Chapter 4: Network Layer

Chapter goals:

- understand principles behind network layer services:
  - network layer service models
  - forwarding versus routing
  - how a router works
  - routing (path selection)
  - dealing with scale
  - advanced topics: IPv6, mobility
- instantiation, implementation in the Internet

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  - Distance Vector
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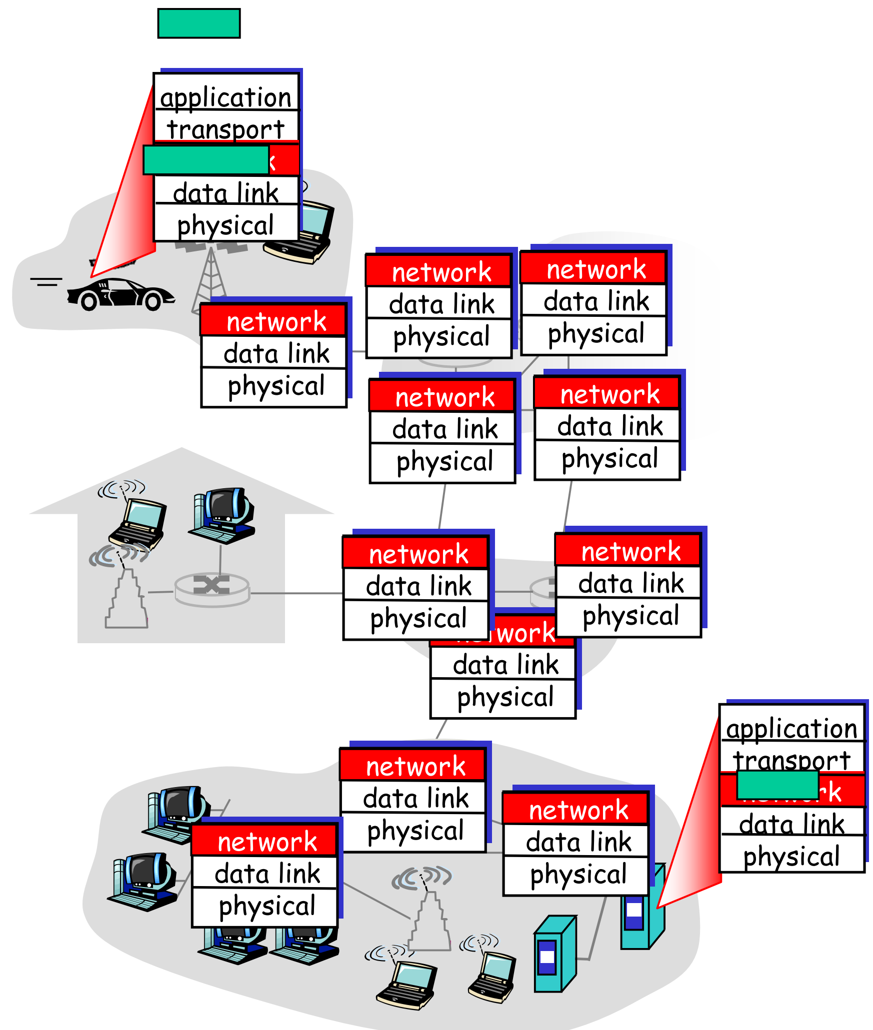
  - RIP
  - OSPF
  - BGP
- 4.7 Broadcast and multicast routing

Network layer

- transport segment from sending to receiving host
- on sending side encapsulates segments into datagrams
- on rcving side, delivers segments to transport layer
- network layer protocols in *every* host, router
- router examines header fields in all IP datagrams passing through it



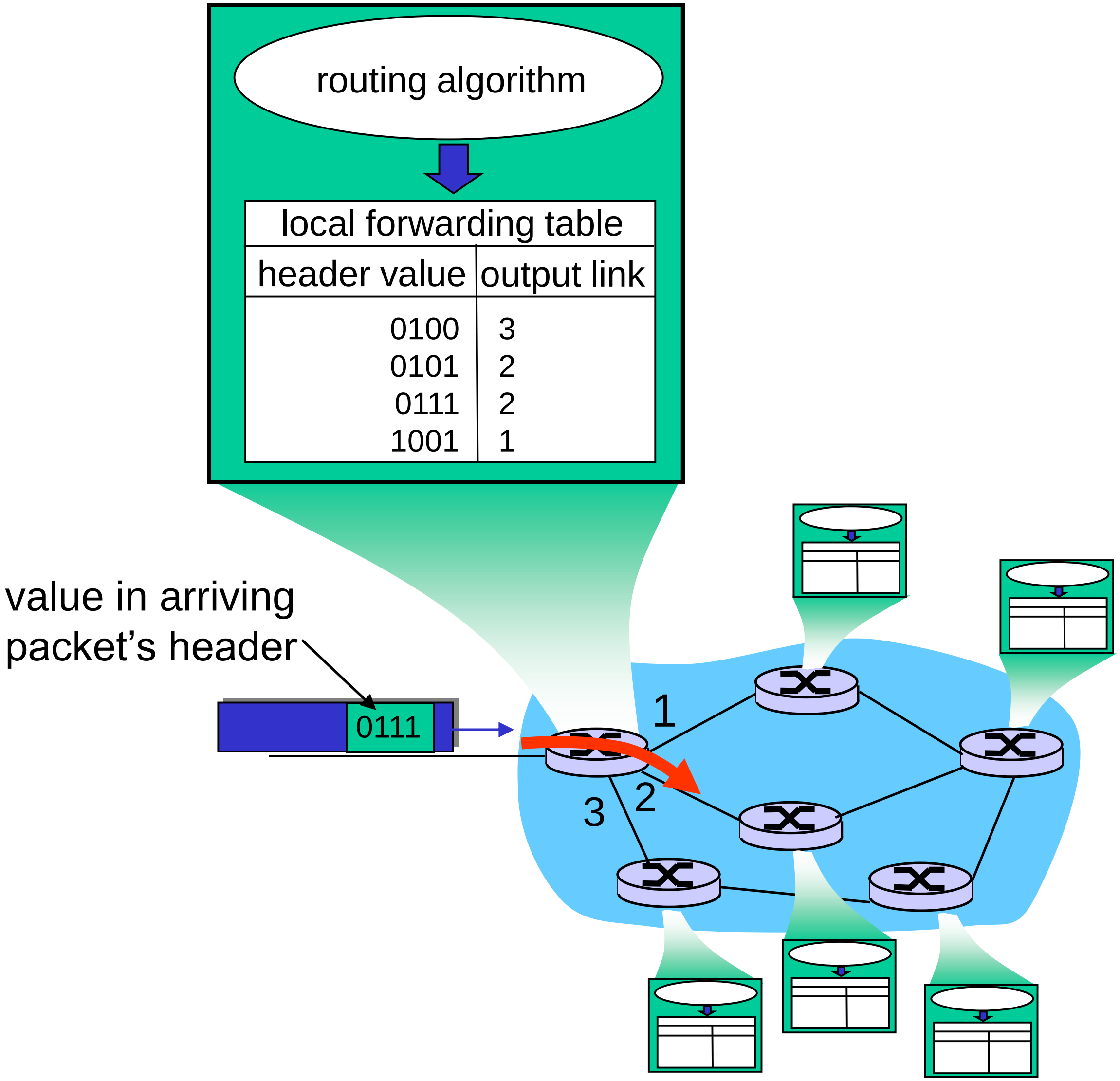
Two Key Network-Layer Functions

- *forwarding:* move packets from router's input to appropriate router output
- *routing:* determine route taken by packets from source to dest.
  - *routing algorithms*

analogy:

- routing: process of planning trip from source to dest
- forwarding: process of getting through single interchange

Interplay between routing and forwarding



Connection setup

- 3rd important function in *some* network architectures:
  - ATM, frame relay, X.25
- before datagrams flow, two end hosts *and* intervening routers establish virtual connection
  - routers get involved
- network vs transport layer connection service:
  - network: between two hosts (may also involve intervening routers in case of VCs)
  - transport: between two processes

Network service model

Q: What *service model* for "channel" transporting datagrams from sender to receiver?

Example services for individual datagrams:

- guaranteed delivery
- guaranteed delivery with less than 40 msec delay

Example services for a flow of datagrams:

- in-order datagram delivery
- guaranteed minimum bandwidth to flow
- restrictions on changes in inter-packet spacing

Network layer service models:

Network Architecture	Service Model	Guarantees ? Bandwidth	Loss	Order	Timing	Congestion feedback
Internet	best effort	none	no	no	no	no (inferred via loss)
ATM	CBR	constant rate	yes	yes	yes	no congestion
ATM	VBR	guaranteed rate	yes	yes	yes	no congestion
ATM	ABR	guaranteed minimum	no	yes	no	yes
ATM	UBR	none	no	yes	no	no

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Network layer connection and connection-less service

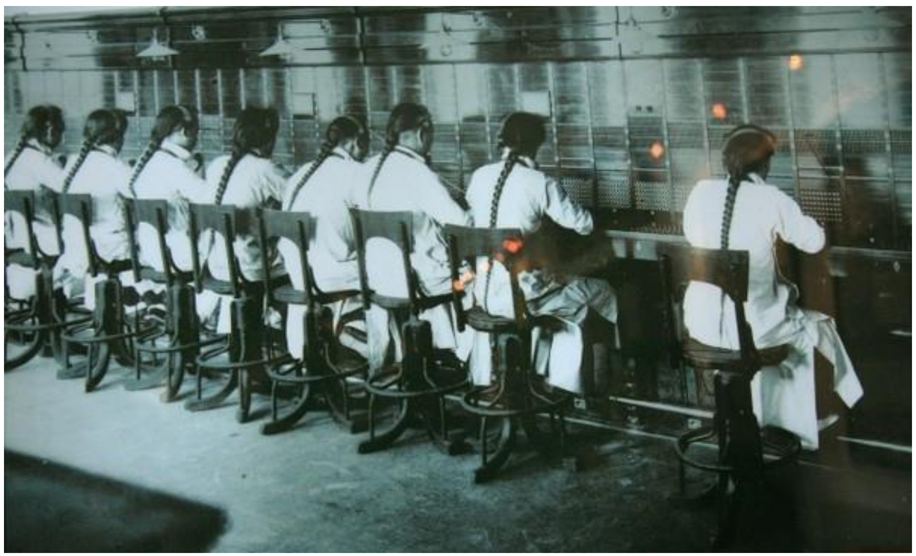
- datagram network provides network-layer connectionless service
- VC network provides network-layer connection service
- analogous to the transport-layer services, but:
  - service: host-to-host
  - no choice: network provides one or the other
  - implementation: in network core

Virtual circuits

"source-to-dest path behaves much like telephone circuit"

- performance-wise
- network actions along source-to-dest path

- call setup, teardown for each call *before* data can flow
- each packet carries VC identifier (not destination host address)
- *every* router on source-dest path maintains "state" for each passing connection
- link, router resources (bandwidth, buffers) may be *allocated* to VC (dedicated resources = predictable service)

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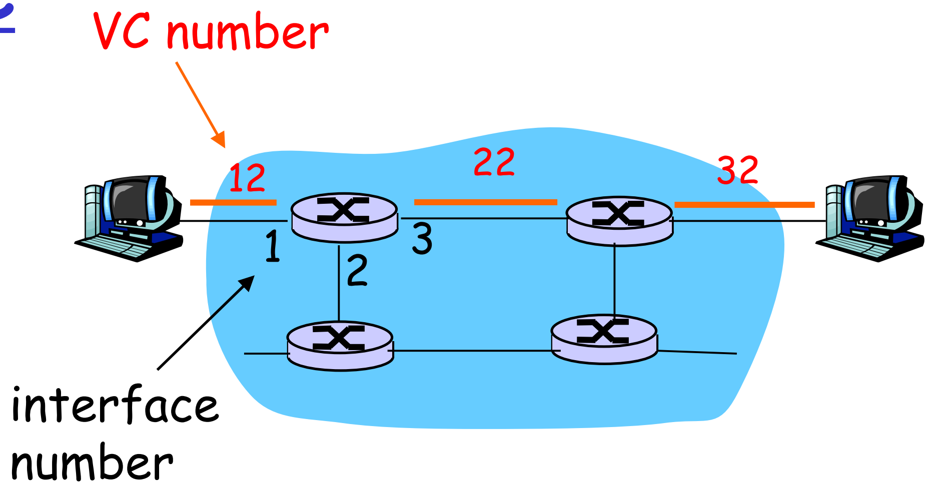
VC implementation

a VC consists of:

1. path from source to destination
2. VC numbers, one number for each link along path
3. entries in forwarding tables in routers along path

- packet belonging to VC carries VC number (rather than dest address)
- VC number can be changed on each link.
  - New VC number comes from forwarding table

Forwarding table



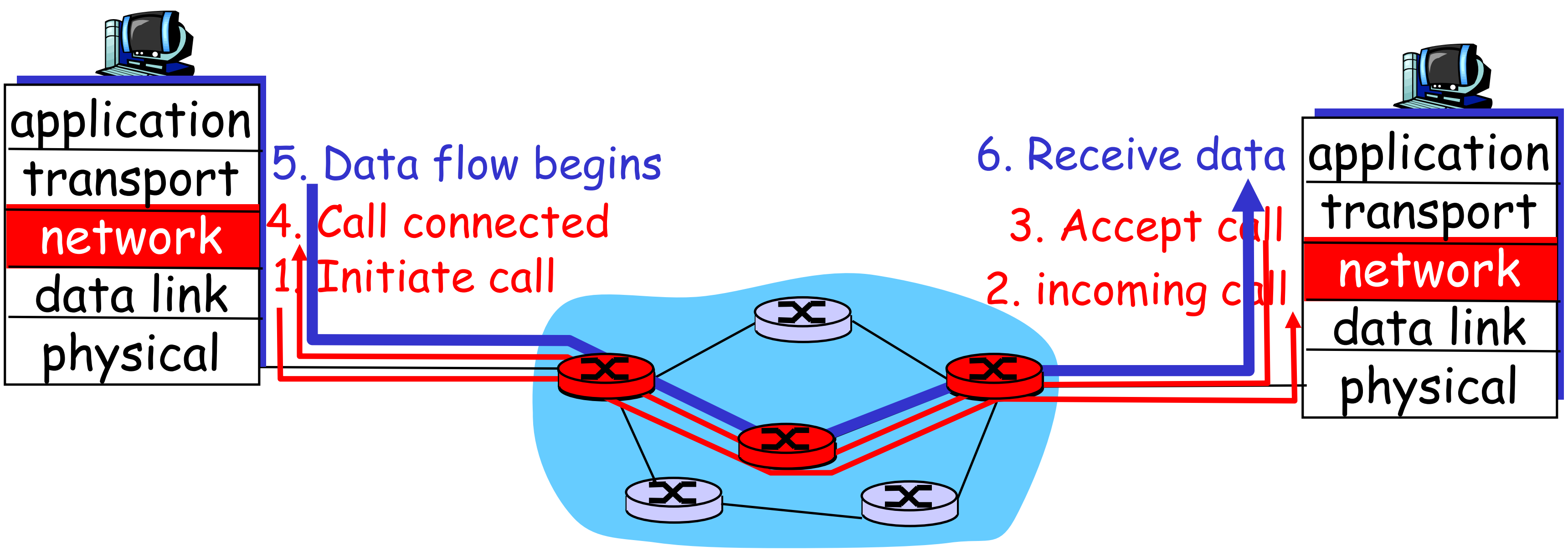
Forwarding table in northwest router:

Incoming interface	Incoming VC #	Outgoing interface	Outgoing VC #
1	12	3	22
2	63	1	18
3	7	2	17
1	97	3	87
…	…	…	…

Routers maintain connection state information!

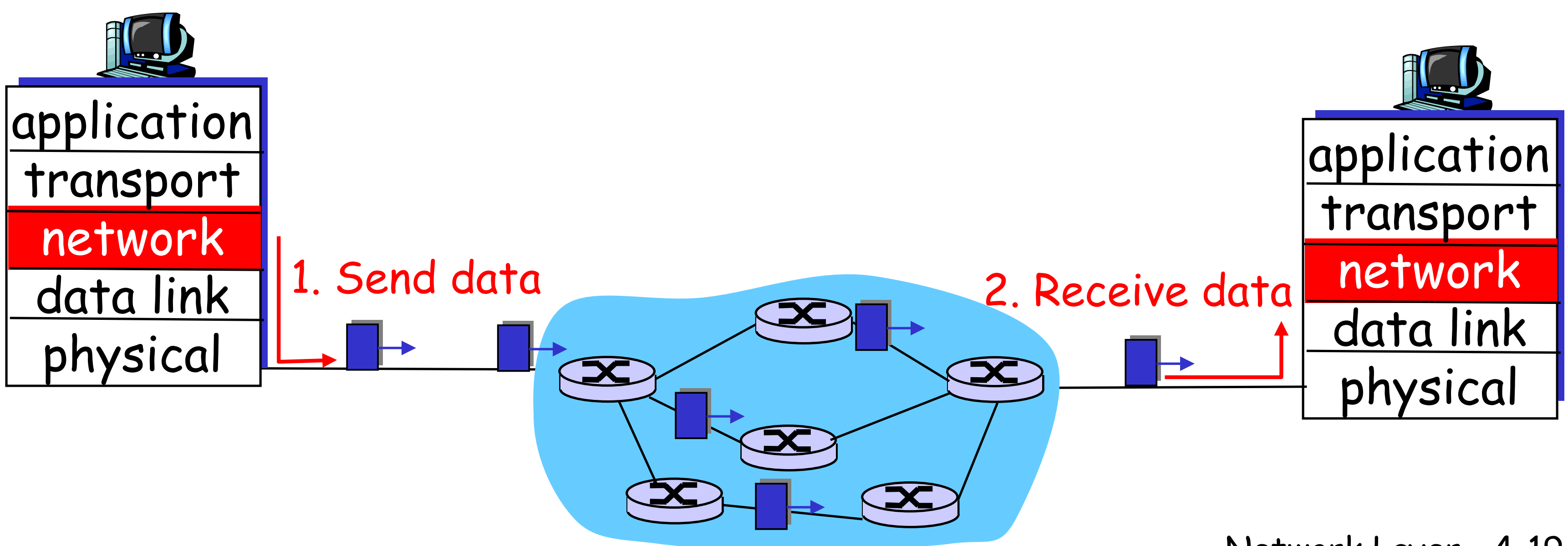
Virtual circuits: signaling protocols

- used to setup, maintain teardown VC
- used in ATM, frame-relay, X.25
- not used in today's Internet



Datagram networks

- no call setup at network layer
- routers: no state about end-to-end connections
  - no network-level concept of "connection"
- packets forwarded using destination host address
  - packets between same source-dest pair may take different paths



Forwarding table

4 billion possible entries

Destination Address Range	Link Interface
11001000 00010111 00010000 00000000 through 11001000 00010111 00010111 11111111	0
11001000 00010111 00011000 00000000 through 11001000 00010111 00011000 11111111	1
11001000 00010111 00011001 00000000 through 11001000 00010111 00011111 11111111	2
otherwise	3

Longest prefix matching

Prefix Match	Link Interface
11001000 00010111 00010	0
11001000 00010111 00011000	1
11001000 00010111 00011	2
otherwise	3

Examples

DA: 11001000 00010111 00010110 10100001 Which interface?

DA: 11001000 00010111 00011000 10101010 Which interface?

Datagram or VC network: why?

Internet (datagram)

- data exchange among computers
  - "elastic" service, no strict timing req.
- "smart" end systems (computers)
  - can adapt, perform control, error recovery
  - simple inside network, complexity at "edge"
- many link types
  - different characteristics
  - uniform service difficult

ATM (VC)

- evolved from telephony
- human conversation:
  - strict timing, reliability requirements
  - need for guaranteed service
- "dumb" end systems
  - telephones
  - complexity inside network

思考题

- 数据报与虚电路
  - 公务车队与旅游车队分别是哪种形式？
  - 八仙过海与鹊桥相会？

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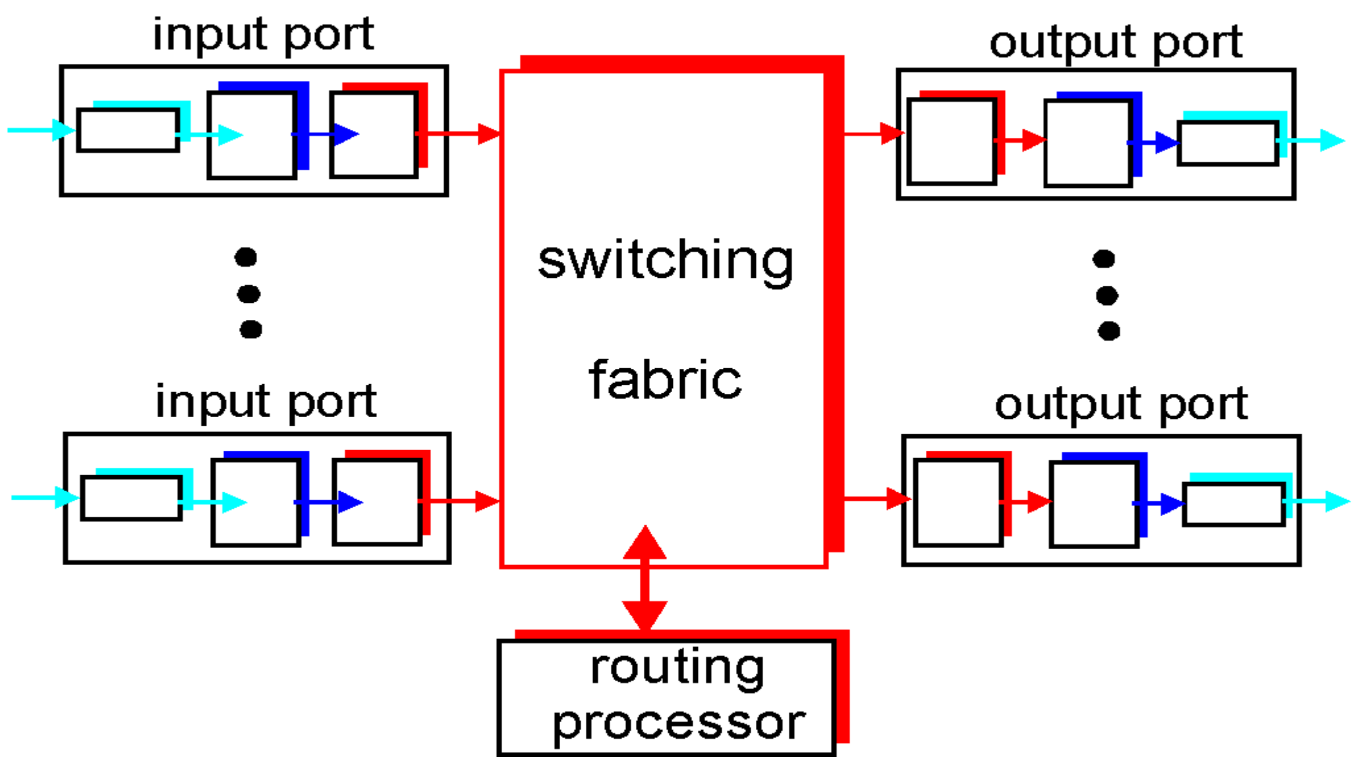
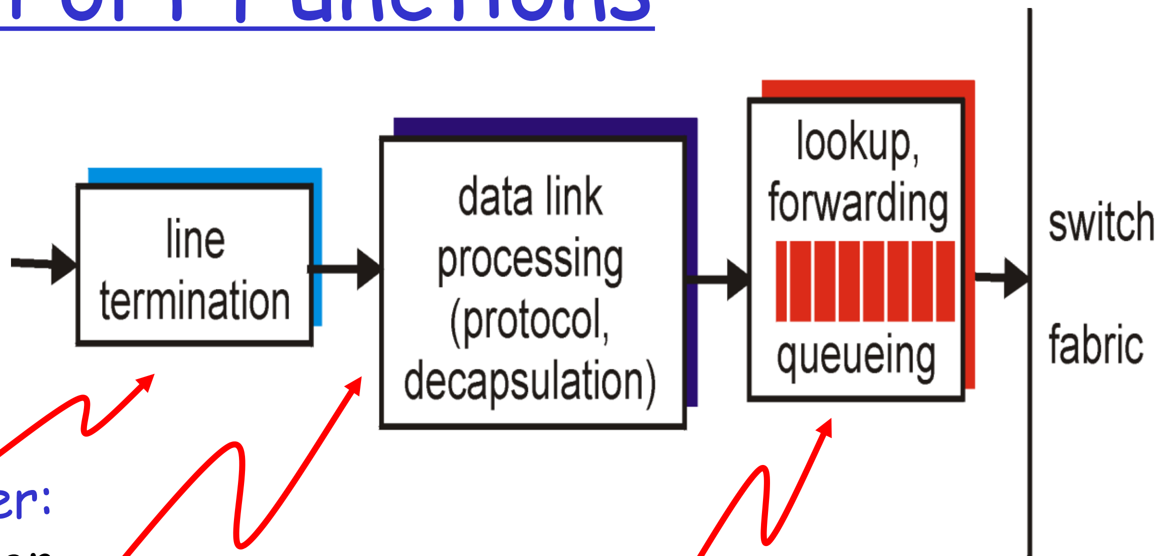
Router Architecture Overview

Two key router functions:

- run routing algorithms/protocol (RIP, OSPF, BGP)
- *forwarding* datagrams from incoming to outgoing link



Input Port Functions



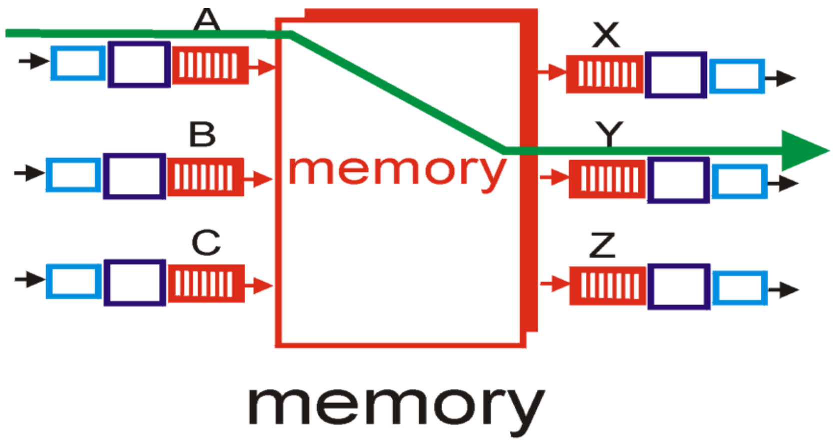
Physical layer:
bit-level reception

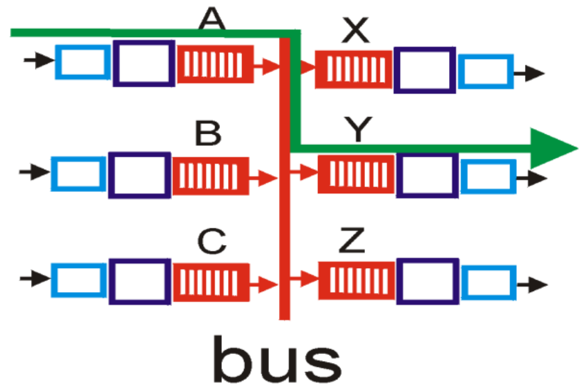
Data link layer:
e.g., Ethernet
see chapter 5

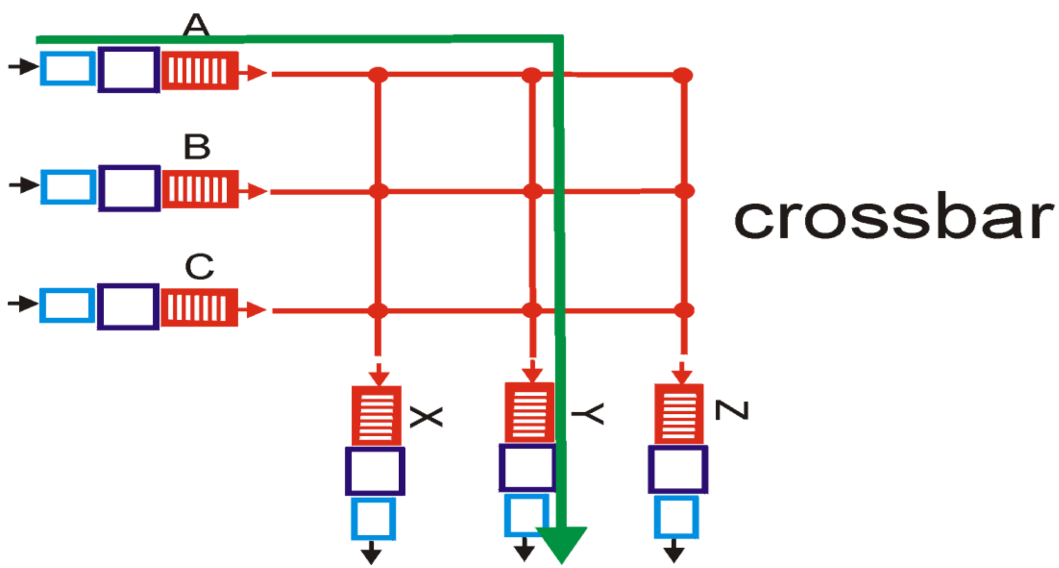
Decentralized switching:

- given datagram dest., lookup output port using forwarding table in input port memory
- goal: complete input port processing at 'line speed'
- queuing: if datagrams arrive faster than forwarding rate into switch fabric

Three types of switching fabrics



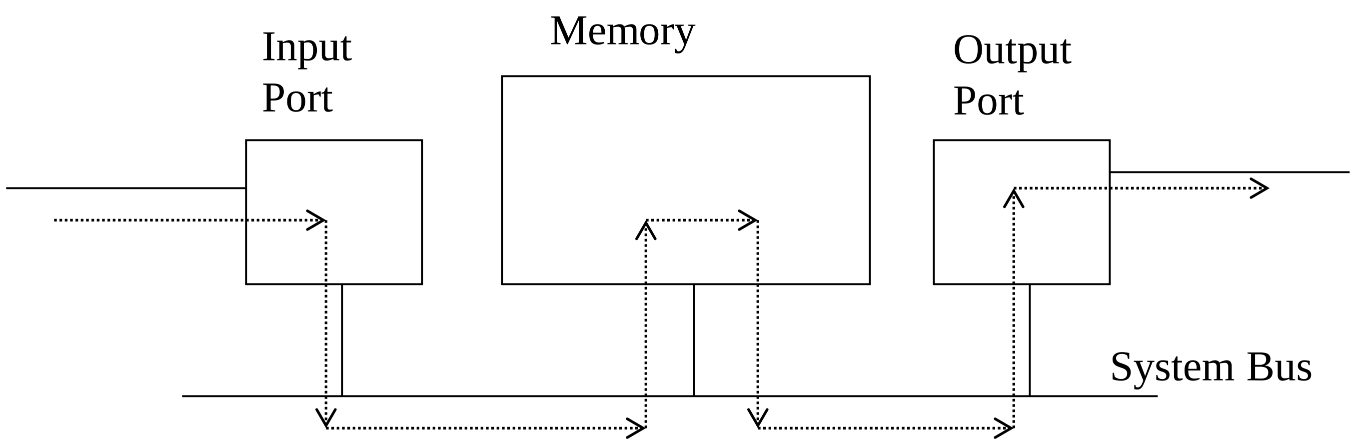




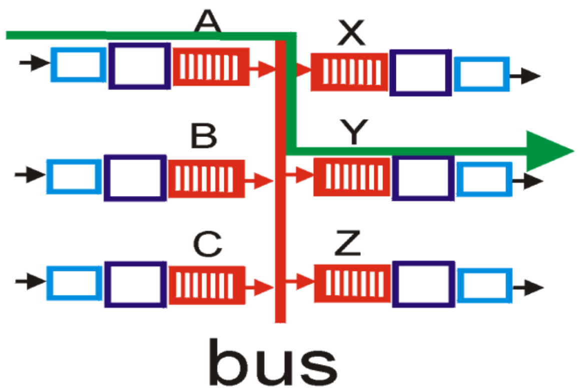
Switching Via Memory

First generation routers:

- traditional computers with switching under direct control of CPU
- packet copied to system's memory
- speed limited by memory bandwidth (2 bus crossings per datagram)



Switching Via a Bus



- datagram from input port memory to output port memory via a shared bus
- bus contention: switching speed limited by bus bandwidth
- 32 Gbps bus, Cisco 5600: sufficient speed for access and enterprise routers

Switching Via An Interconnection Network

- overcome bus bandwidth limitations
- Banyan networks, other interconnection nets initially developed to connect processors in multiprocessor
- advanced design: fragmenting datagram into fixed length cells, switch cells through the fabric.
- Cisco 12000: switches 60 Gbps through the interconnection network

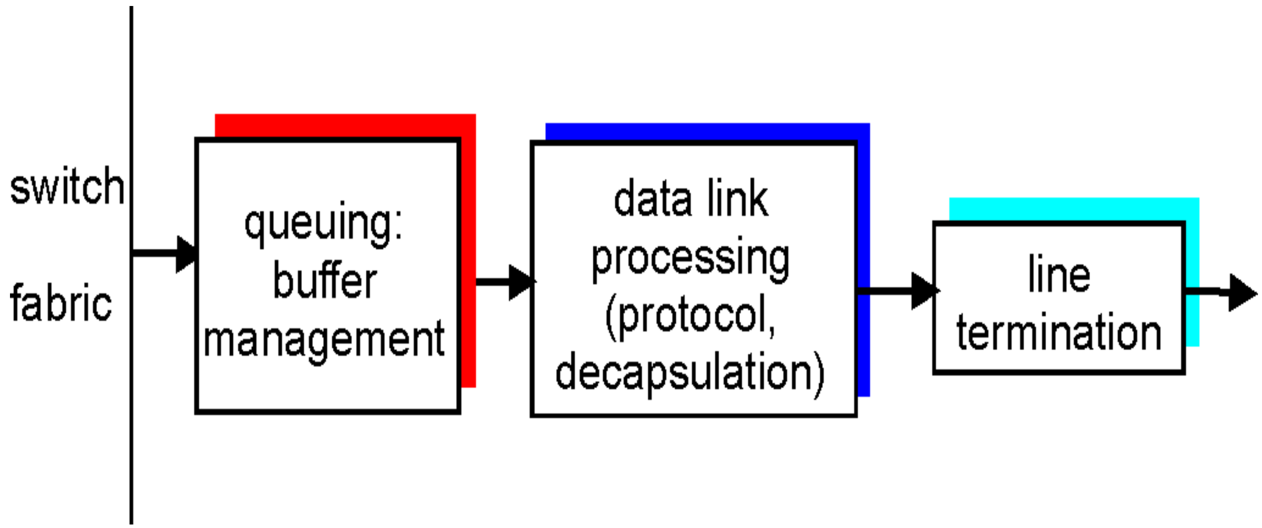

CISCO SYSTEMS
Cisco 12000

12.0.1.28

```
This router maintains eBGP peerings with customer-facing
throughout the AT&T IP Services Backbone:

IPv4:
 12.123.21.243  Atlanta    12.123.133.124 Austin     12.12
 12.123.5.240   Chicago    12.123.17.244  Dallas     12.12
 12.123.37.250  Denver     12.123.134.124 Houston    12.12
 12.123.1.236   New York   12.123.33.249  Orlando    12.12
 12.123.142.124 Phoenix    12.123.145.124 SanDiego   12.12
 12.123.25.245  St.Louis   12.123.45.252  Seattle    12.12

IPv6:
 2001:1890:FF:FFFF:12:122:124:12   Atlanta
 2001:1890:FF:FFFF:12:122:127:66   Chicago
 2001:1890:FF:FFFF:12:122:124:138  Dallas
 2001:1890:FF:FFFF:12:122:120:7    Fort Lauderdale
 2001:1890:FF:FFFF:12:122:125:6    Los Angeles
 2001:1890:FF:FFFF:12:122:125:44   New York
 2001:1890:FF:FFFF:12:122:125:106  Philadelphia
 2001:1890:FF:FFFF:12:122:125:132  Phoenix
 2001:1890:FF:FFFF:12:122:126:232  San Francisco
 2001:1890:FF:FFFF:12:122:125:224  Seattle
 2001:1890:FF:FFFF:12:122:126:9    St. Louis
 2001:1890:FF:FFFF:12:122:126:64   Washington

*** Please Note:
Ping and traceroute delay figures measured here are unre
high CPU load experienced when complicated "show" comman

For questions about this route-server, send email to: ja

*** Log in with username "rviews", no password required

User Access Verification

Username:
```

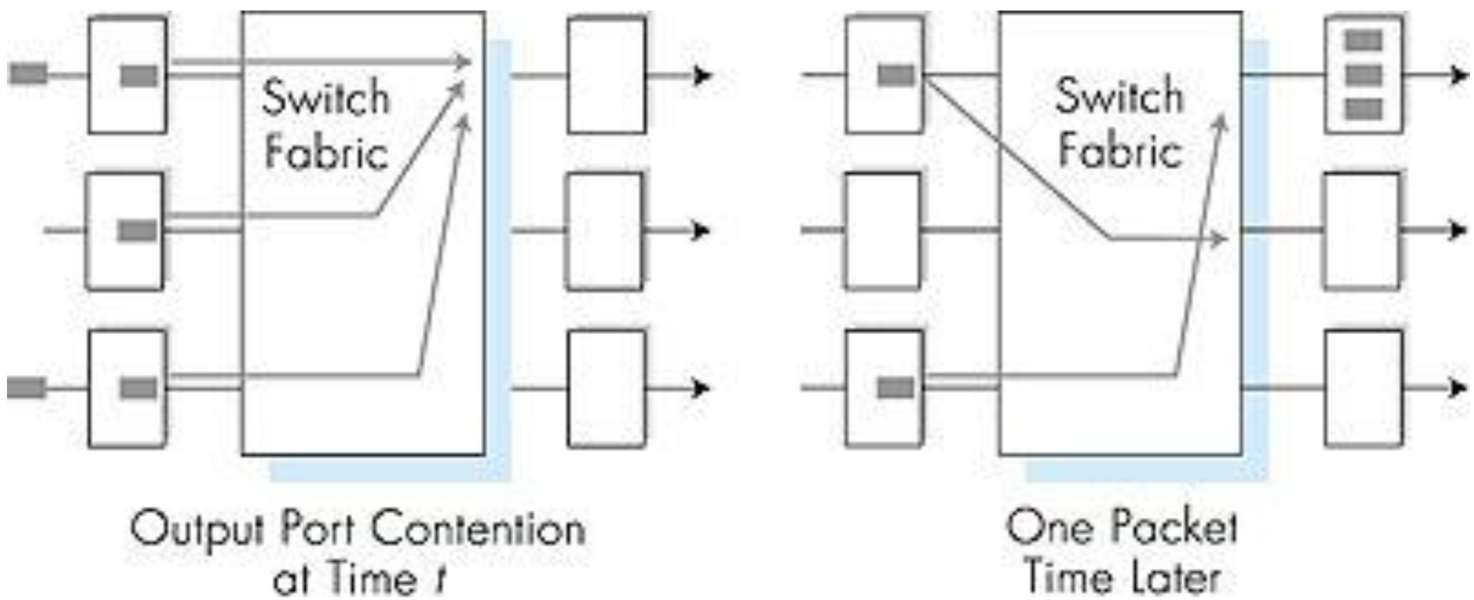
```
route-server>show ip route summary
IP routing table name is Default-IP-Routing-Table(0)
IP routing table maximum-paths is 32
Route Source    Networks    Subnets     Overhead    Memory (bytes)
connected       0           1           64          152
static          1           3           256         608
bgp 65000       148777      243304      25093184    59710552
  External: 392081 Internal: 0 Local: 0
internal        4512                                5288064
Total           153290      243308      25093504    64999376
```

Output Ports



- *Buffering* required when datagrams arrive from fabric faster than the transmission rate
- *Scheduling discipline* chooses among queued datagrams for transmission

Output port queueing



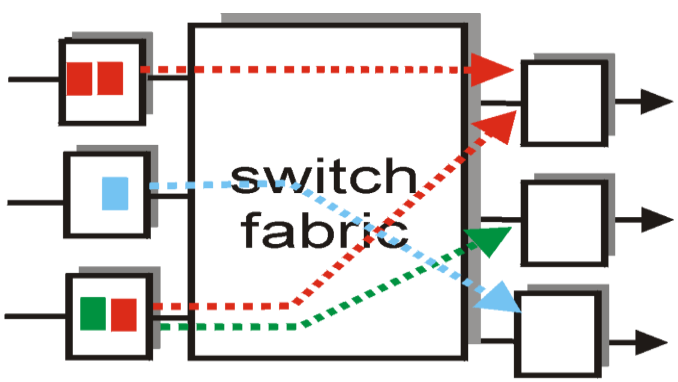
- buffering when arrival rate via switch exceeds output line speed
- *queueing (delay) and loss due to output port buffer overflow!*

How much buffering?

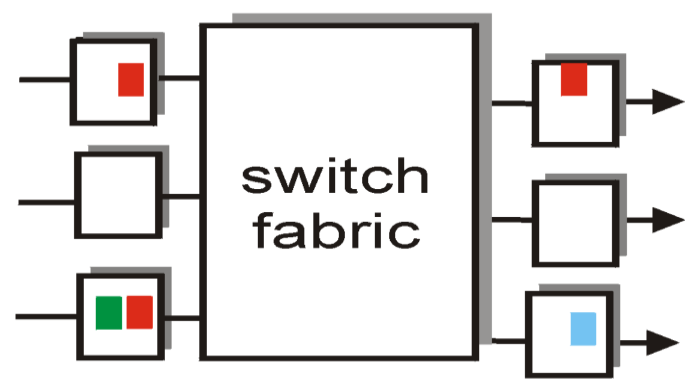
- RFC 3439 rule of thumb: average buffering equal to "typical" RTT (say 250 msec) times link capacity C
  - e.g., C = 10 Gps link: 2.5 Gbit buffer
- Recent recommendation: with N flows, buffering equal to $\dfrac{RTT \cdot C}{\sqrt{N}}$

Input Port Queuing

- Fabric slower than input ports combined -> queueing may occur at input queues
- Head-of-the-Line (HOL) blocking: queued datagram at front of queue prevents others in queue from moving forward
- *queueing delay and loss due to input buffer overflow!*



output port contention at time t - only one red packet can be transferred



green packet experiences HOL blocking

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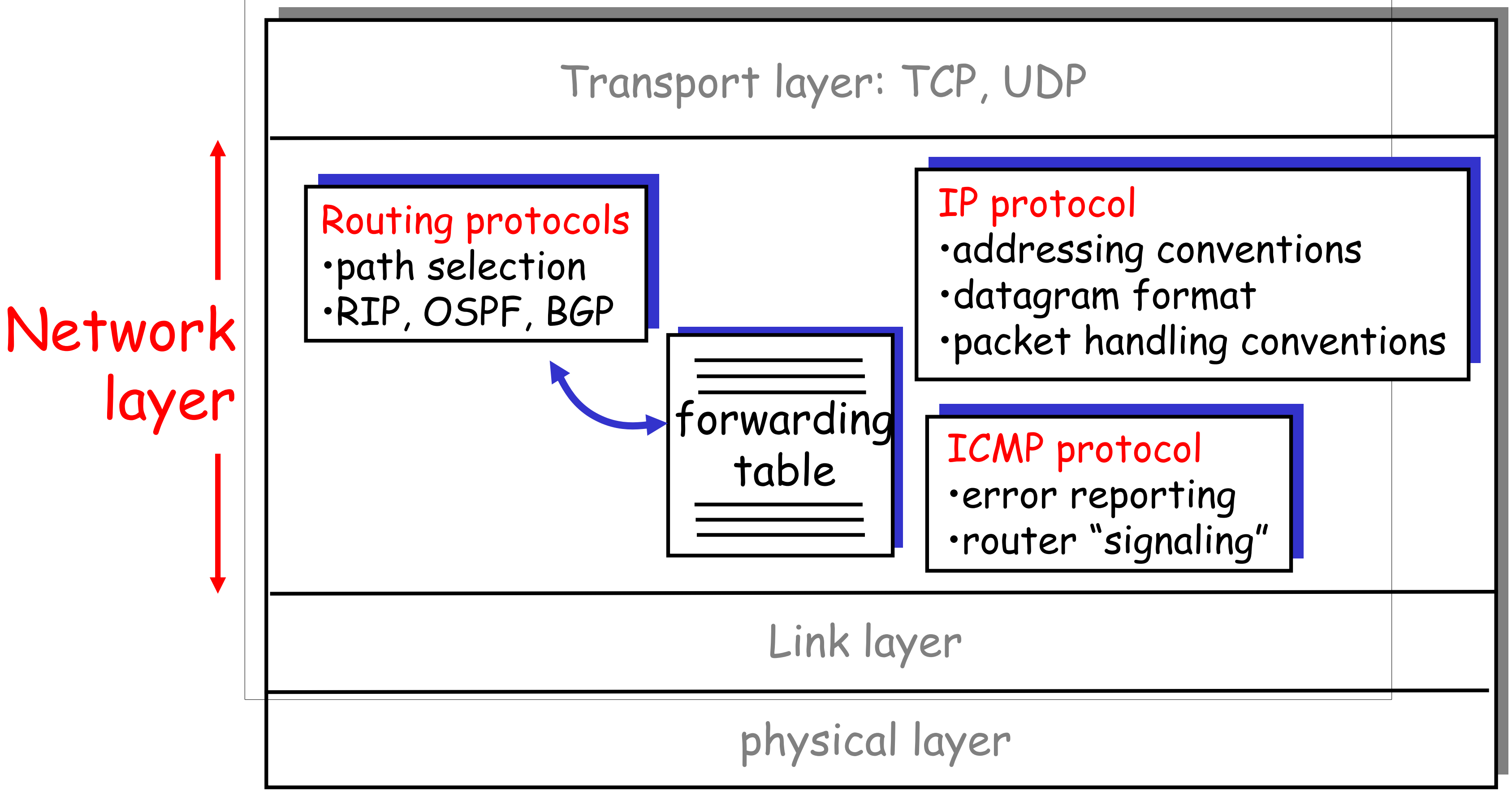
The Internet Network layer

Host, router network layer functions:



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IP datagram format

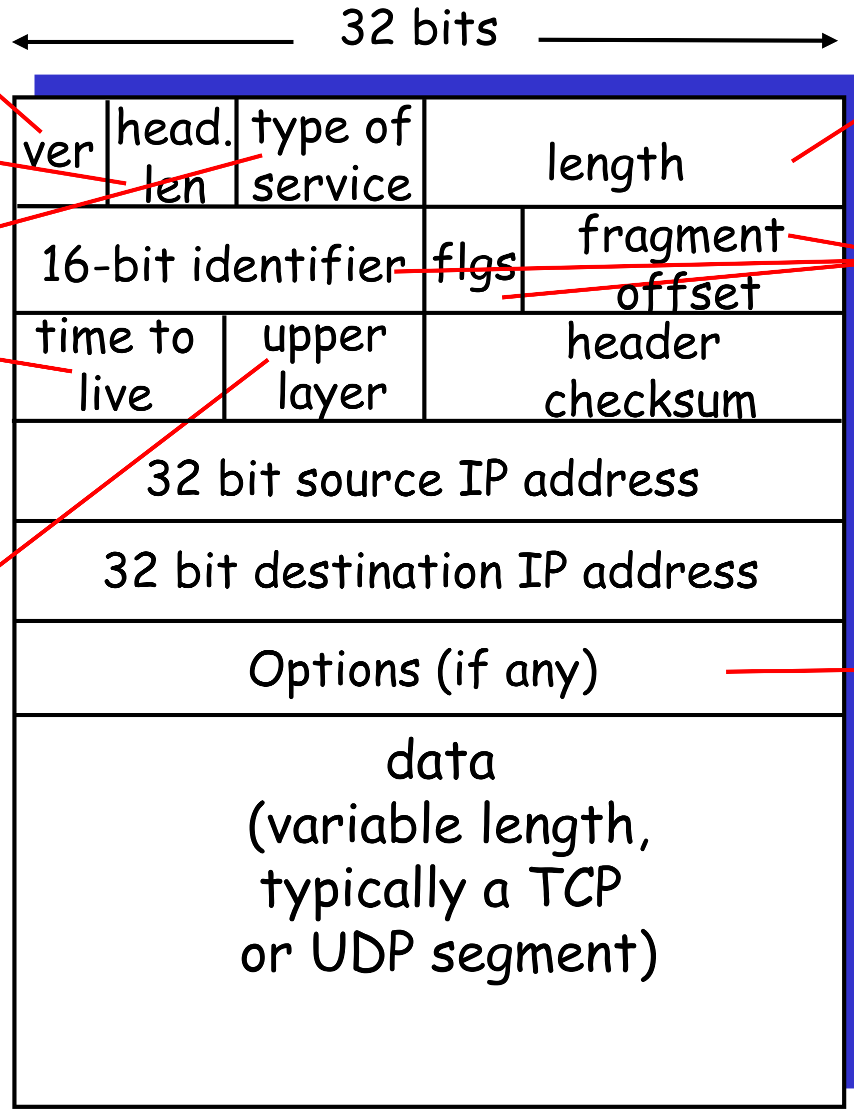
IP protocol version number

header length (bytes)

"type" of data

max number remaining hops (decremented at each router)

upper layer protocol to deliver payload to



total datagram length (bytes)

for fragmentation/ reassembly

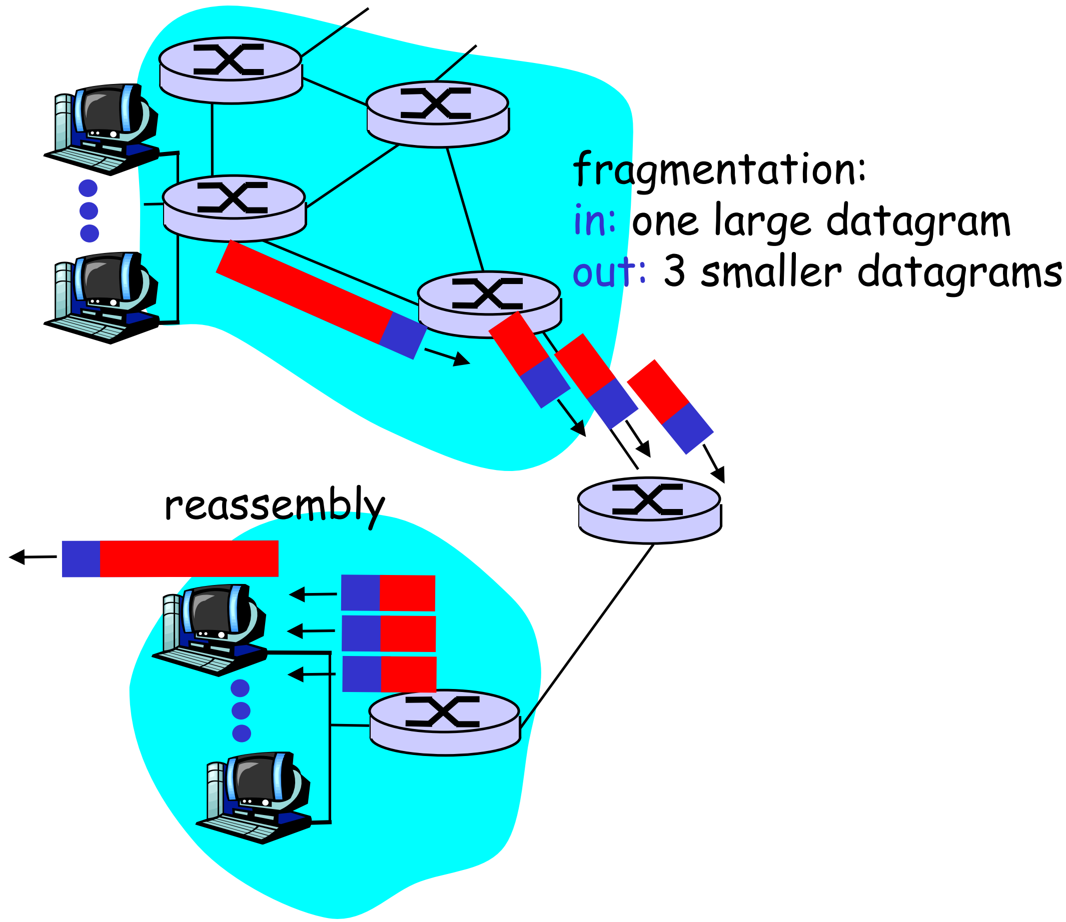
E.g. timestamp, record route taken, specify list of routers to visit.

<u>how much overhead with TCP?</u>

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

IP Fragmentation & Reassembly

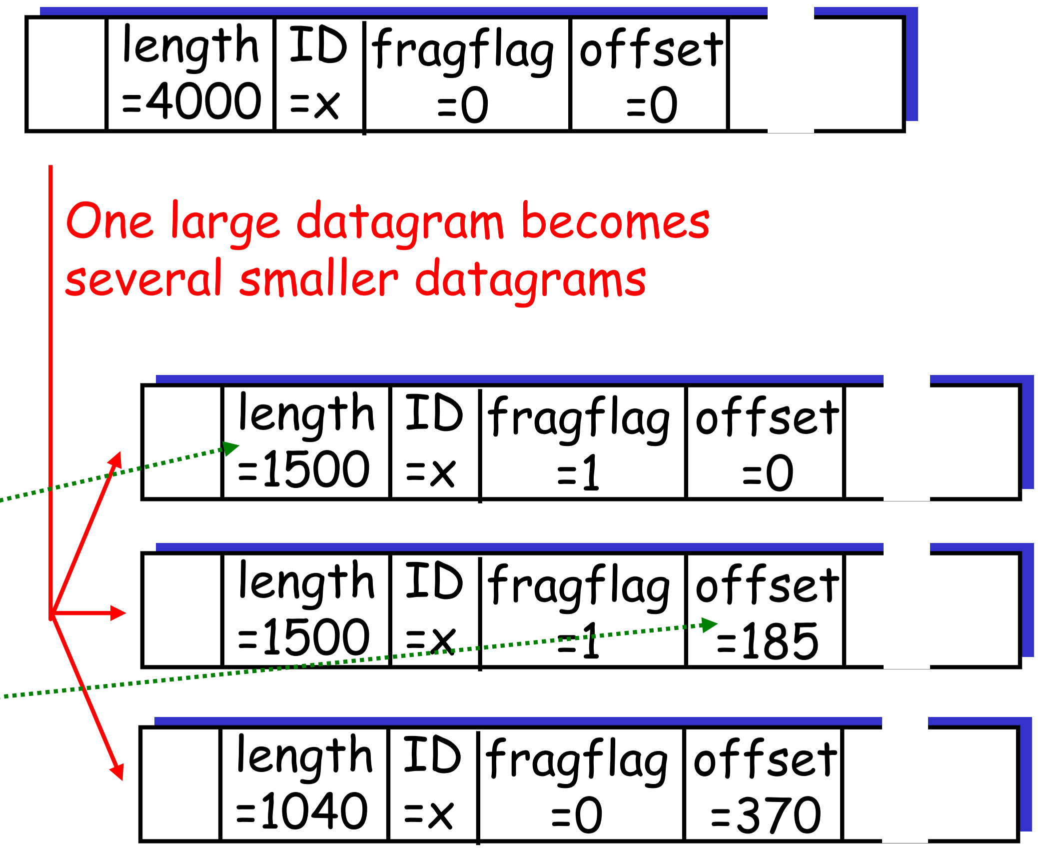
- network links have MTU (max.transfer size) - largest possible link-level frame.
  - different link types, different MTUs
- large IP datagram divided ("fragmented") within net
  - one datagram becomes several datagrams
  - "reassembled" only at final destination
  - IP header bits used to identify,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



IP Fragmentation and Reassembly

Example

- 4000 byte datagram
- MTU = 1500 bytes



1480 bytes in data field

offset = 1480/8

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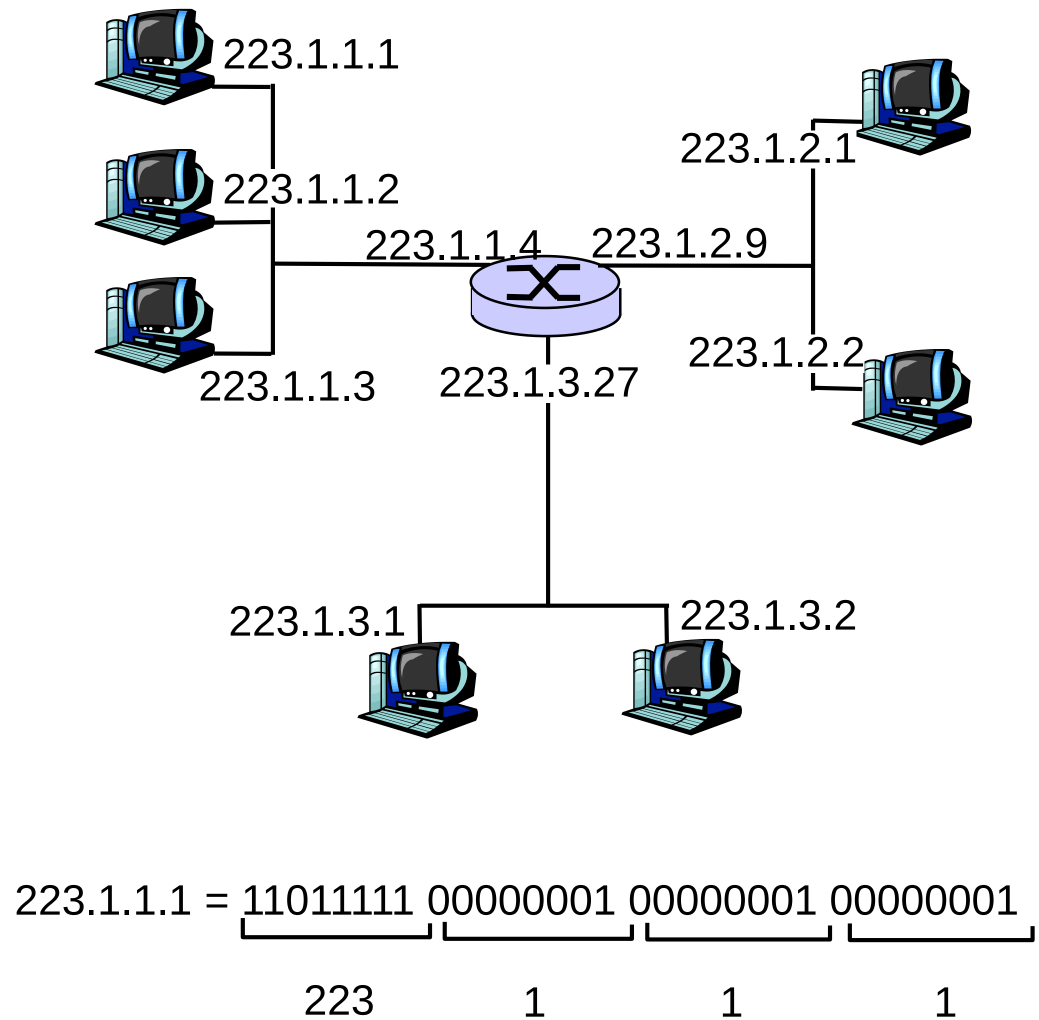
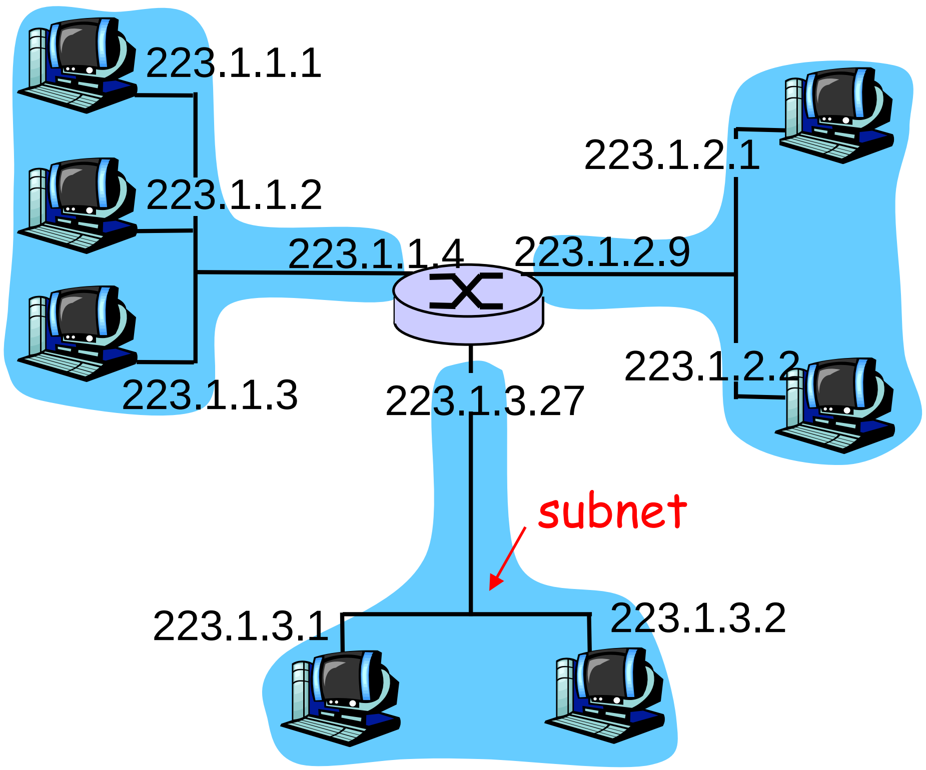
IP Addressing: introduction

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



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

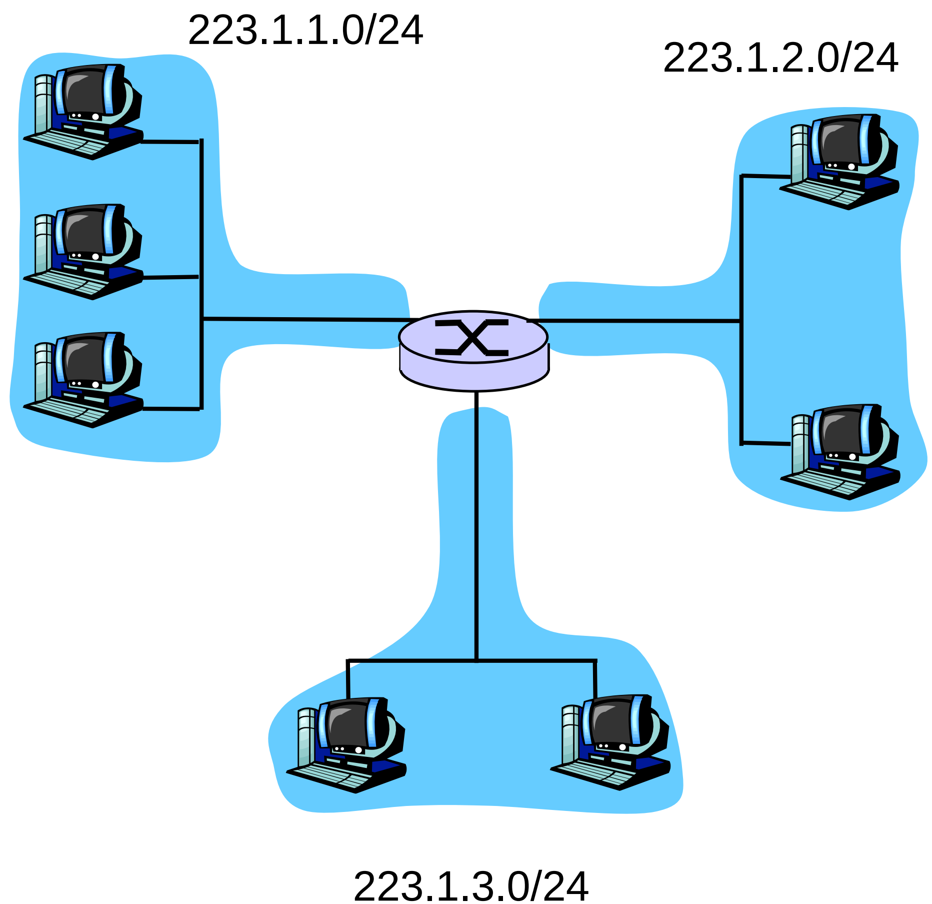


network consisting of 3 subnets

Subnets

Recipe

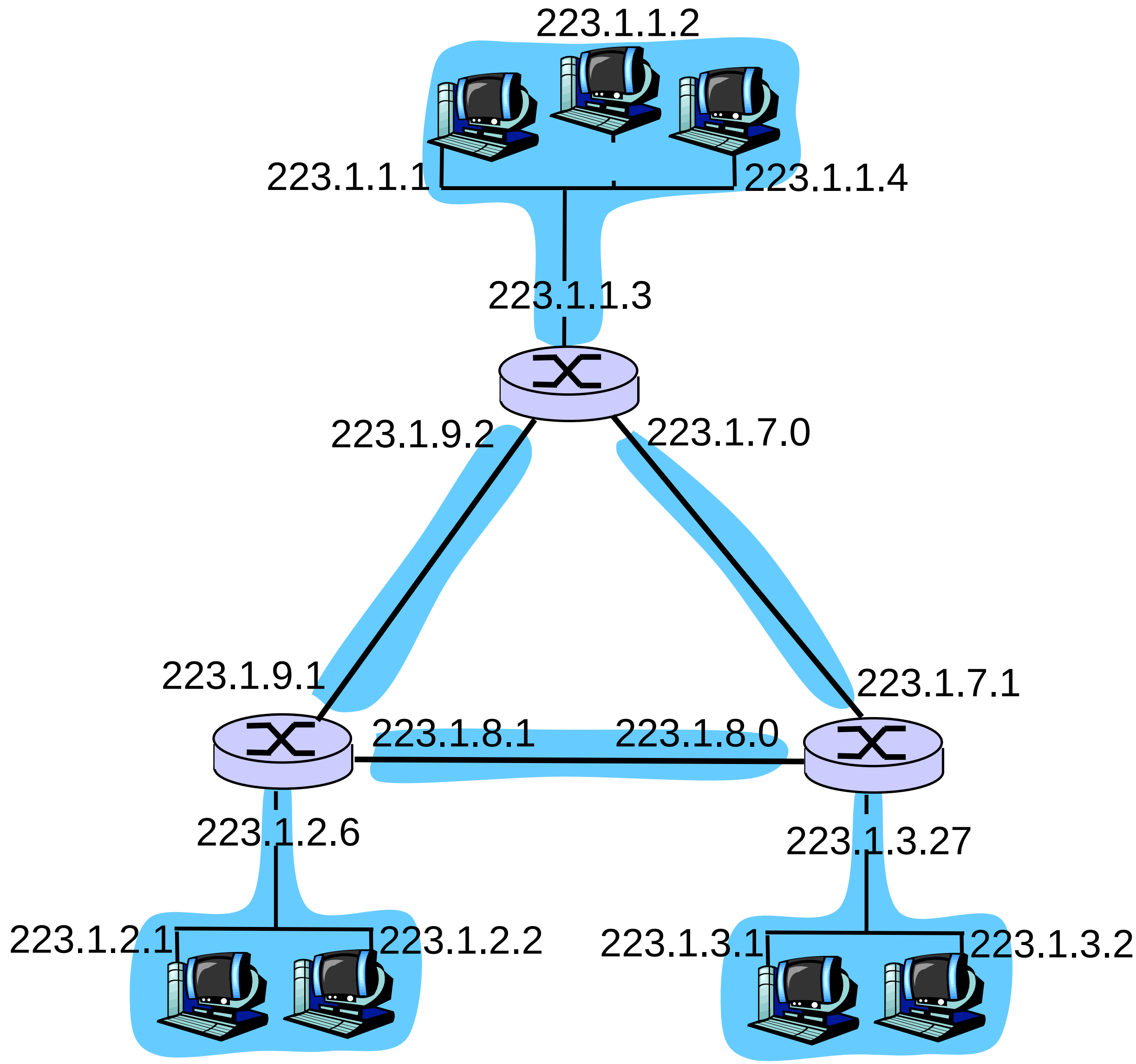
- To determine the subnets, detach each interface from its host or router, creating islands of isolated networks. Each isolated network is called a subnet.



Subnet mask: /24

Subnets

How many?



Historical classful network architecture

Class	Leading bits	Size of *network number* bit field	Size of *rest* bit field	Number of networks	Addresses per network	Start address	End address
A	0	8	24	128 (2^7)	16,777,216 (2^{24})	0.0.0.0	127.255.255.255
B	10	16	16	16,384 (2^{14})	65,536 (2^{16})	128.0.0.0	191.255.255.255
C	110	24	8	2,097,152 (2^{21})	256 (2^8)	192.0.0.0	223.255.255.255

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

IP addresses: how to get one?

Q: How does a *host* get 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

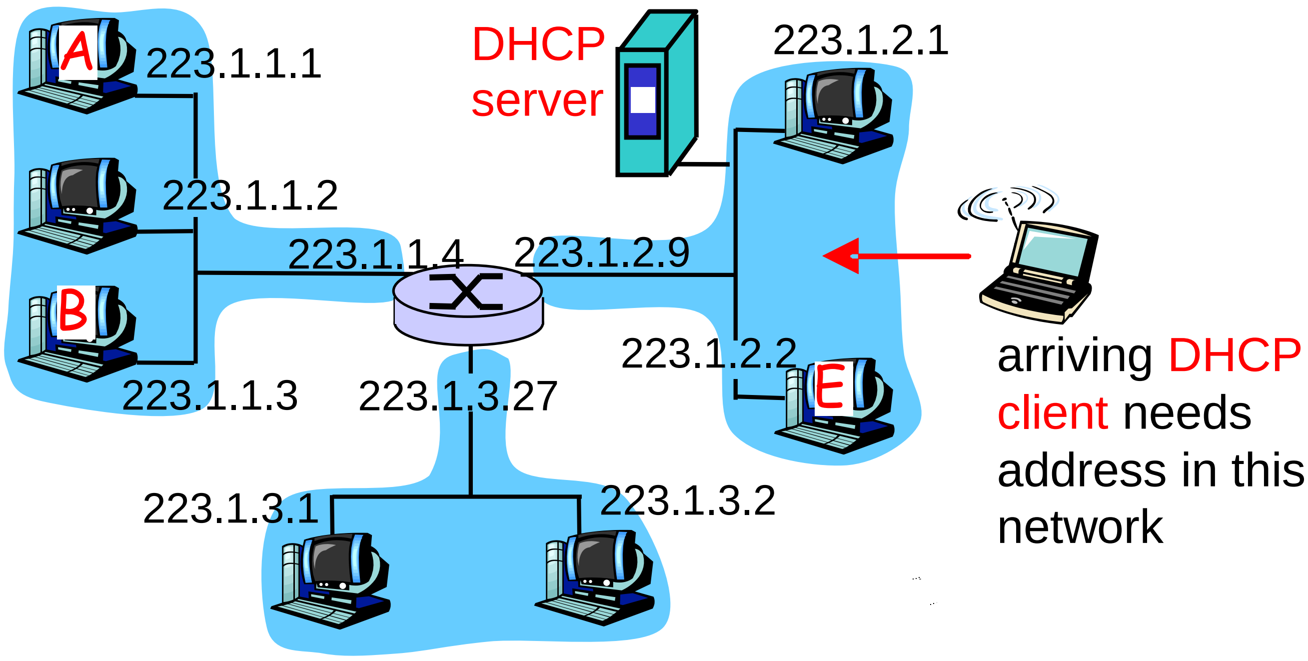
Allows reuse of addresses (only hold address while connected an "on")

Support for mobile users who want to join network (more shortly)

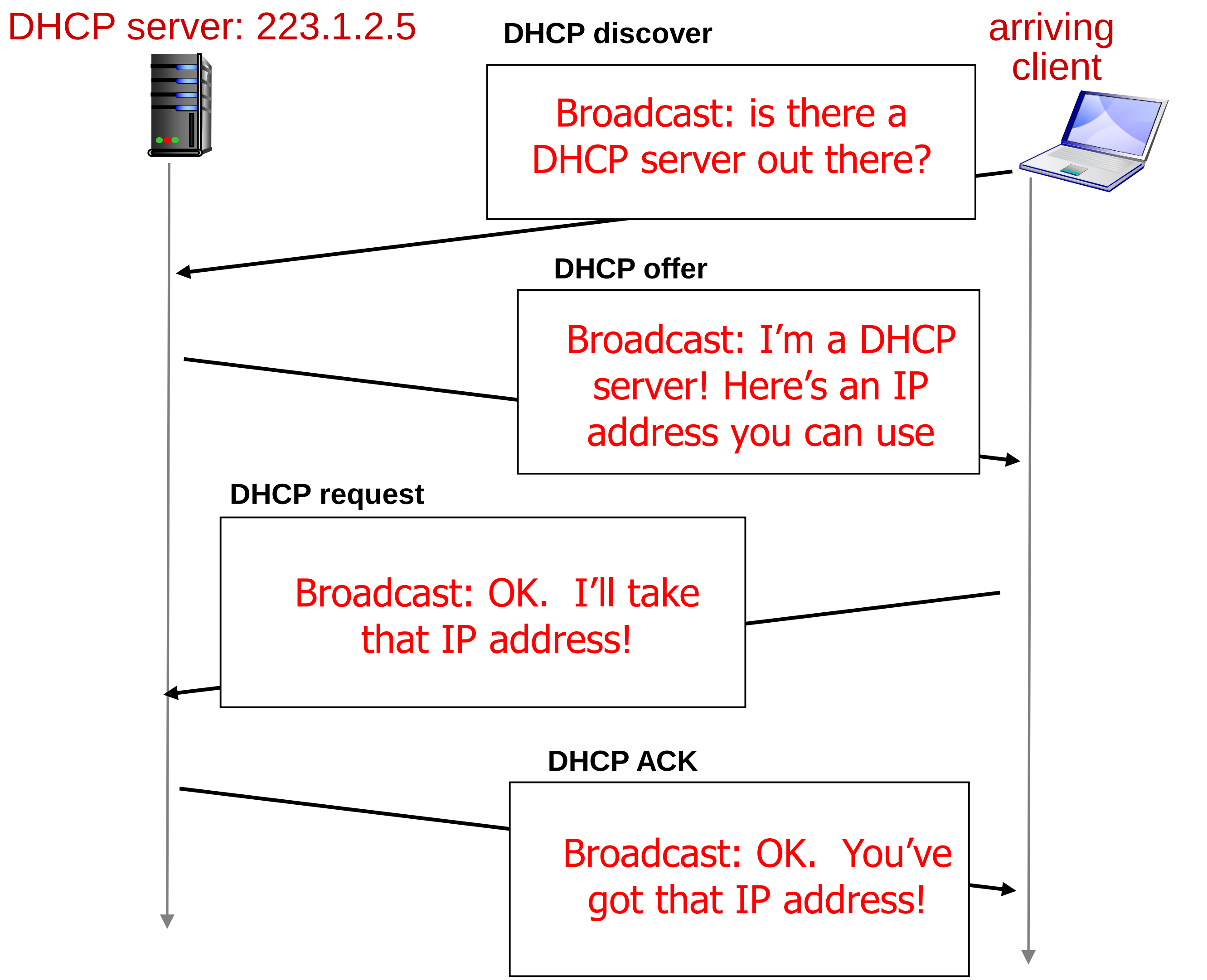
DHCP overview:

- 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

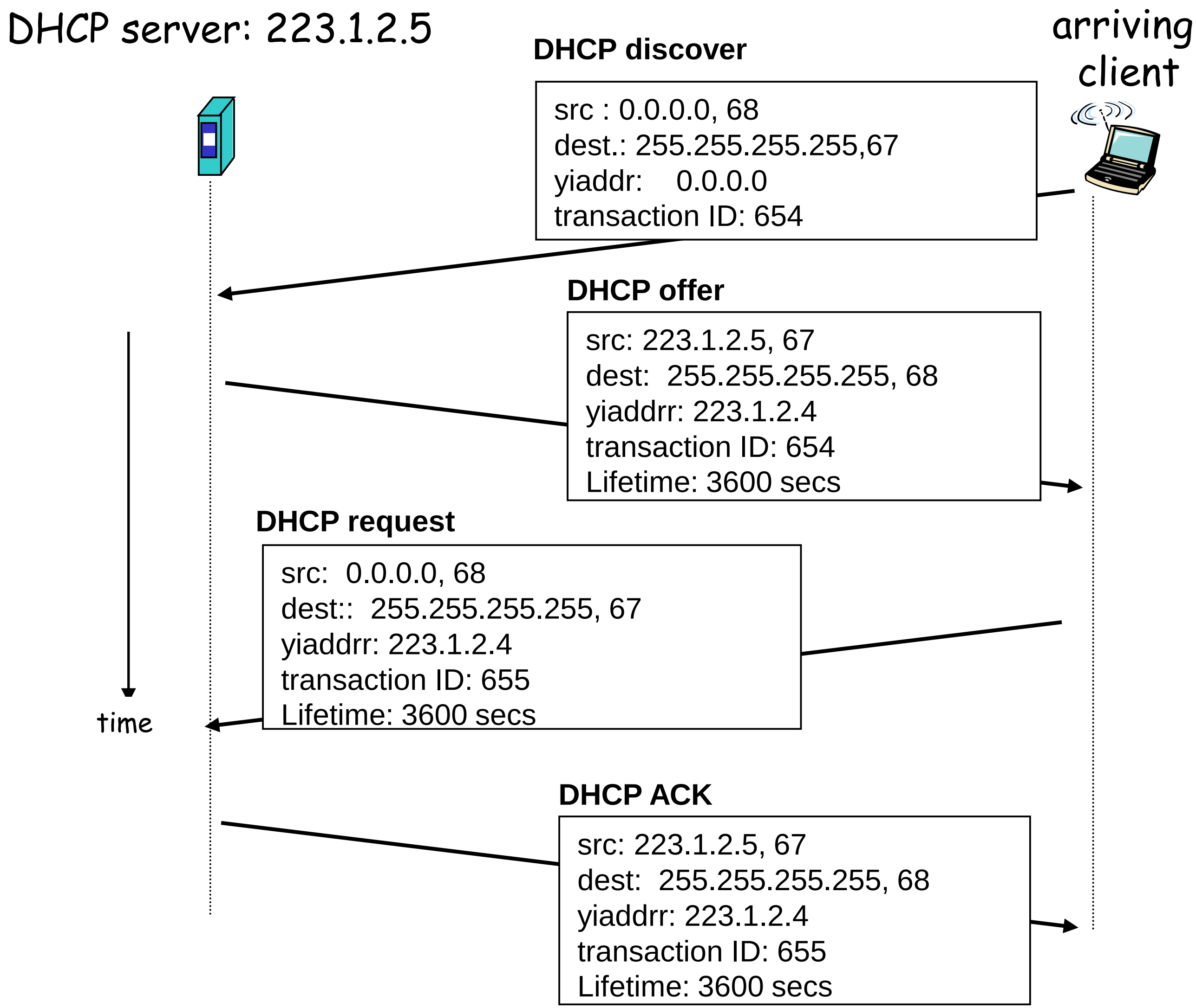
DHCP client-server scenario



DHCP client-server scenario



DHCP client-server scenario



IP addresses: how to get one?

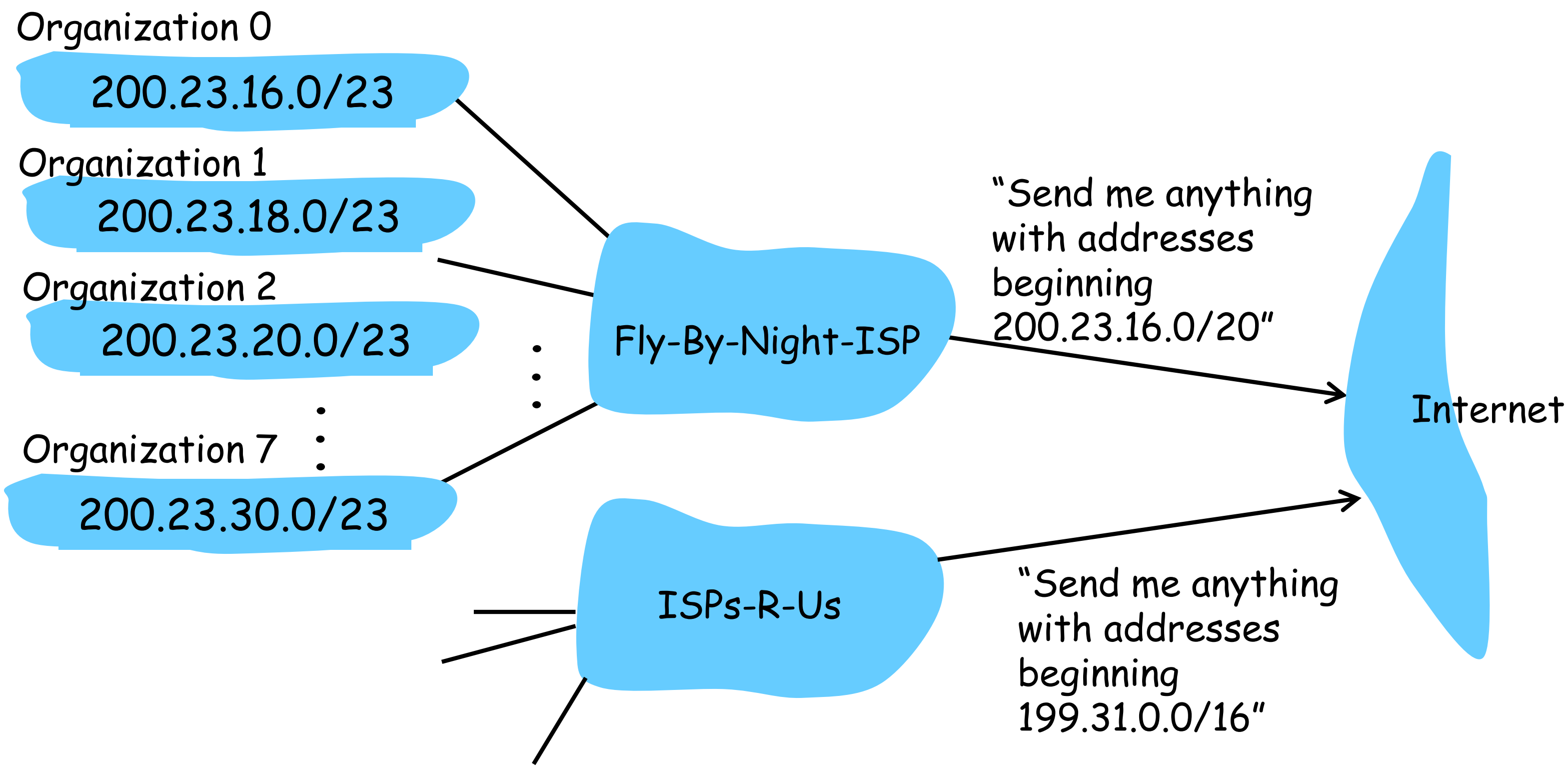
Q: How does *network* get subnet part of IP addr?

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

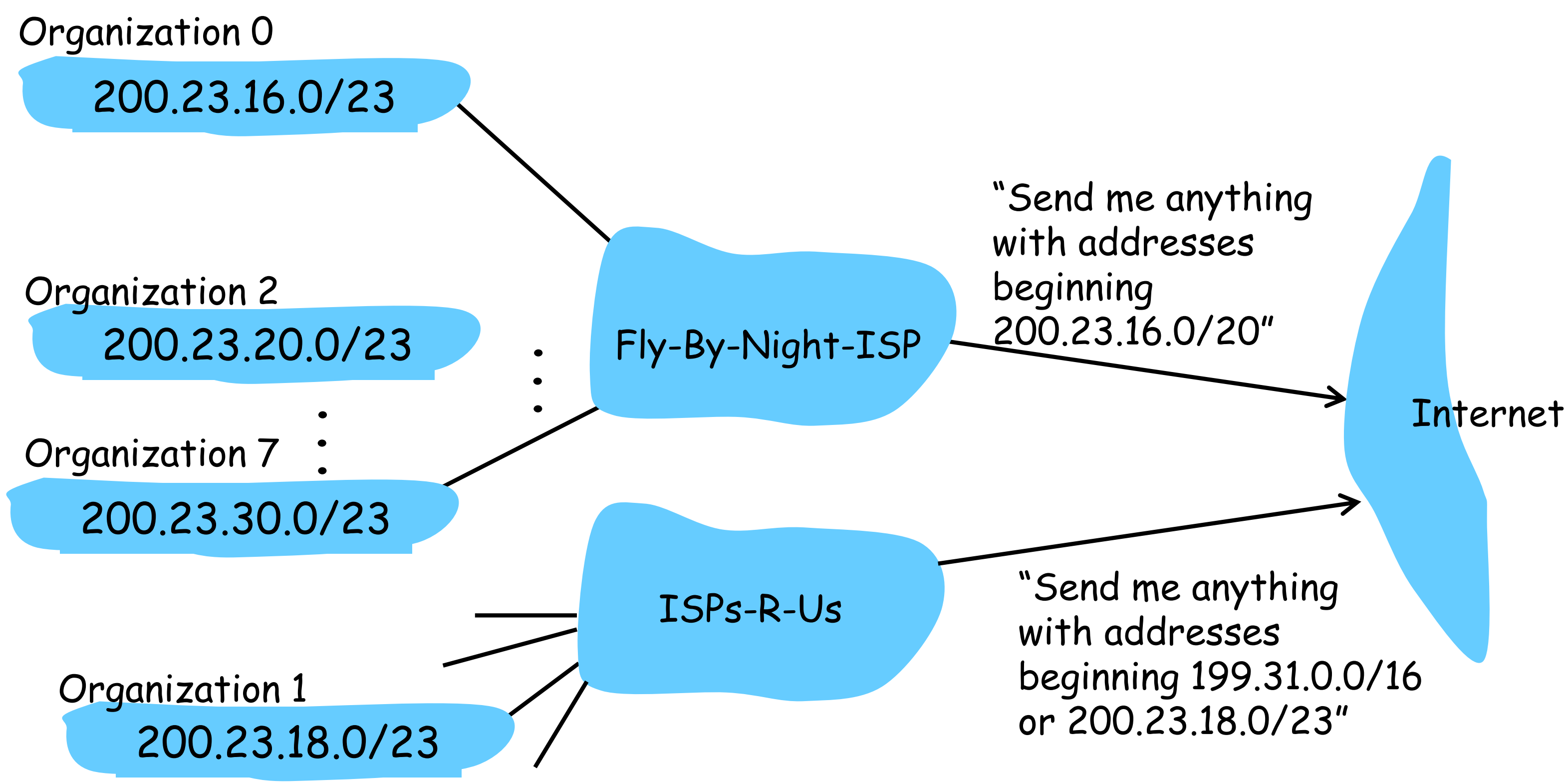
Hierarchical addressing: route aggregation

Hierarchical addressing allows efficient advertisement of routing information:



Hierarchical addressing: more specific routes

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



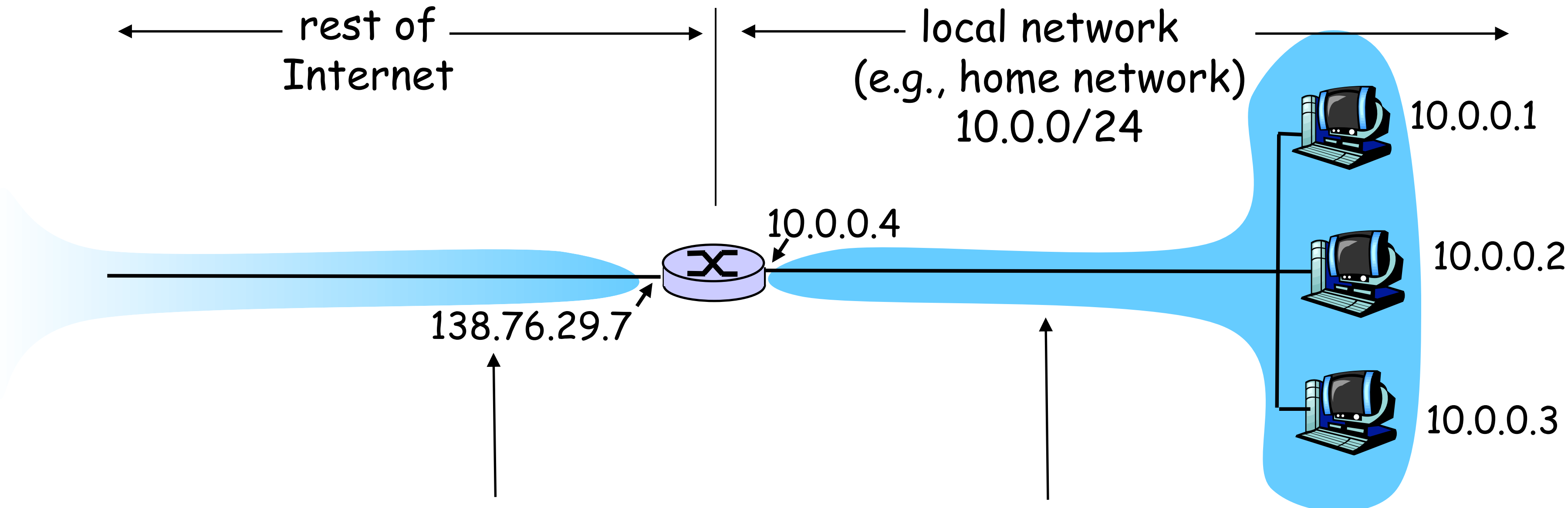
IP addressing: the last word...

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

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:

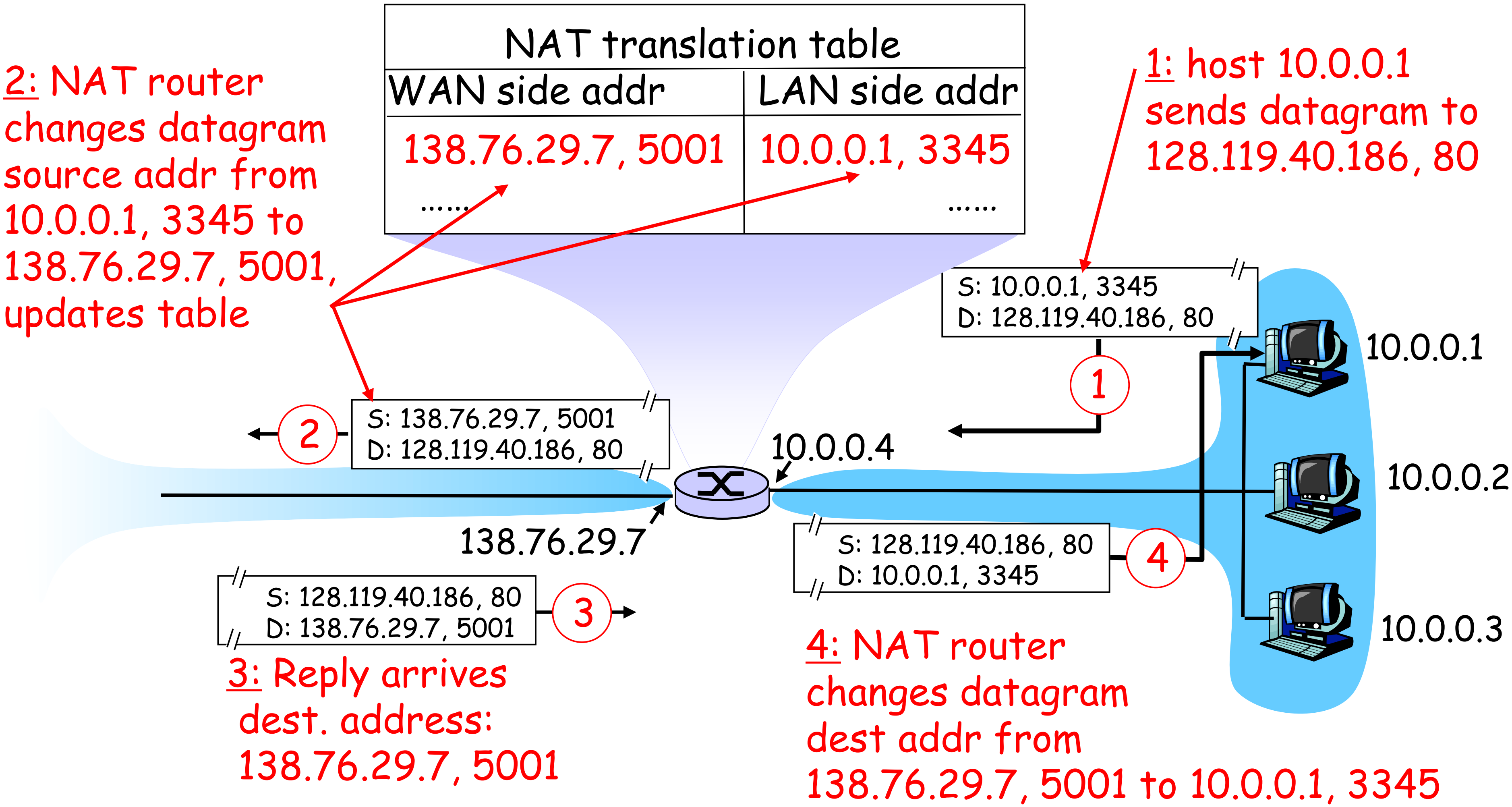
- *outgoing datagrams: replace* (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)

  . . . 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

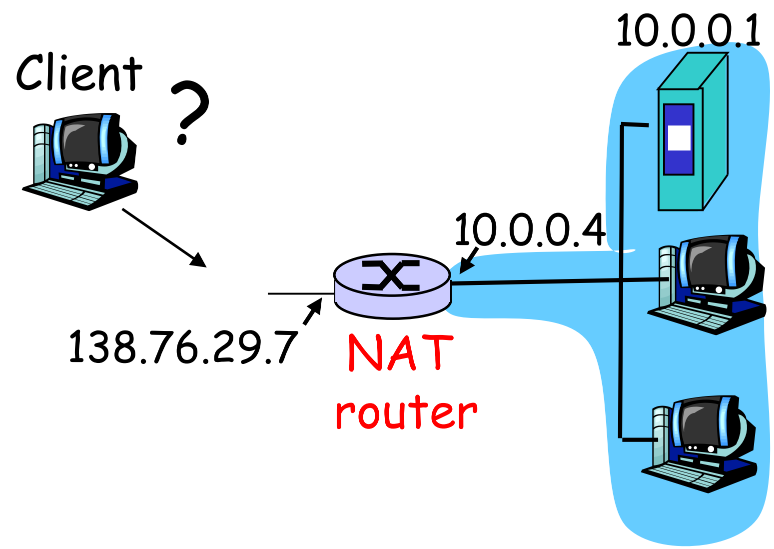


NAT: Network Address Translation

- 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

NAT traversal problem

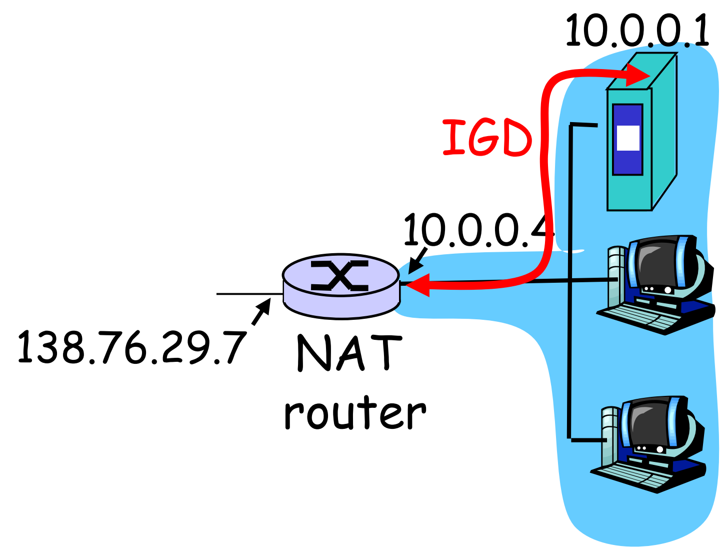
- client wants to connect to server with address 10.0.0.1
  - server address 10.0.0.1 local to LAN (client can't use it as destination addr)
  - only one externally visible NATted address: 138.76.29.7
- solution 1: statically configure NAT to forward incoming connection requests at given port to server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



NAT traversal problem

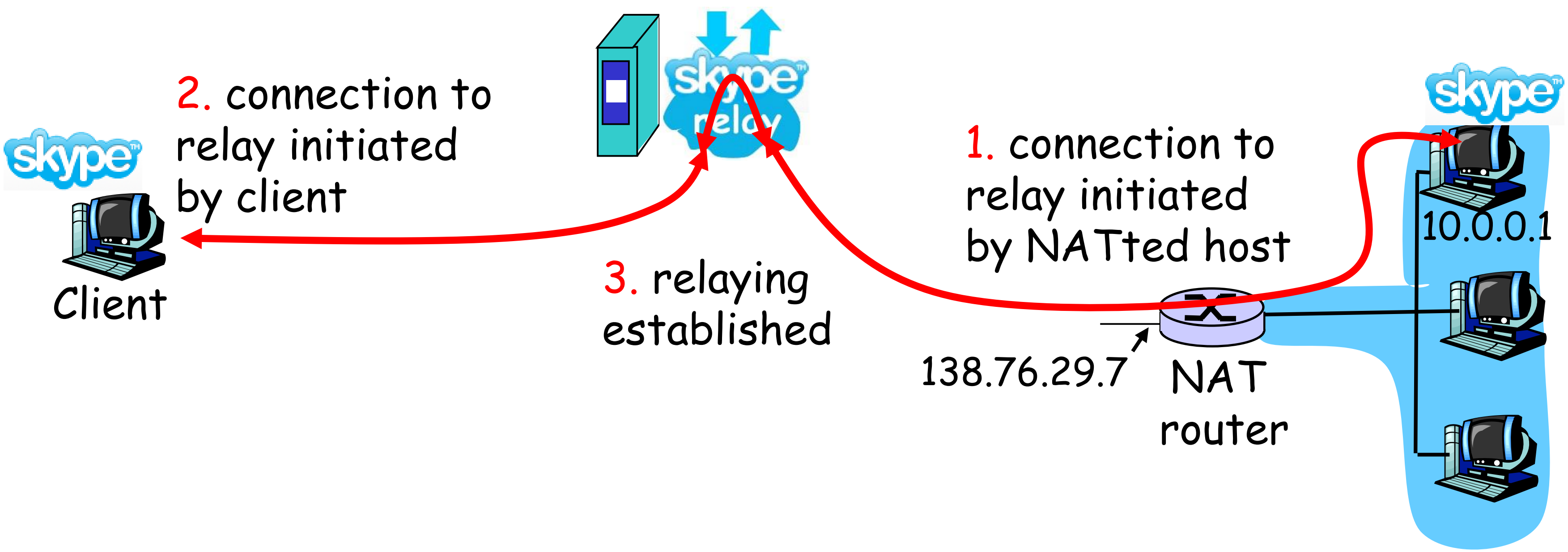
- solution 2: Universal Plug and Play (UPnP) Internet Gateway Device (IGD) Protocol. Allows NATted host to:
  - learn public IP address (138.76.29.7)
  - add/remove port mappings (with lease times)

  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



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

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 "port unreachable" packet (type 3, code 3)
- When source gets this ICMP, stops.

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IPv6

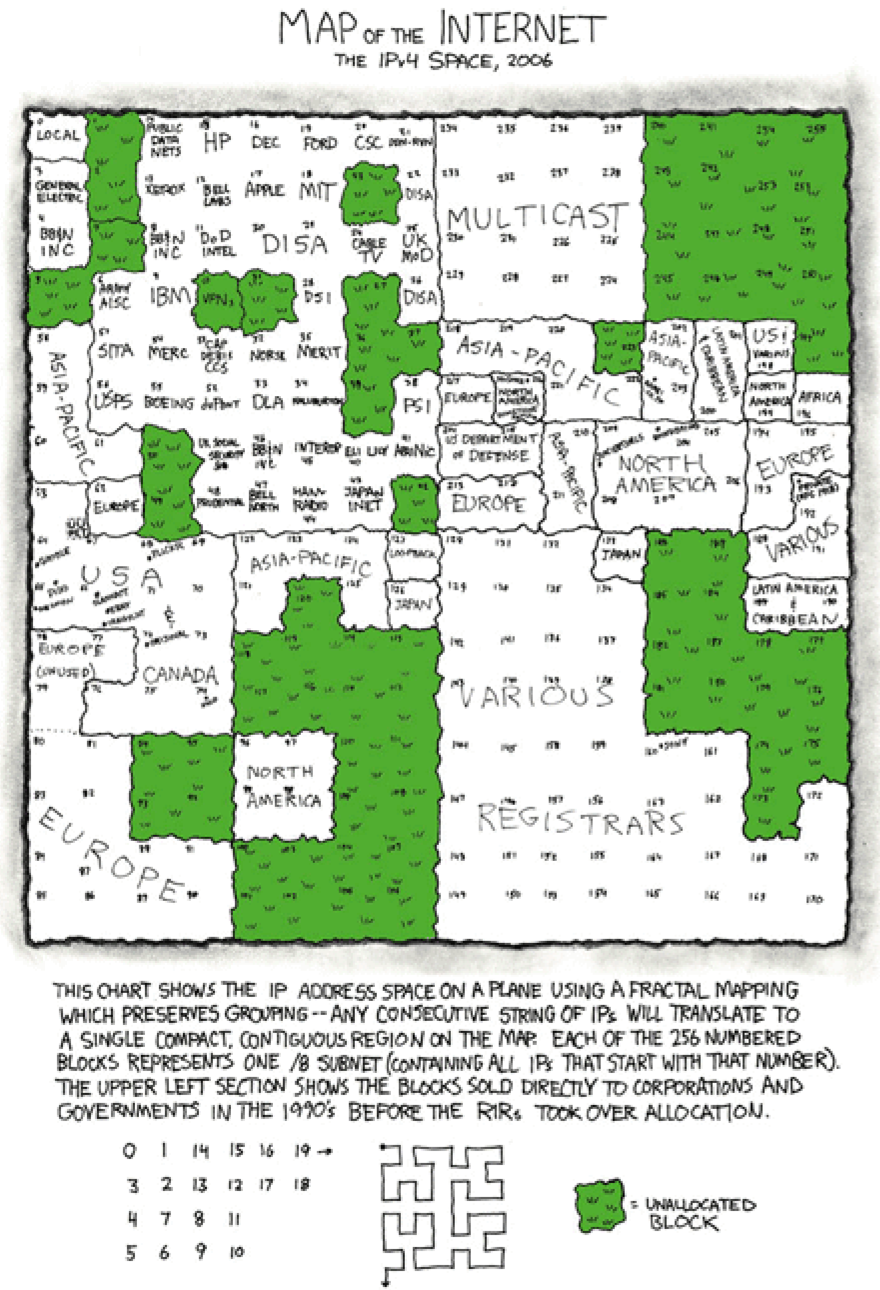
- Initial motivation: 32-bit address space soon to be completely allocated. Now, depleted!
- Additional motivation:
  - header format helps speed processing/forwarding
  - header changes to facilitate QoS

  IPv6 datagram format:
  - fixed-length 40 byte header
  - no fragmentation allowed

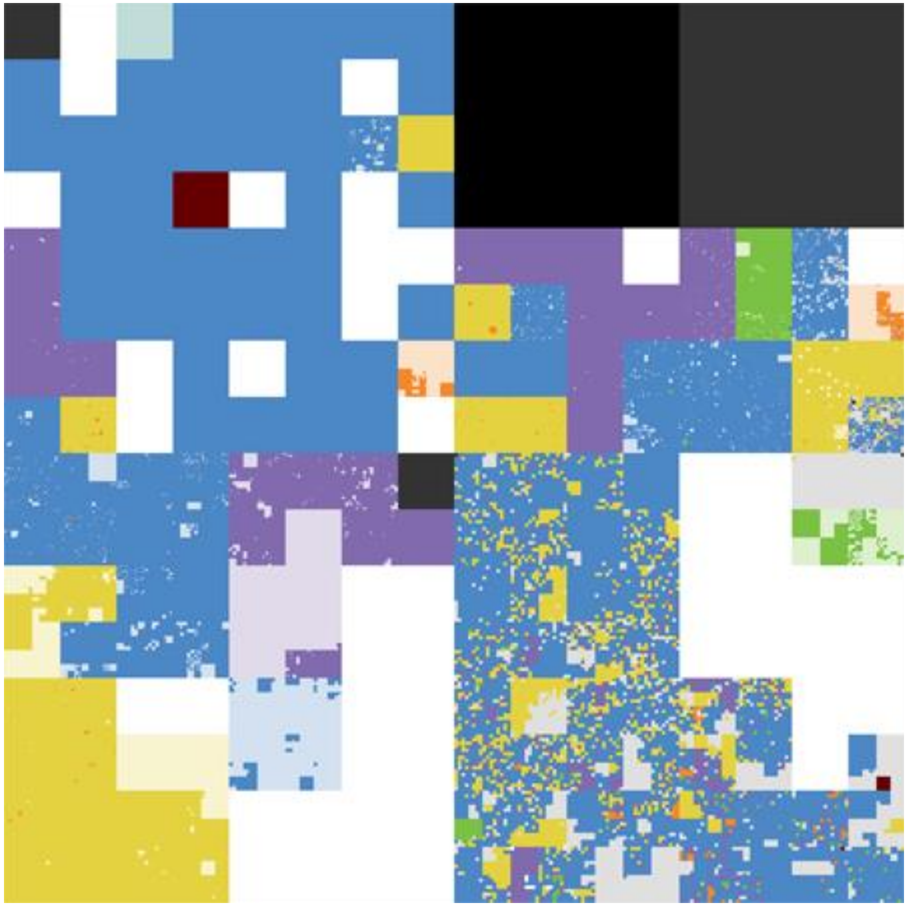
Historical classful network architecture

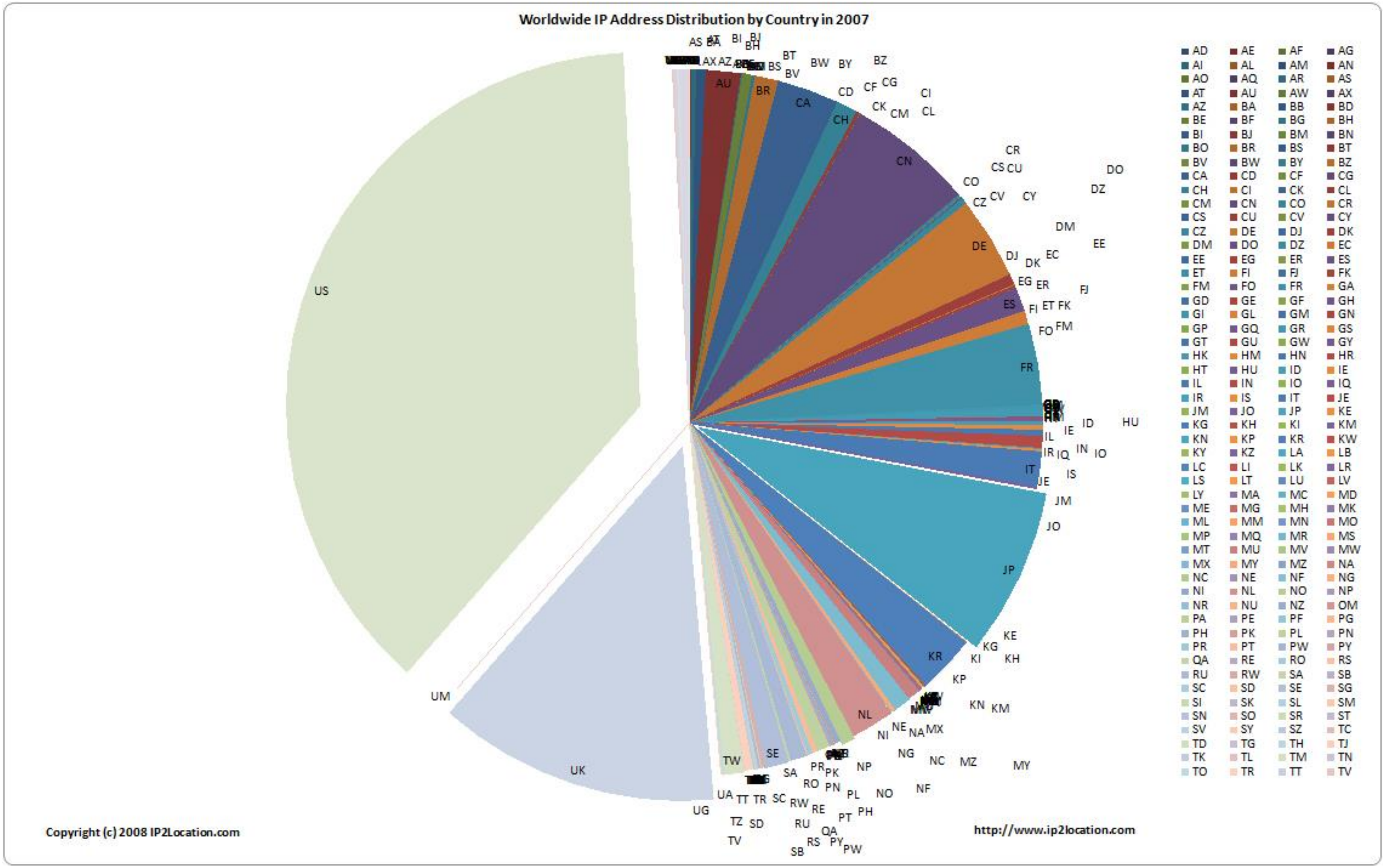
Class	Leading bits	Size of *network number* bit field	Size of *rest* bit field	Number of networks	Addresses per network	Start address	End address
A	0	8	24	128 (2^7)	16,777,216 (2^{24})	0.0.0.0	127.255.255.255
B	10	16	16	16,384 (2^{14})	65,536 (2^{16})	128.0.0.0	191.255.255.255
C	110	24	8	2,097,152 (2^{21})	256 (2^8)	192.0.0.0	223.255.255.255

Prefix	Designation	Date	Whois	Status [1]	Note
000/8	IANA - Local Identification	1981-09		RESERVED	[2]
001/8	APNIC	2010-01	whois.apnic.net	ALLOCATED	
002/8	RIPE NCC	2009-09	whois.ripe.net	ALLOCATED	
003/8	General Electric Company	1994-05	whois.arin.net	LEGACY	
004/8	Level 3 Communications, Inc.	1992-12	whois.arin.net	LEGACY	
005/8	RIPE NCC	2010-11	whois.ripe.net	ALLOCATED	
006/8	Army Information Systems Center	1994-02		LEGACY	
007/8	Administered by ARIN	1995-04	whois.arin.net	LEGACY	
008/8	Level 3 Communications, Inc.	1992-12	whois.arin.net	LEGACY	
009/8	IBM	1992-08	whois.arin.net	LEGACY	
010/8	IANA - Private Use	1995-06		RESERVED	[3]
011/8	DoD Intel Information Systems	1993-05		LEGACY	
012/8	AT&T Bell Laboratories	1995-06	whois.arin.net	LEGACY	
013/8	Xerox Corporation	1991-09	whois.arin.net	LEGACY	
014/8	APNIC	2010-04	whois.apnic.net	ALLOCATED	[4]
015/8	Hewlett-Packard Company	1994-07	whois.arin.net	LEGACY	
016/8	Digital Equipment Corporation	1994-11	whois.arin.net	LEGACY	
017/8	Apple Computer Inc.	1992-07	whois.arin.net	LEGACY	
018/8	MIT	1994-01	whois.arin.net	LEGACY	
019/8	Ford Motor Company	1995-05	whois.arin.net	LEGACY	
020/8	Computer Sciences Corporation	1994-10	whois.arin.net	LEGACY	


MAP OF THE INTERNET
THE IPv4 SPACE, 2006
LOCAL
GENERAL ELECTRIC
BBN INC
PUBLIC DATA NETS
HP
DEC
FORD
CSC
XEROX
BELL LABS
APPLE
MIT
DISA
BBN INC
DoD INTEL
DISA
CABLE TV
UK MoD
ARMY AISC
IBM
VPN
DSI
DISA
SITA
MERC
NORSK
MERIT
USPS
BOEING
duPont
DLA
PSI
ASIA-PACIFIC
EUROPE
BBN INC
INTEROP
ELI LILLY
ARINC
PRUDENTIAL
BELL NORTH
HAM RADIO
JAPAN INET
MULTICAST
ASIA-PACIFIC
EUROPE
NORTH AMERICA
ASIA-PACIFIC
LATIN AMERICA & CARIBBEAN
USI
NORTH AMERICA
AFRICA
US DEPARTMENT OF DEFENSE
EUROPE
ASIA-PACIFIC
NORTH AMERICA
EUROPE
VARIOUS
USA
ASIA-PACIFIC
LOOPBACK
JAPAN
JAPAN
LATIN AMERICA & CARIBBEAN
EUROPE (UNUSED)
CANADA
VARIOUS
NORTH AMERICA
EUROPE
REGISTRARS
THIS CHART SHOWS THE IP ADDRESS SPACE ON A PLANE USING A FRACTAL MAPPING WHICH PRESERVES GROUPING -- ANY CONSECUTIVE STRING OF IPs WILL TRANSLATE TO A SINGLE COMPACT, CONTIGUOUS REGION ON THE MAP. EACH OF THE 256 NUMBERED BLOCKS REPRESENTS ONE /8 SUBNET (CONTAINING ALL IPs THAT START WITH THAT NUMBER). THE UPPER LEFT SECTION SHOWS THE BLOCKS SOLD DIRECTLY TO CORPORATIONS AND GOVERNMENTS IN THE 1990's BEFORE THE RIRs TOOK OVER ALLOCATION.
0 1 14 15 16 19
3 2 13 12 17 18
4 7 8 11
5 6 9 10
= UNALLOCATED BLOCK


ARIN
RIPE NCC
AFRINIC
APNIC
LACNIC





Worldwide IP Address Distribution by Country in 2007
US
UK
UM
JP
CN
DE
FR
CA
KR
NL
AU
IT
TW
Copyright (c) 2008 IP2Location.com
http://www.ip2location.com

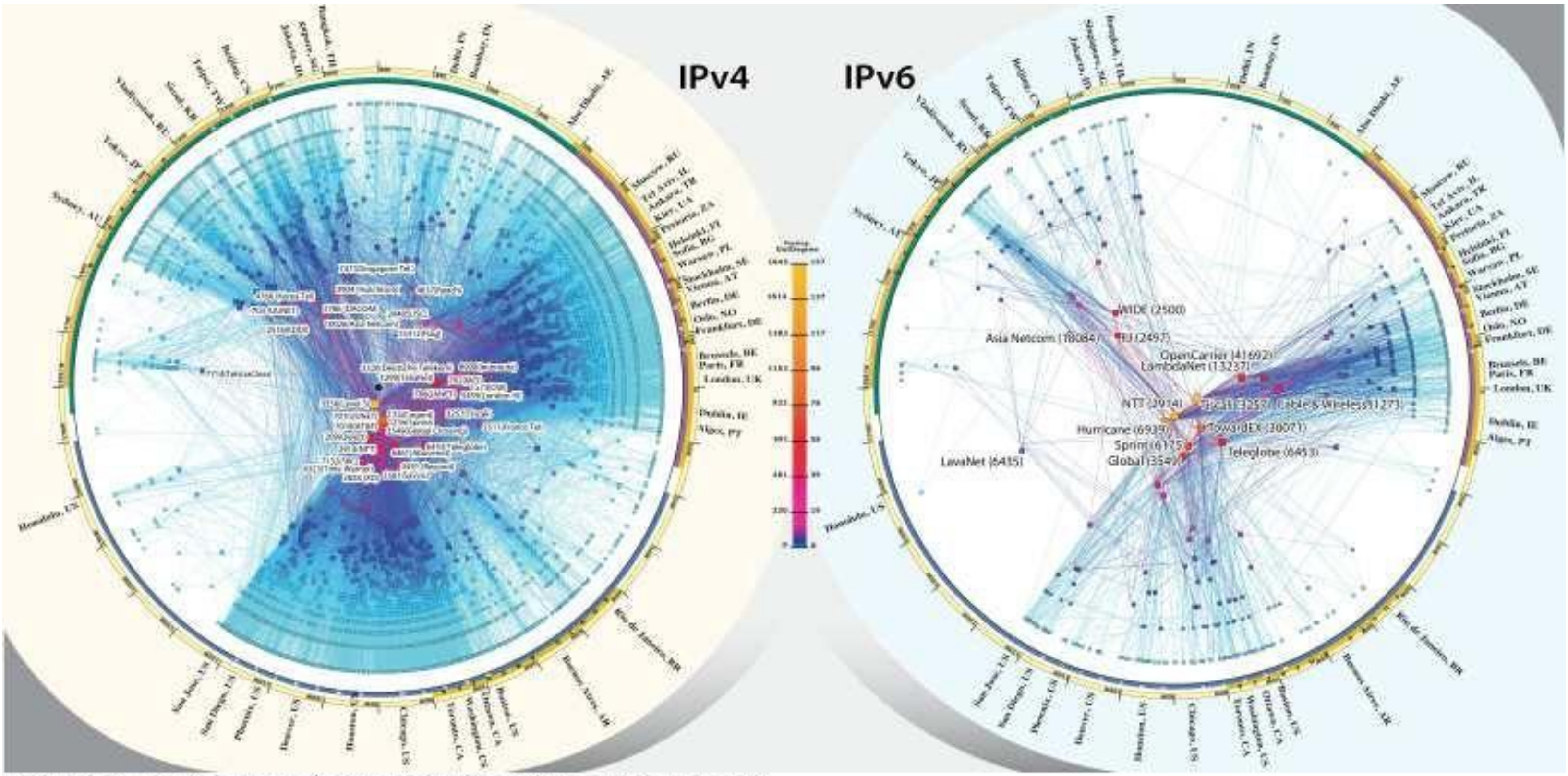
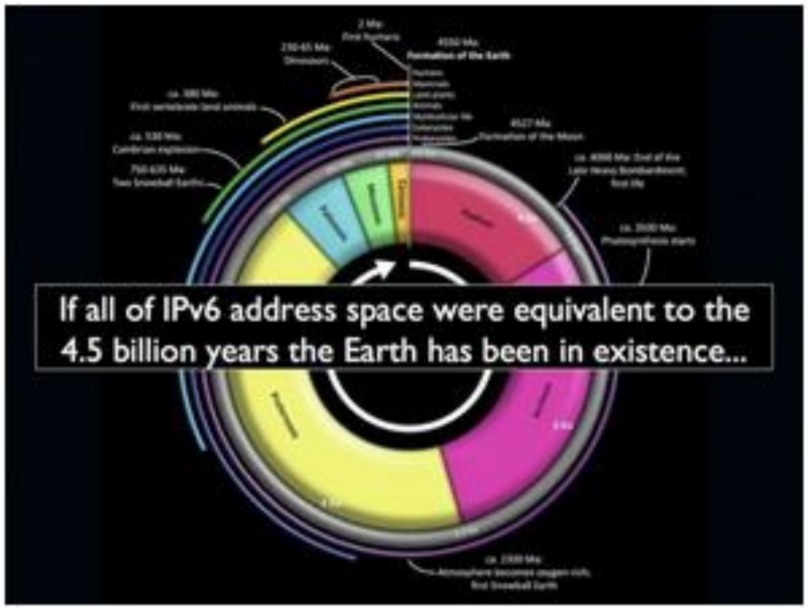
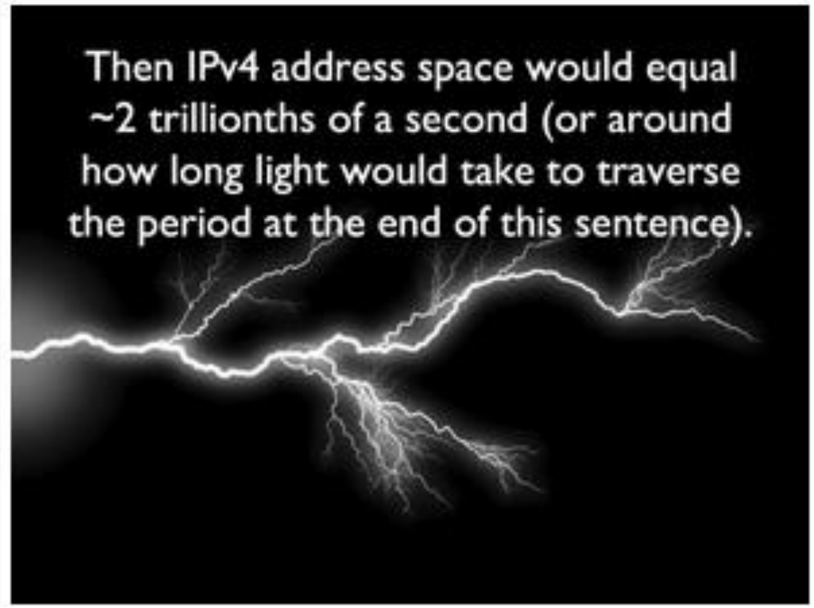
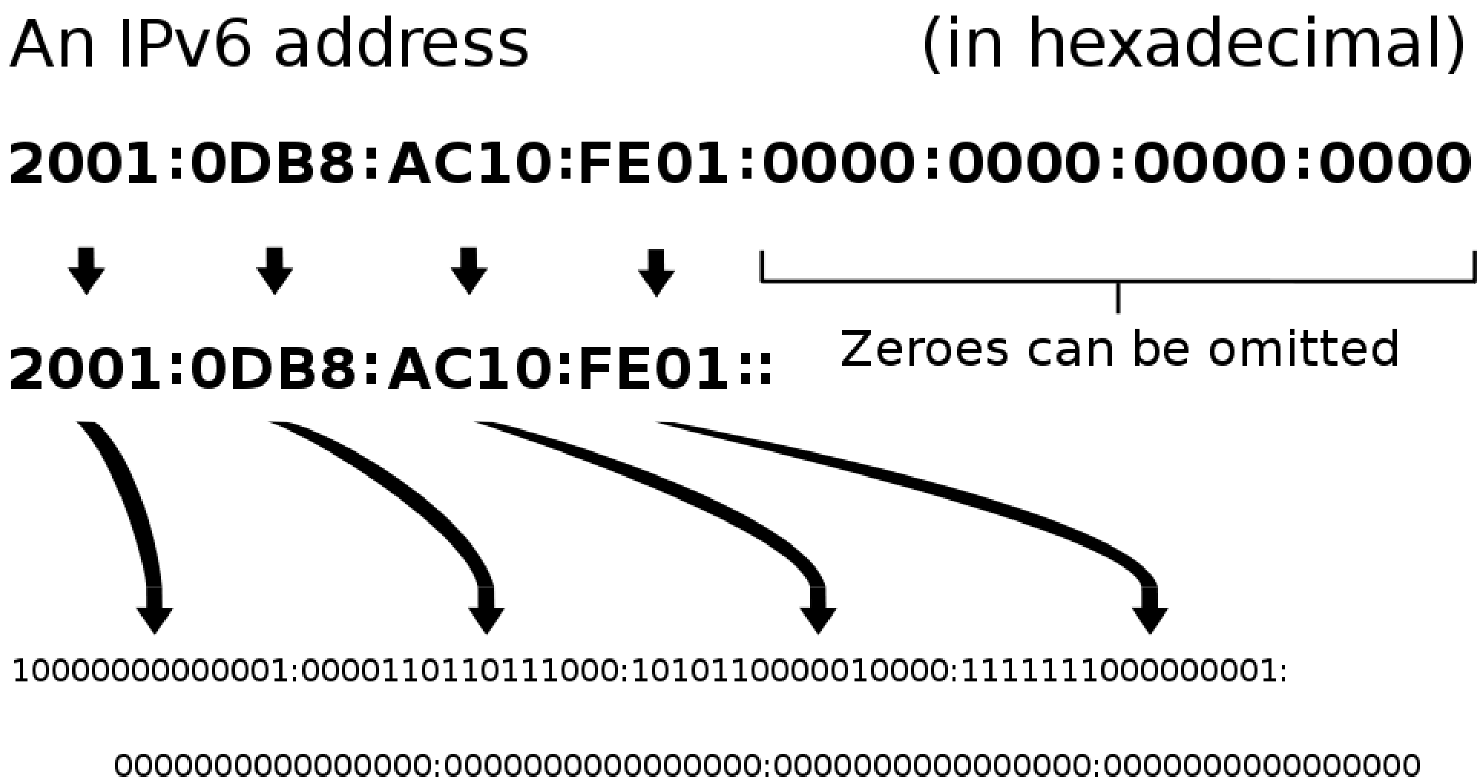


Figure 1: IPv4 and IPv6 Internet Populations Compared
(December 2008; Courtesy Cooperative Association for Internet Data Analysis)


If all of IPv6 address space were equivalent to the
4.5 billion years the Earth has been in existence...

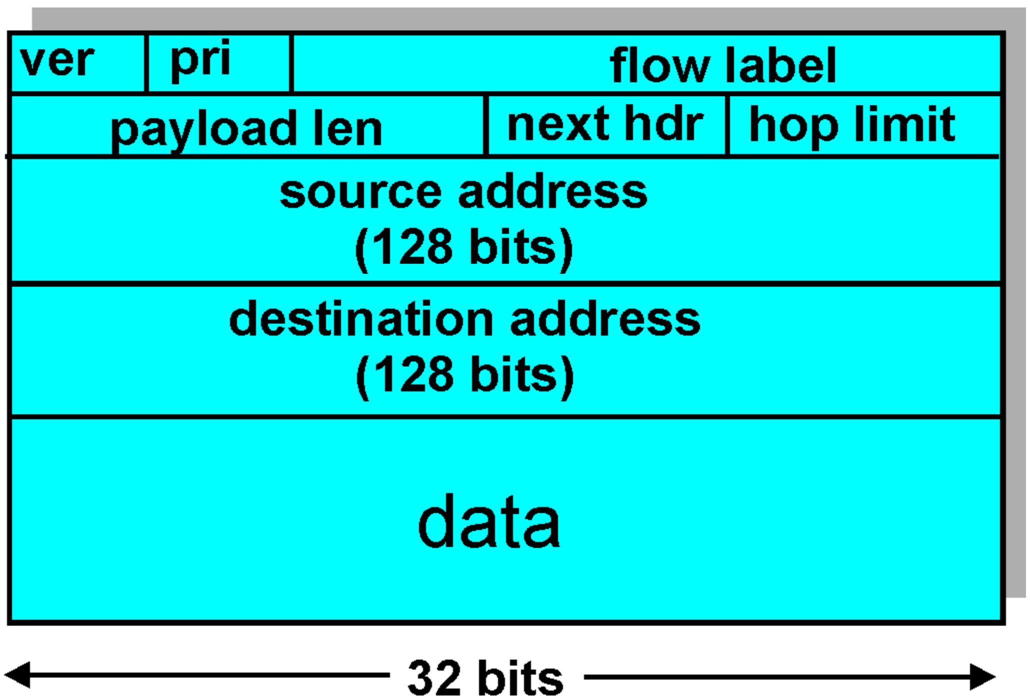

Then IPv4 address space would equal
~2 trillionths of a second (or around
how long light would take to traverse
the period at the end of this sentence).



An IPv6 address
(in hexadecimal)
2001:0DB8:AC10:FE01:0000:0000:0000:0000
Zeroes can be omitted
2001:0DB8:AC10:FE01::
10000000000001:0000110110111000:1010110000010000:1111111000000001:
0000000000000000:0000000000000000:0000000000000000:0000000000000000

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



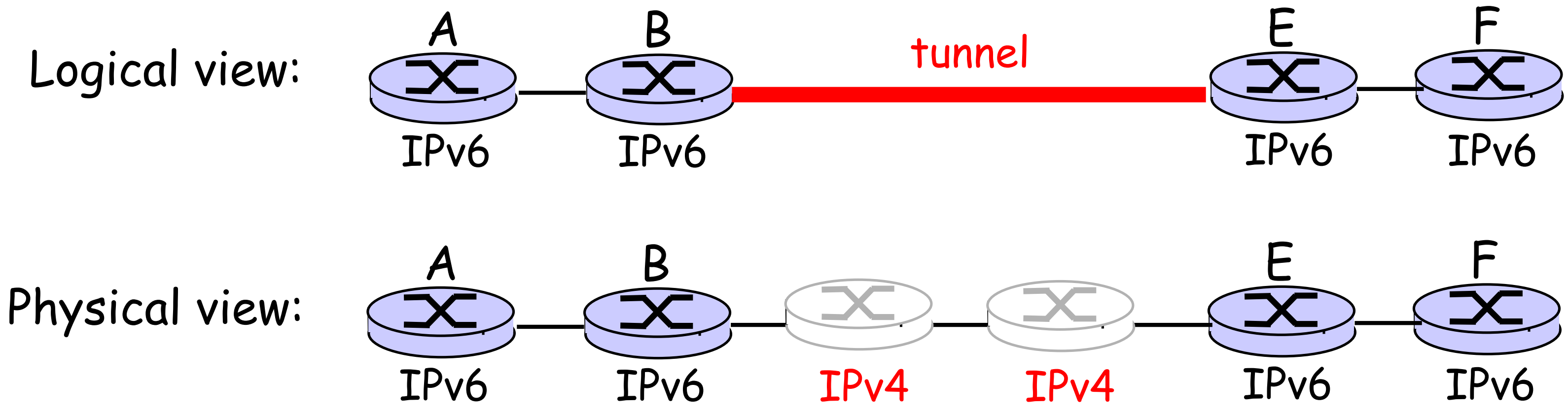
Other Changes from IPv4

- *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

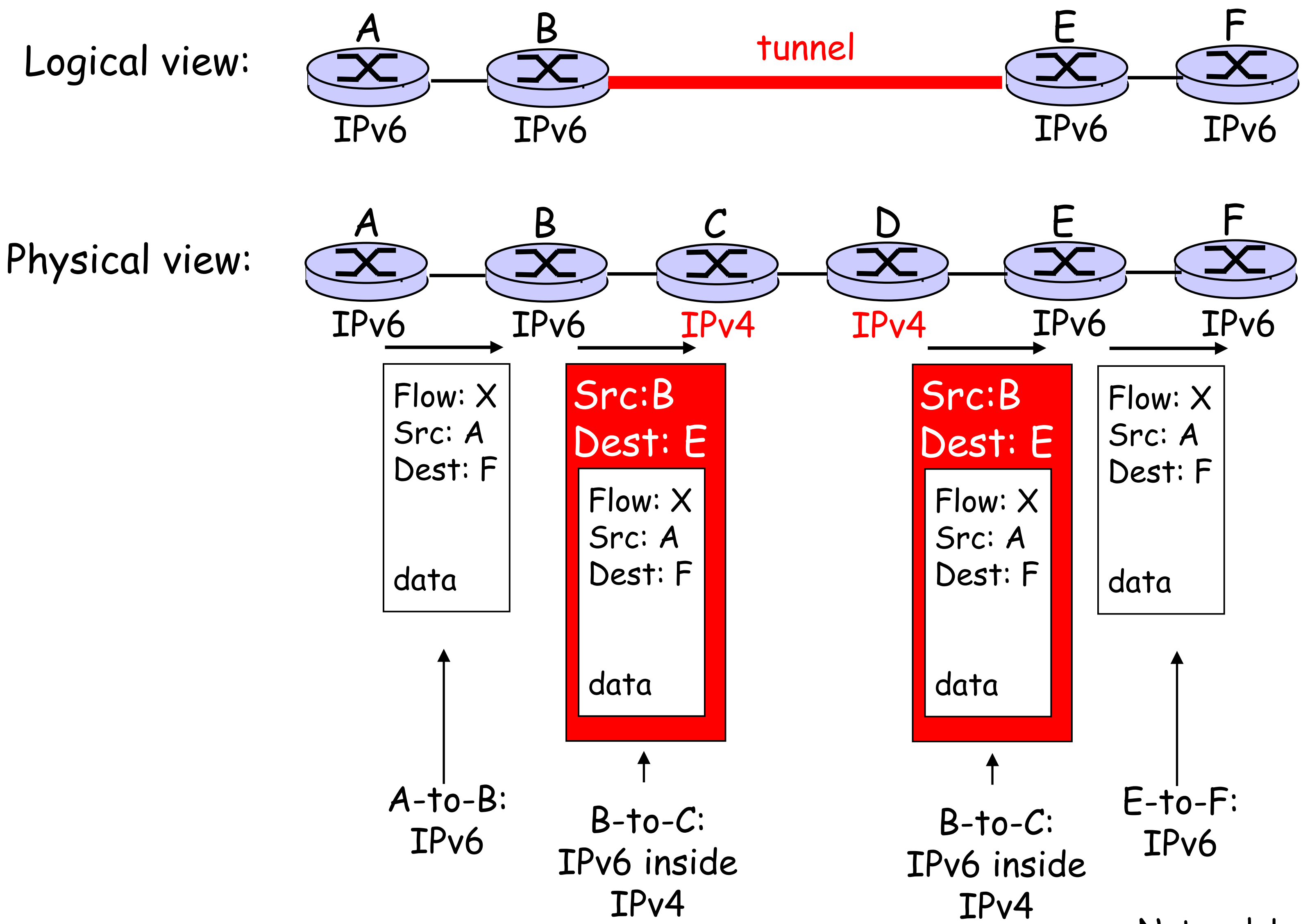
Transition From IPv4 To IPv6

- 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
E
F
tunnel
IPv6
IPv6
IPv6
IPv6
Physical view:
A
B
E
F
IPv6
IPv6
IPv4
IPv4
IPv6
IPv6

Tunneling



Logical view:
A
B
tunnel
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