Internet and IP addressing

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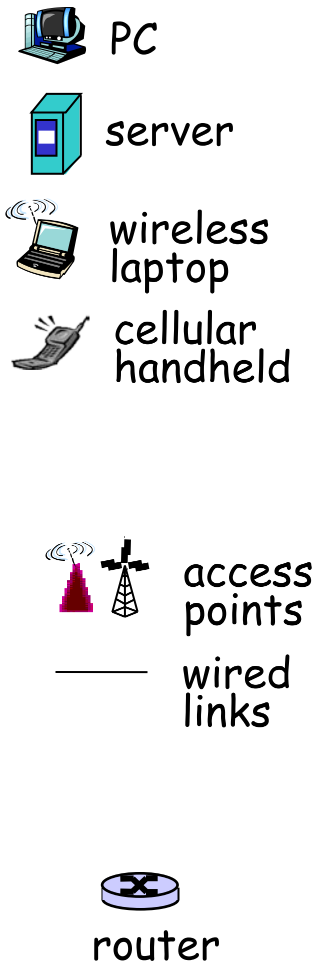
CS 3103: Compute Networks and Protocols

Communication Network Taxonomy

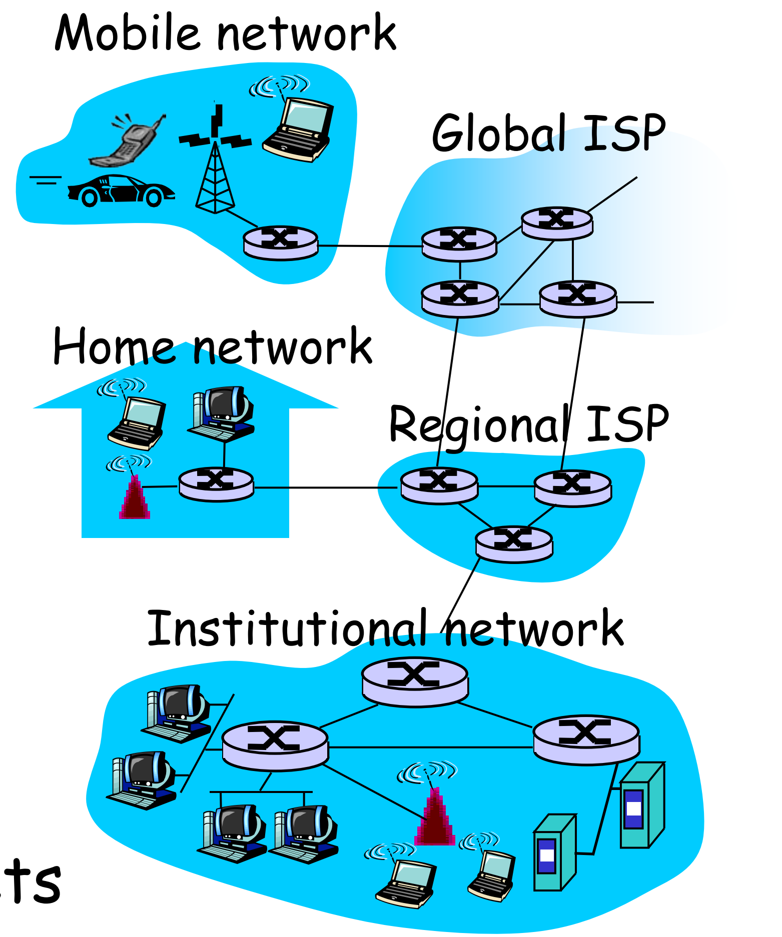
- Telephony Network
  - parses number dialed
  - sets up a circuit between caller & callee
  - sends signal to ring
- Pros
  - no end-point intelligence
  - good voice performance
- Cons
  - difficult to add service
  - achieve performance by overprovisioning

- The Internet
  - data parceled into packets
  - routed independently
  - arrive out of order
  - may be dropped
- Pros
  - intelligence at end-points
  - decentralized control
  - operates over various access technologies
- Cons
  - no quality of service
  - no trusted infrastructure

What's the Internet: "nuts and bolts" view

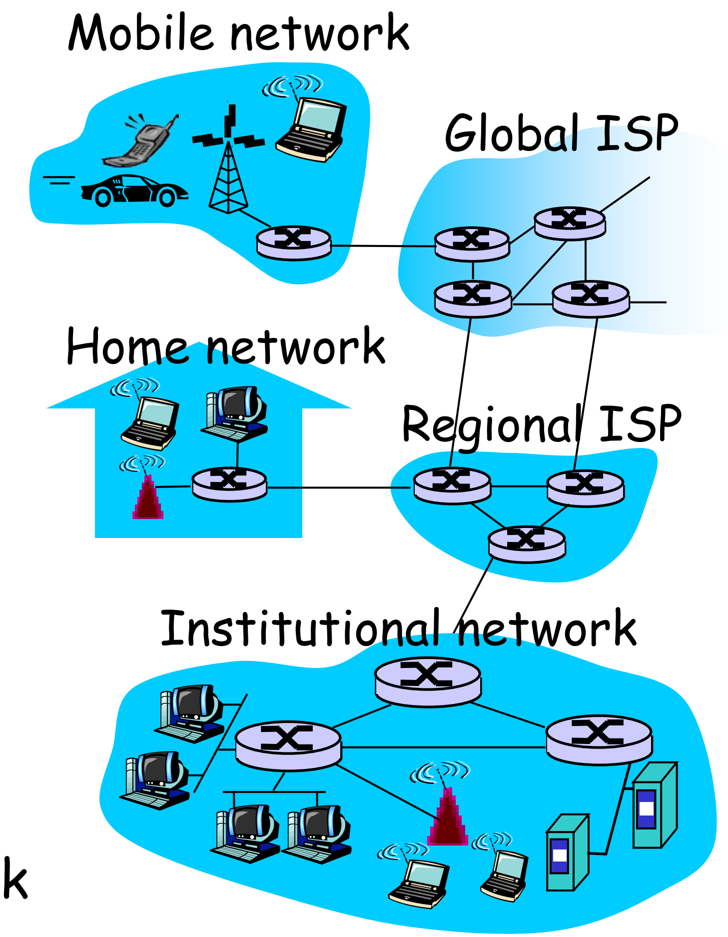


- millions of connected computing devices: *hosts = end systems*
  - running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate = *bandwidth*
- *routers:* forward packets (chunks of data)



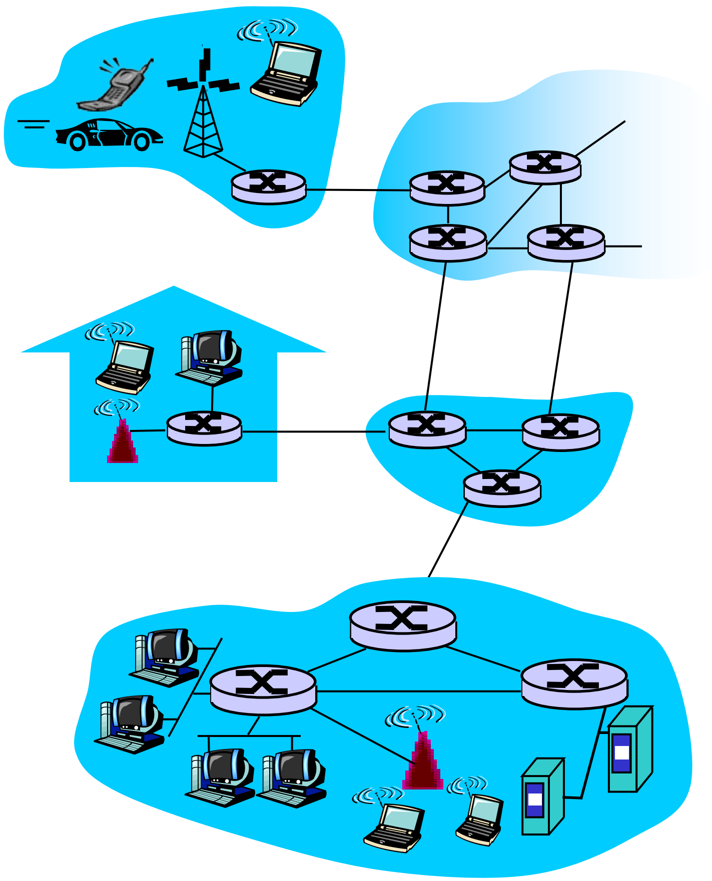
What's the Internet: "nuts and bolts" view

- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, Ethernet
- *Internet:* "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force (http://www.ietf.org/)



What's the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - Web, VoIP, email, games, e-commerce, file sharing
- communication services provided to apps:
  - reliable data delivery from source to destination
  - "best effort" (unreliable) data delivery

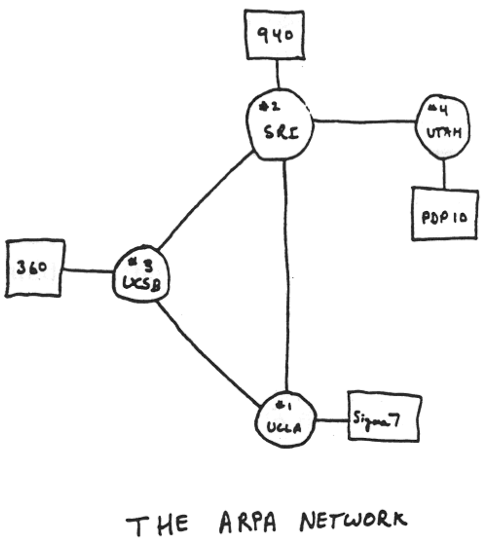


Internet History

1961-1972: Early packet-switching principles

- 1961: Kleinrock - queueing theory shows effectiveness of packet-switching
- 1964: Baran - packet-switching in military nets
- 1967: ARPAnet conceived by Advanced Research Projects Agency
- 1969: first ARPAnet node operational

- 1972:
  - ARPAnet public demonstration
  - NCP (Network Control Protocol) first host-host protocol
  - first e-mail program
  - ARPAnet has 15 nodes



Internet History

1972-1980: Internetworking, new and proprietary nets

- 1970: ALOHAnet satellite network in Hawaii
- 1974: Cerf and Kahn - architecture for interconnecting networks
- 1976: Ethernet at Xerox PARC
- late70's: proprietary architectures: DECnet, SNA, XNA
- late 70's: switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:

- minimalism, autonomy - no internal changes required to interconnect networks
- best effort service model
- stateless routers
- decentralized control

define today's Internet architecture

Internet History

1980-1990: new protocols, a proliferation of networks

- 1983: deployment of TCP/IP
- 1982: smtp e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: ftp protocol defined
- 1988: TCP congestion control

- new national networks: Csnet, BITnet, NSFnet, Minitel
- 100,000 hosts connected to confederation of networks

Internet History

1990, 2000's: commercialization, the Web, new apps

- early 1990's: ARPAnet decommissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- early 1990s: Web
  - hypertext [Bush 1945, Nelson 1960's]
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic, later Netscape
  - late 1990's: commercialization of the Web

late 1990's – 2000's:

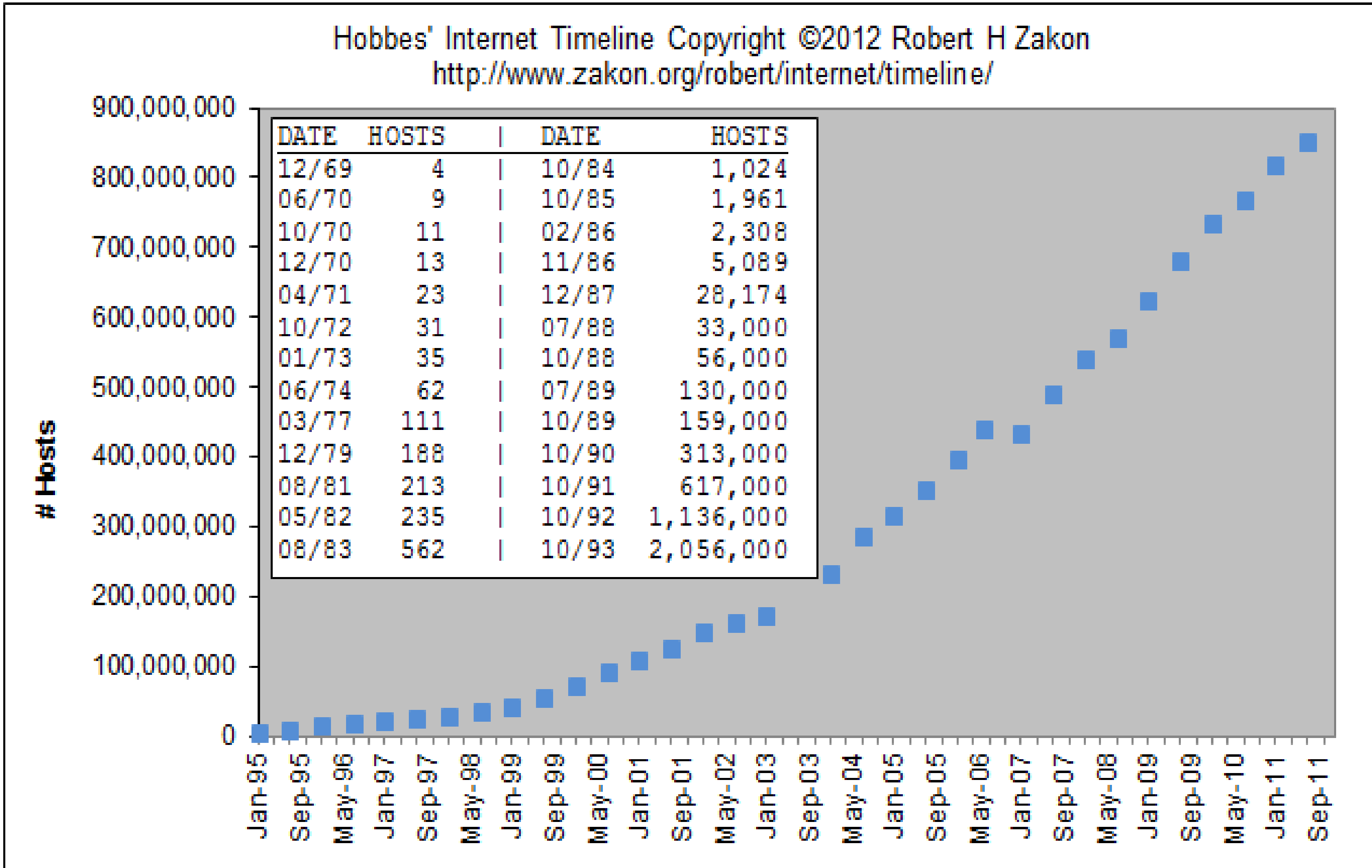
- more killer apps: instant messaging, P2P file sharing
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps

Internet History

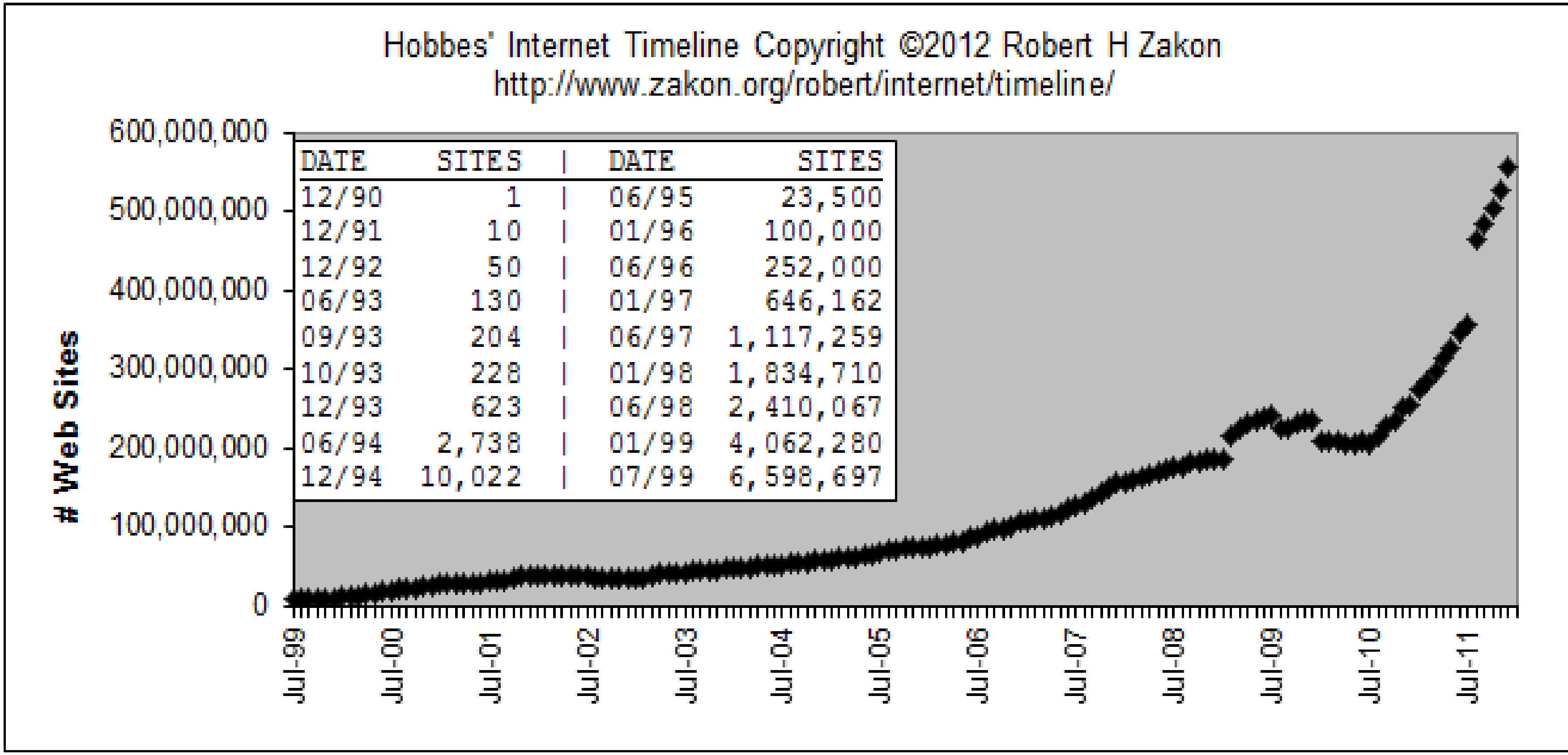
2010:

- ~750 million hosts
- voice, video over IP
- P2P applications: BitTorrent (file sharing) Skype (VoIP), PPLive (video)
- more applications: YouTube, gaming, Twitter
- wireless, mobility

Growth of Internet Hosts

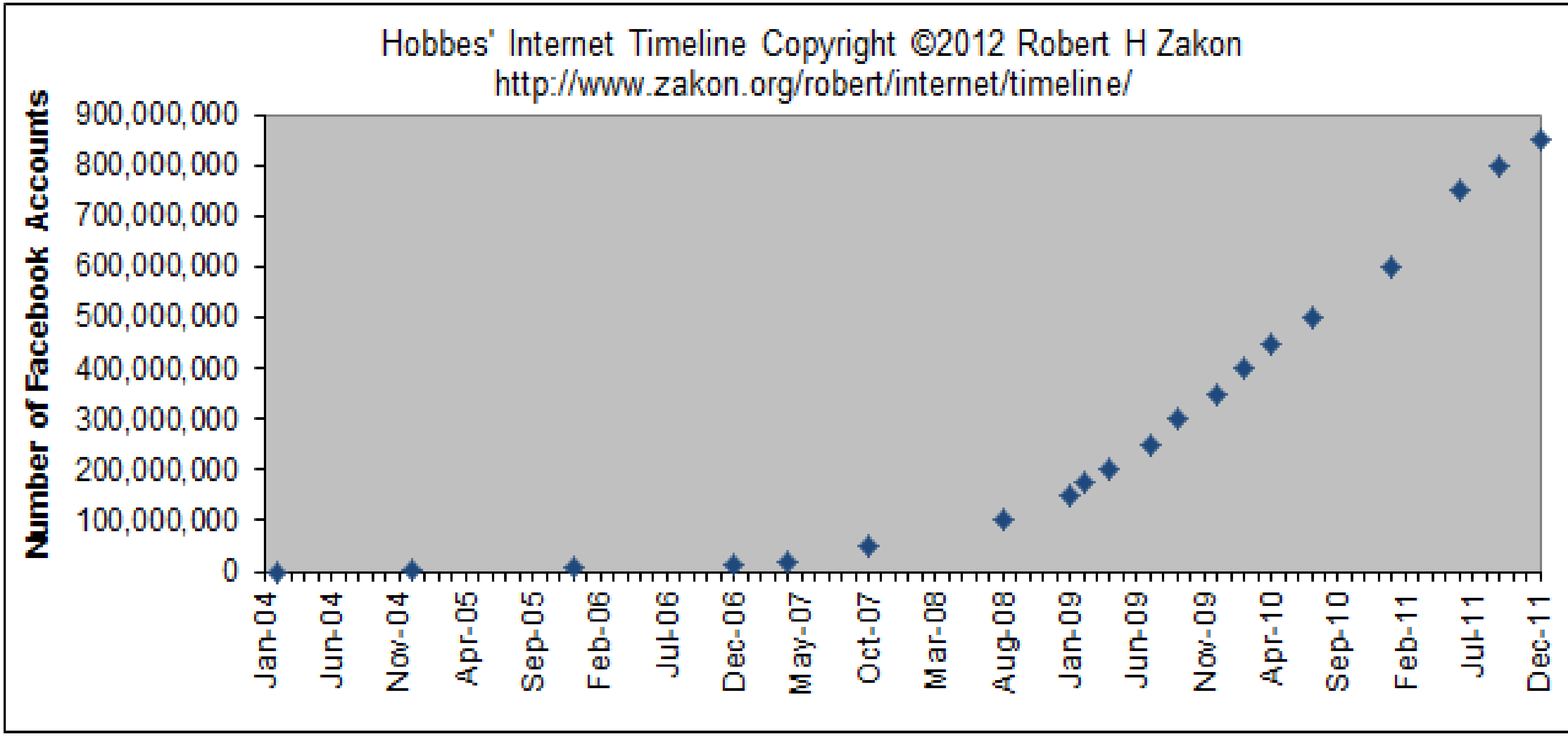


Growth of WWW Sites



DATE	SITES	DATE	SITES
12/90	1	06/95	23,500
12/91	10	01/96	100,000
12/92	50	06/96	252,000
06/93	130	01/97	646,162
09/93	204	06/97	1,117,259
10/93	228	01/98	1,834,710
12/93	623	06/98	2,410,067
06/94	2,738	01/99	4,062,280
12/94	10,022	07/99	6,598,697

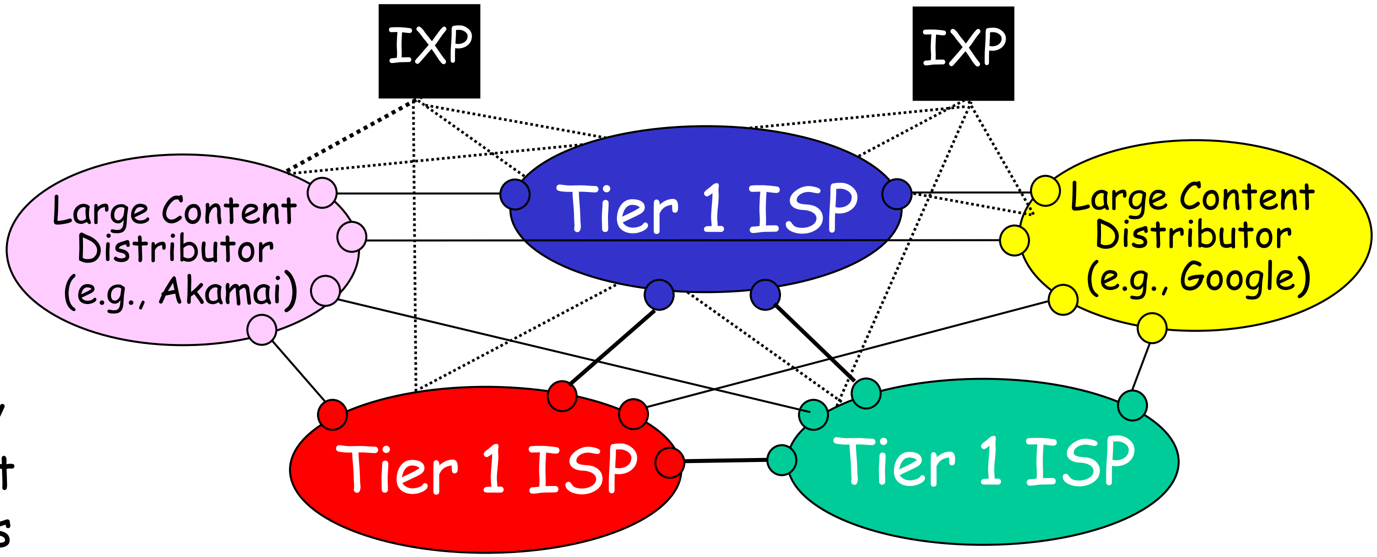
Growth of Facebook Accounts



Internet structure: network of networks

- roughly hierarchical
- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., Verizon, Sprint, AT&T, Qwest, Level3), national & international coverage
  - large content distributors (Google, Akamai, Microsoft)
  - treat each other as equals (no charges)

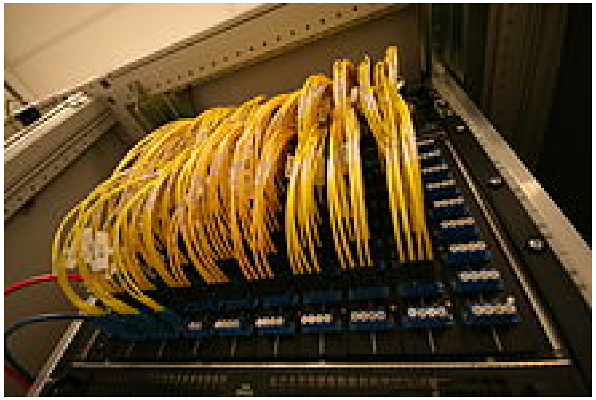
Tier-1 ISPs & Content Distributors, interconnect (peer) privately … or at Internet Exchange Points IXPs



Internet Exchange Point (IXP)

Frankfurt Internet Exchange (DE-CIX)

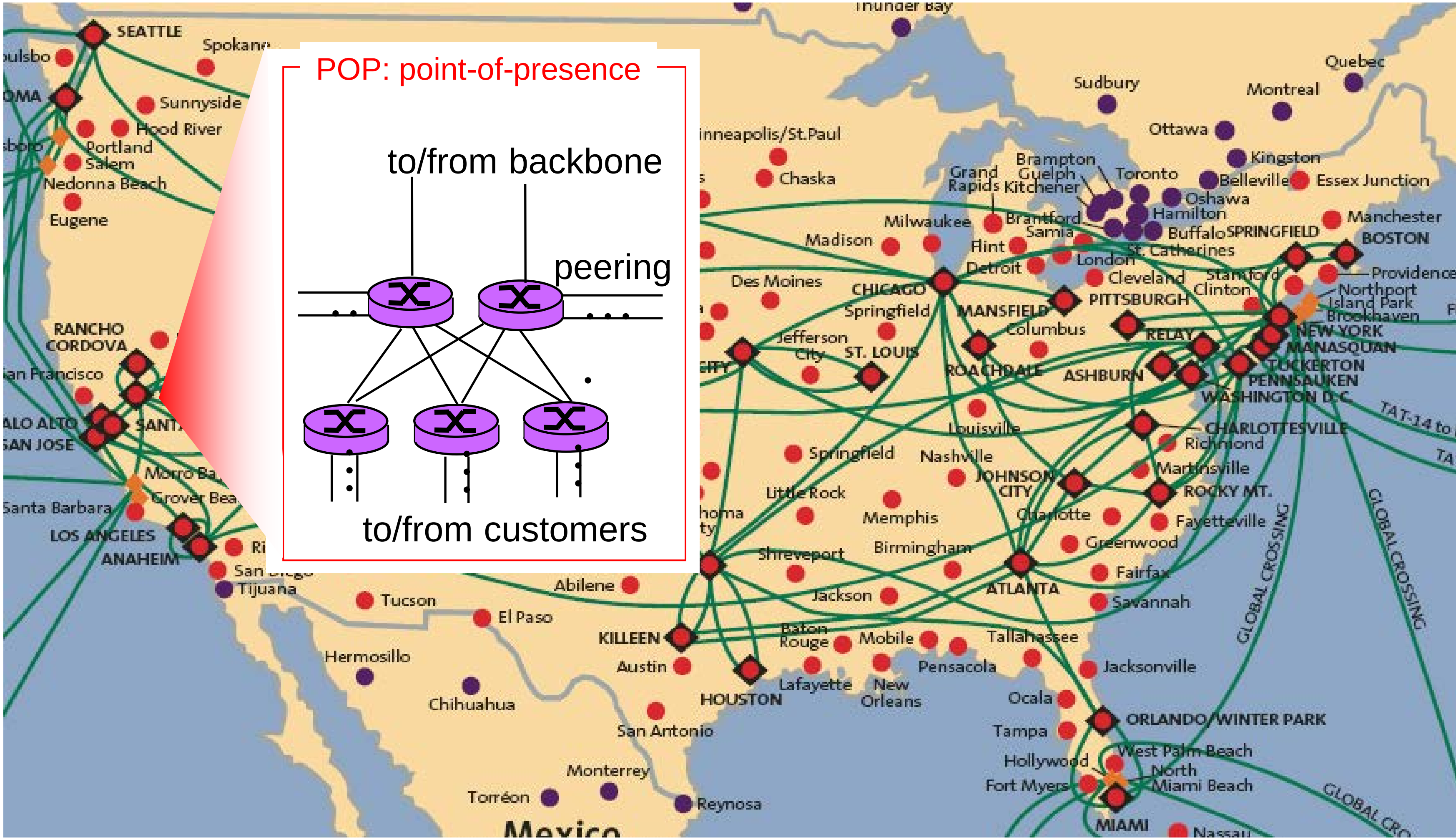
London Internet Exchange (LINX)



Amsterdam Internet Exchange (AMS-IX)

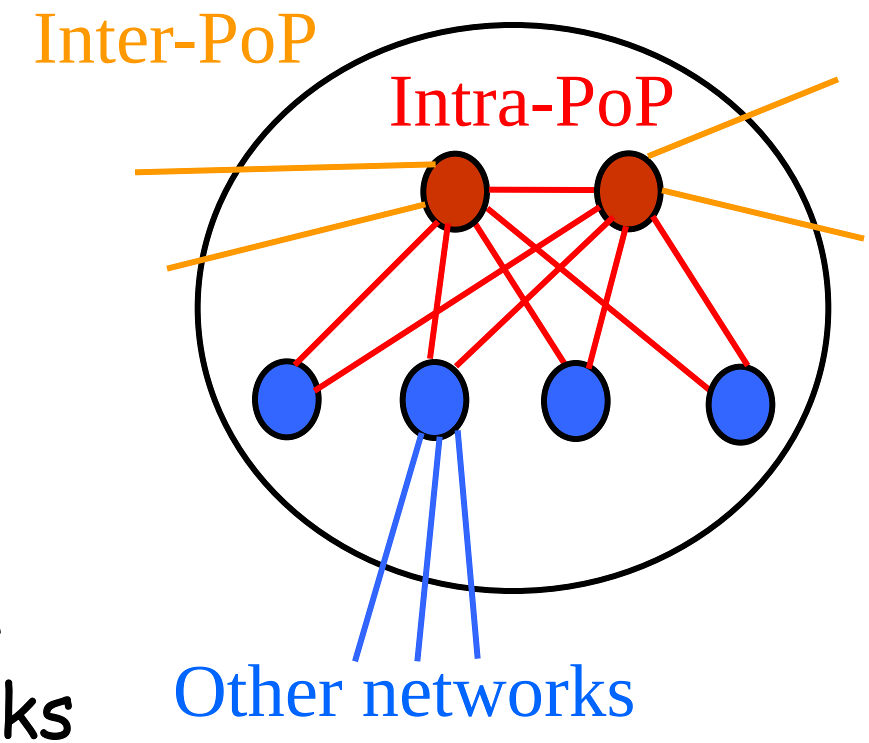
- PeeringDB: **http://www.peeringdb.com/**

Tier-1 ISP: e.g., Sprint



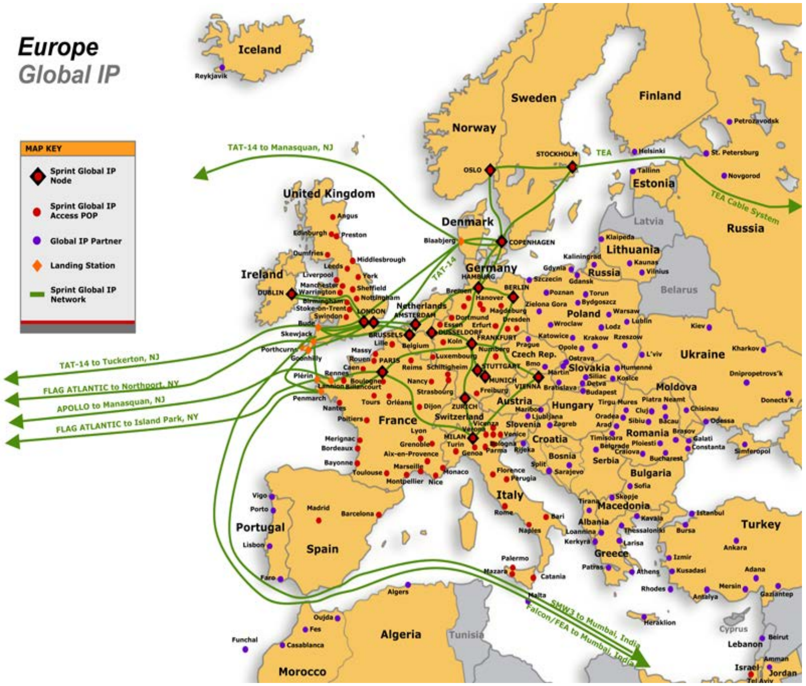
Points-of-Presence (PoPs)

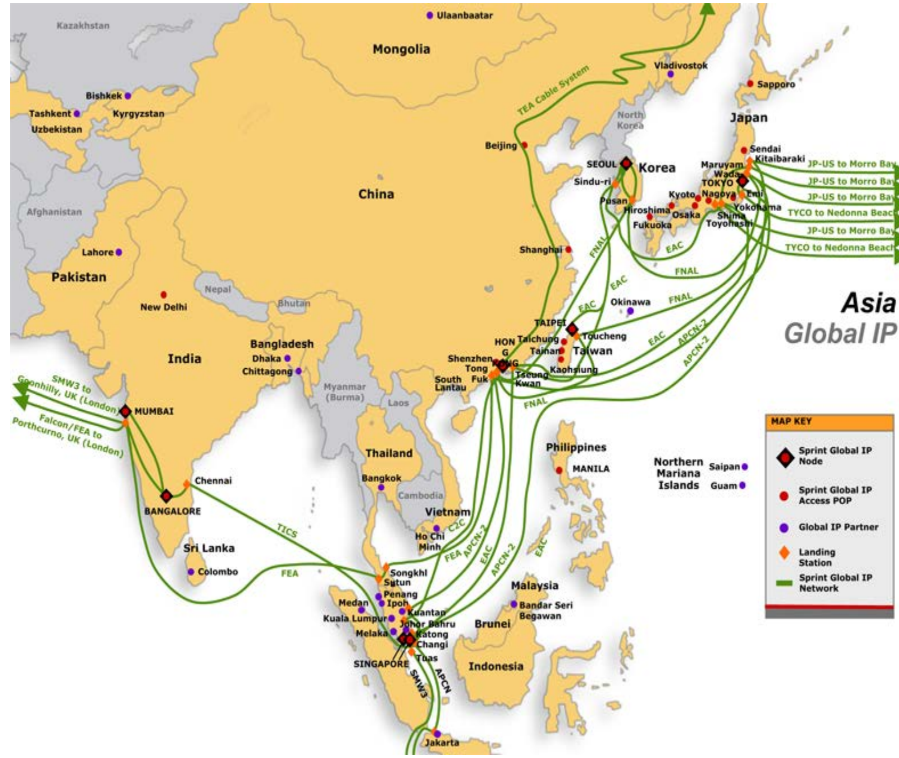
- Inter-PoP links
  - Long distances
  - High bandwidth
- Intra-PoP links
  - Short cables between racks or floors
  - Aggregated bandwidth
- Links to other networks
  - Wide range of media and bandwidth

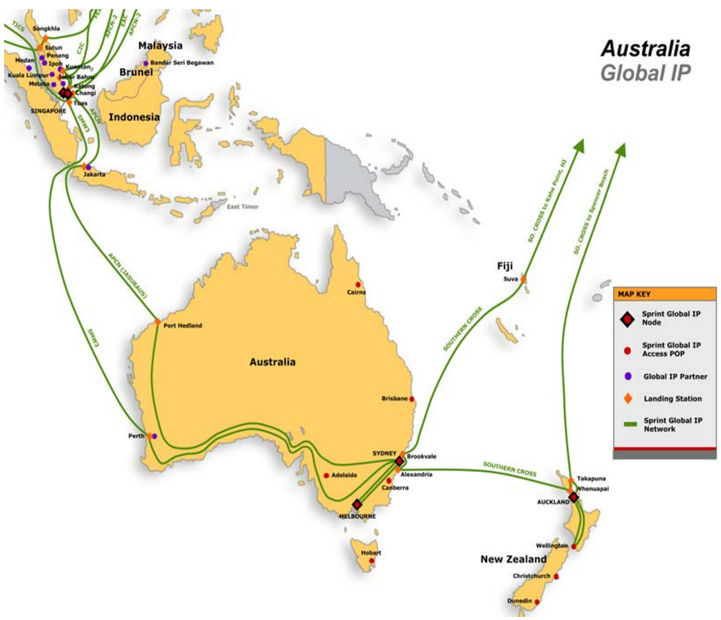


Where to Locate Nodes and Links

- Placing Points-of-Presence (PoPs)
  - Large population of potential customers
  - Other providers or exchange points
  - Cost and availability of real-estate
  - Mostly in major metropolitan areas
- Placing links between PoPs
  - Already fiber in the ground
  - Needed to limit propagation delay
  - Needed to handle the traffic load


Europe
Global IP
MAP KEY
Sprint Global IP Node
Sprint Global IP Access POP
Global IP Partner
Landing Station
Sprint Global IP Network
TAT-14 to Manasquan, NJ
TEA Cable System
TAT-14 to Tuckerton, NJ
FLAG ATLANTIC to Northport, NY
APOLLO to Manasquan, NJ
FLAG ATLANTIC to Island Park, NY
SMW3 to Mumbai, India
Falcon/FEA to Mumbai, India


Asia
Global IP
MAP KEY
Sprint Global IP Node
Sprint Global IP Access POP
Global IP Partner
Landing Station
Sprint Global IP Network
TEA Cable System
JP-US to Morro Bay, CA
TYCO to Nedonna Beach, OR
SMW3 to Goonhilly, UK (London)
Falcon/FEA to Porthcurno, UK (London)

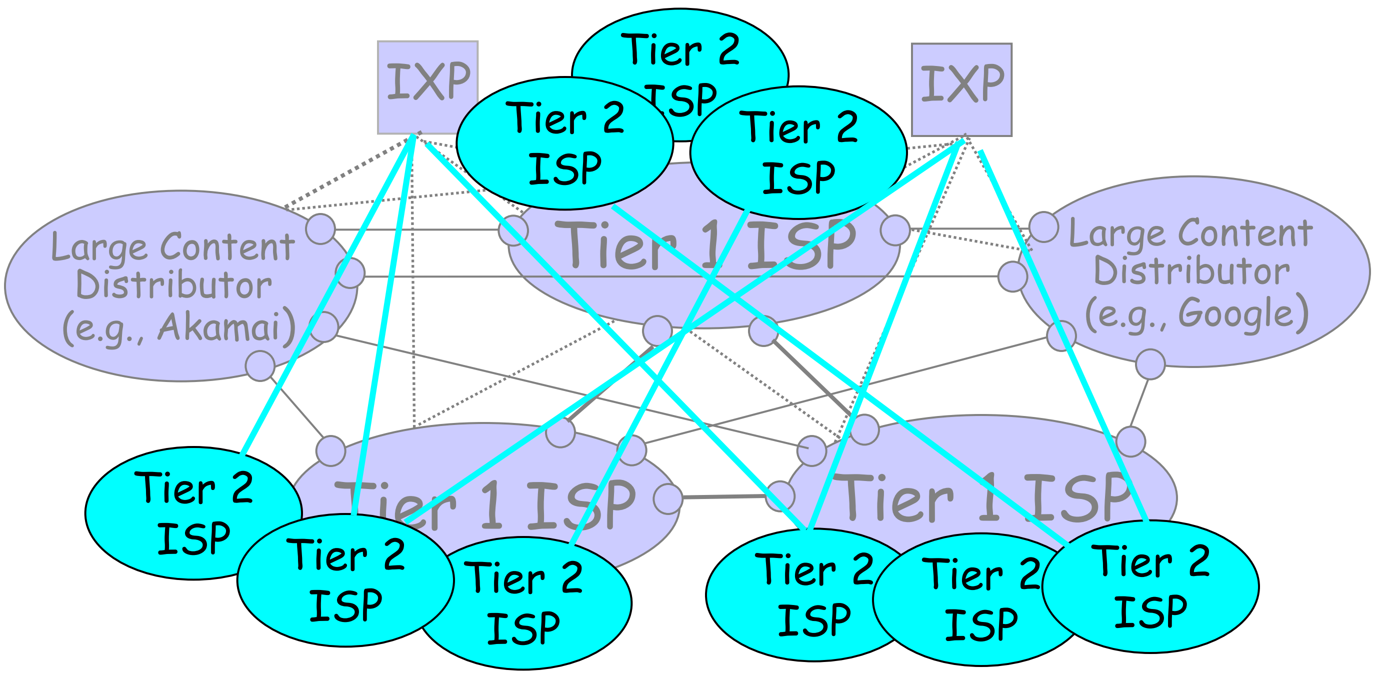

Australia
Global IP
MAP KEY
Sprint Global IP Node
Sprint Global IP Access POP
Global IP Partner
Landing Station
Sprint Global IP Network


Europe
Africa
Middle East
Global IP
MAP KEY
Sprint Global IP Node
Sprint Global IP Access POP
Global IP Partner
Landing Station
Sprint Global IP Network
TEA Cable System

Internet structure: network of networks

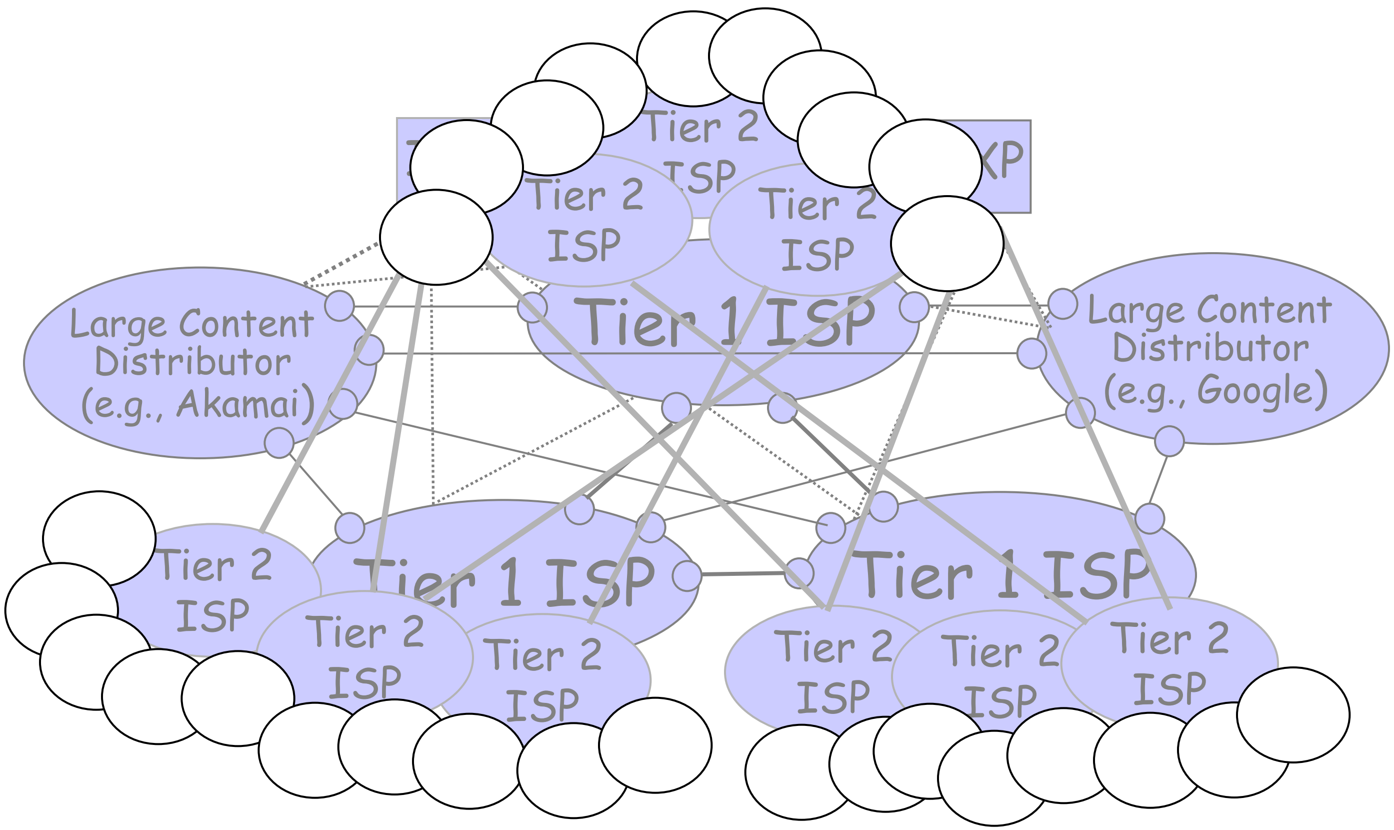
"tier-2" ISPs: smaller (often regional) ISPs

- connect to one or more tier-1 *(provider)* ISPs
  - each tier-1 has many tier-2 *customer nets*
  - tier 2 pays tier 1 provider
- tier-2 nets sometimes peer directly with each other (bypassing tier 1) , or at IXP



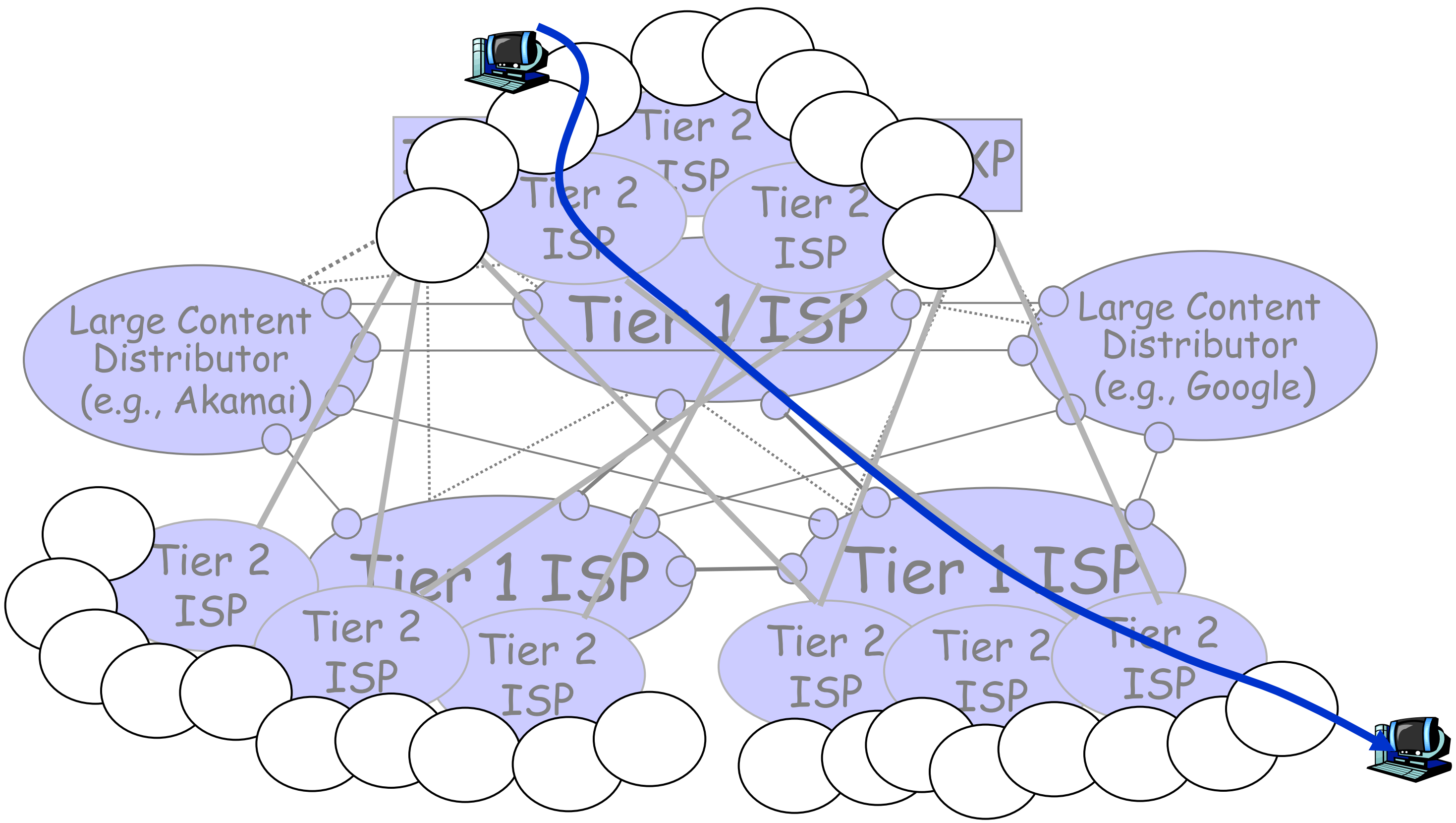
Internet structure: network of networks

- "Tier-3" ISPs, local ISPs
- customer of tier 1 or tier 2 network
  - last hop ("access") network (closest to end systems)

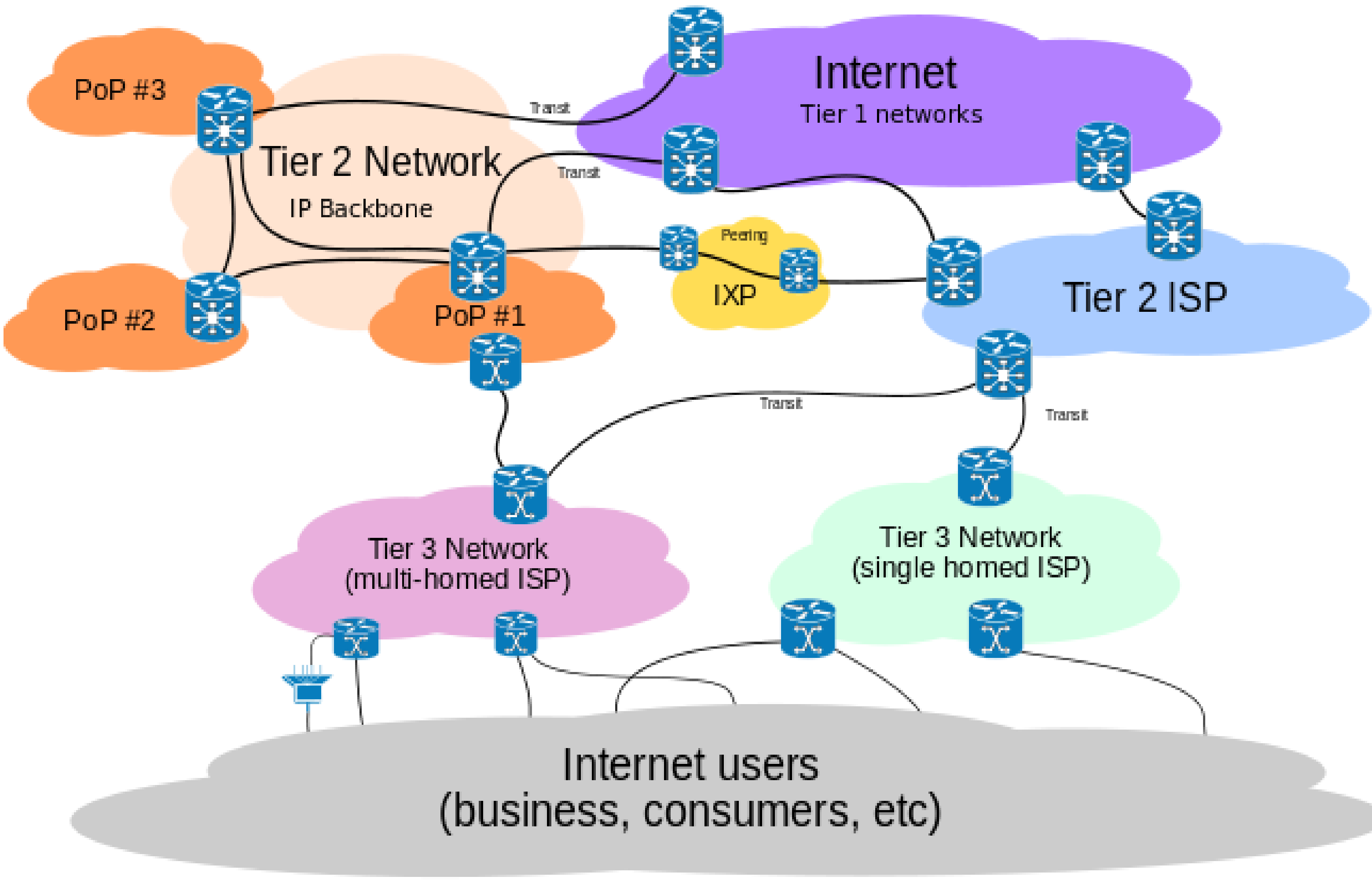


Internet structure: network of networks

- a packet passes through *many* networks from source host to destination host



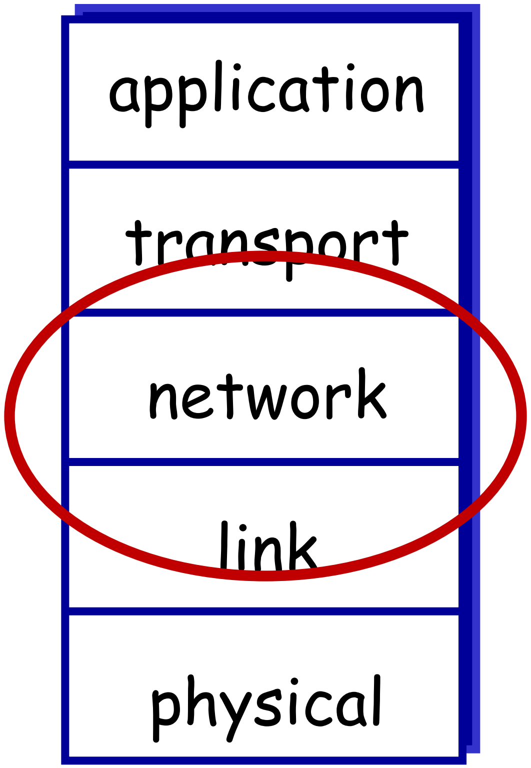
Internet structure: network of networks



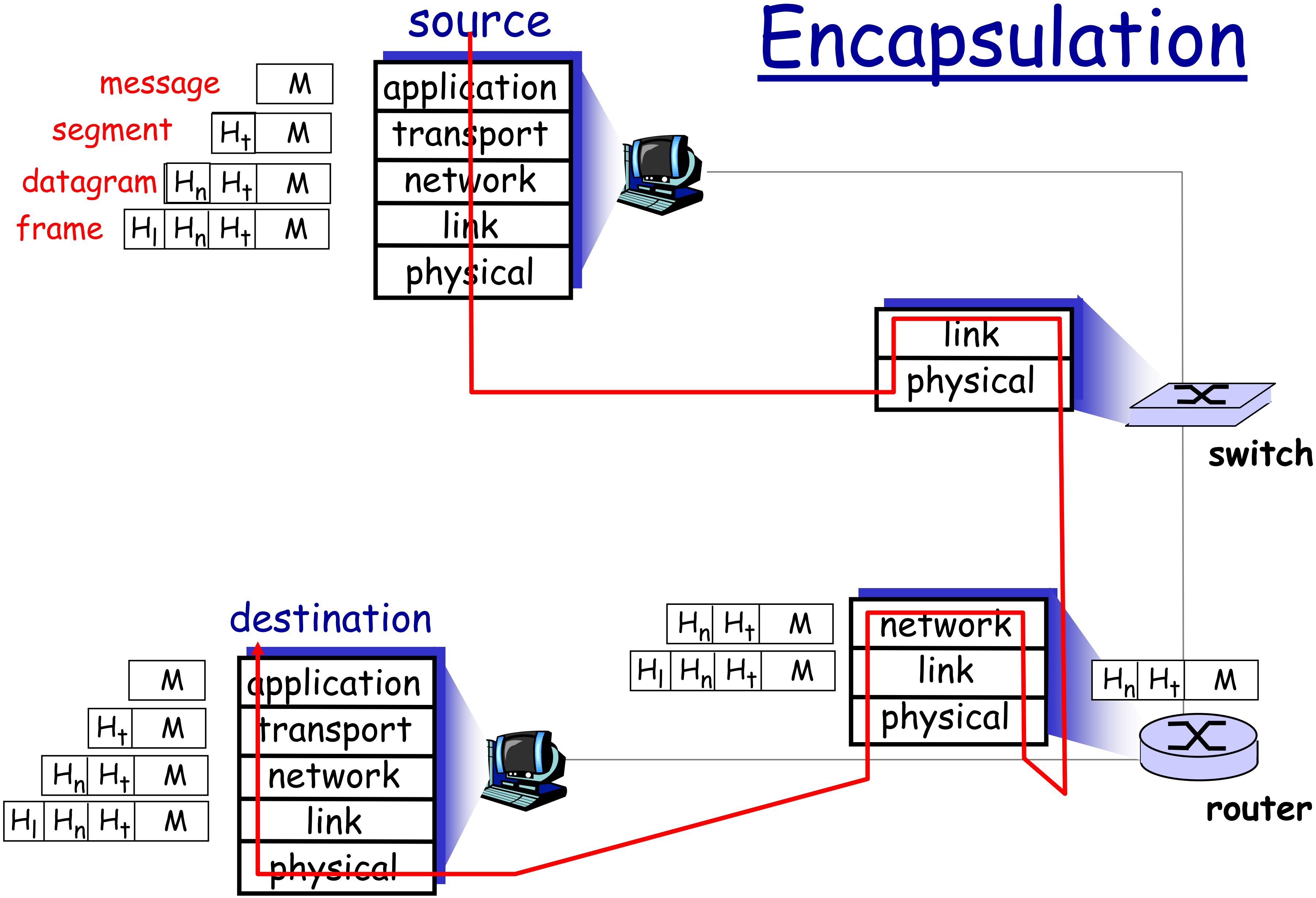
Source: wikipedia

Internet protocol stack

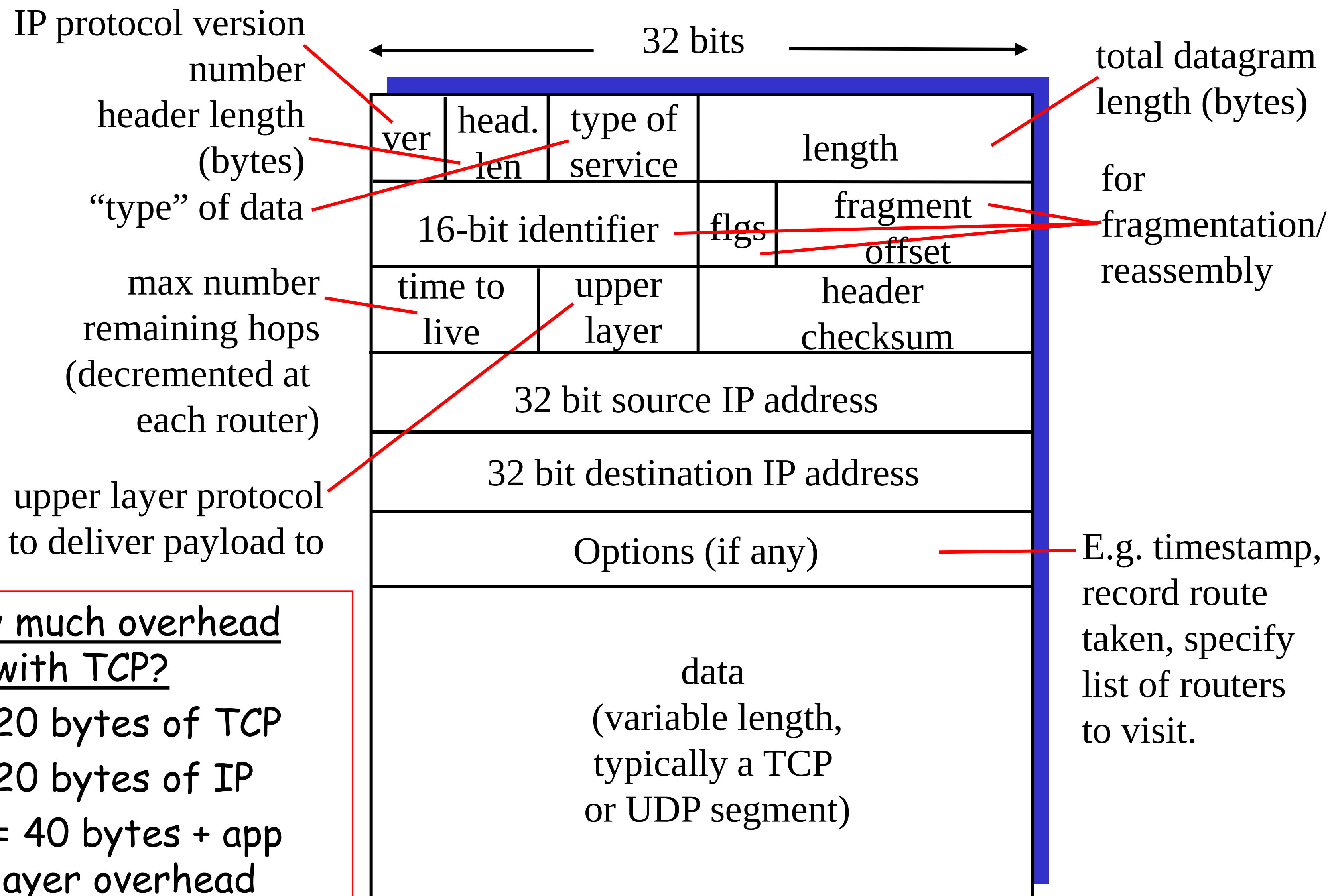
- application: supporting network applications
  - FTP, SMTP, HTTP
- transport: process-process data transfer
  - TCP, UDP
- network: routing of datagrams from source to destination
  - IP, routing protocols
- link: data transfer between neighboring network elements
  - Ethernet, 802.111 (WiFi), PPP
- physical: bits "on the wire"



Encapsulation



IP datagram format

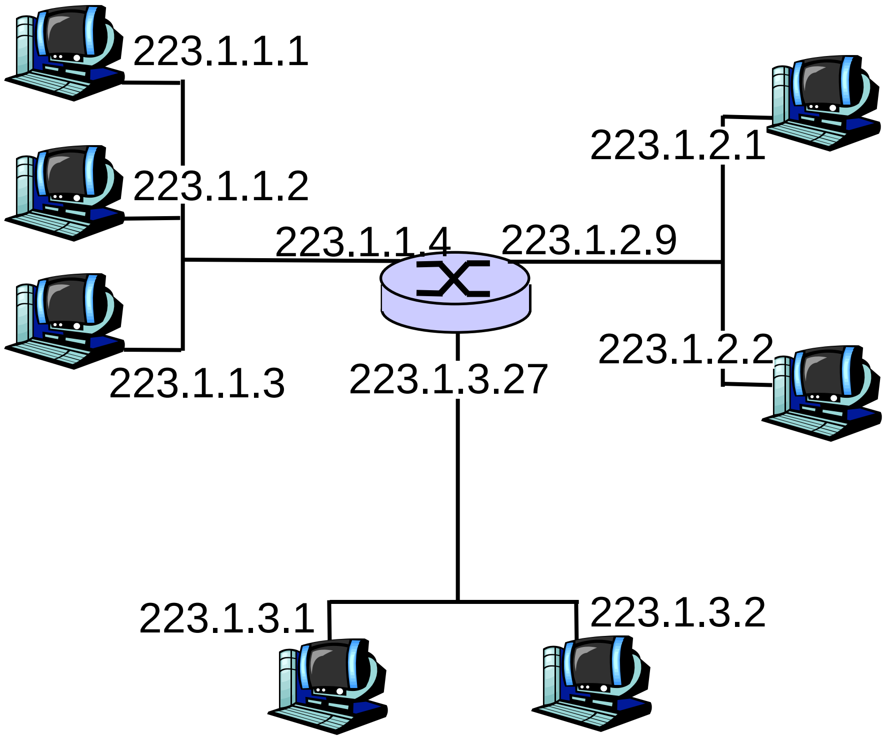


<u>how much overhead with TCP?</u>

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

IP Addressing: introduction

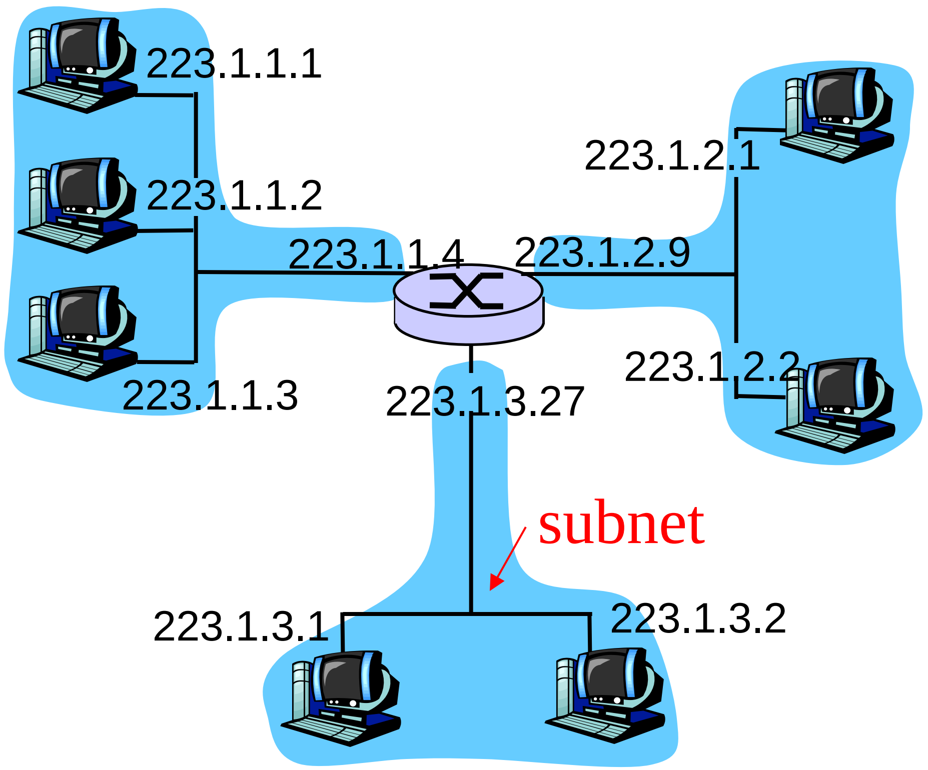
- IP address: 32-bit identifier for host, router *interface*
- *interface:* connection between host/router and physical link
  - router's typically have multiple interfaces
  - host typically has one interface
  - IP addresses associated with each interface



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

Subnets

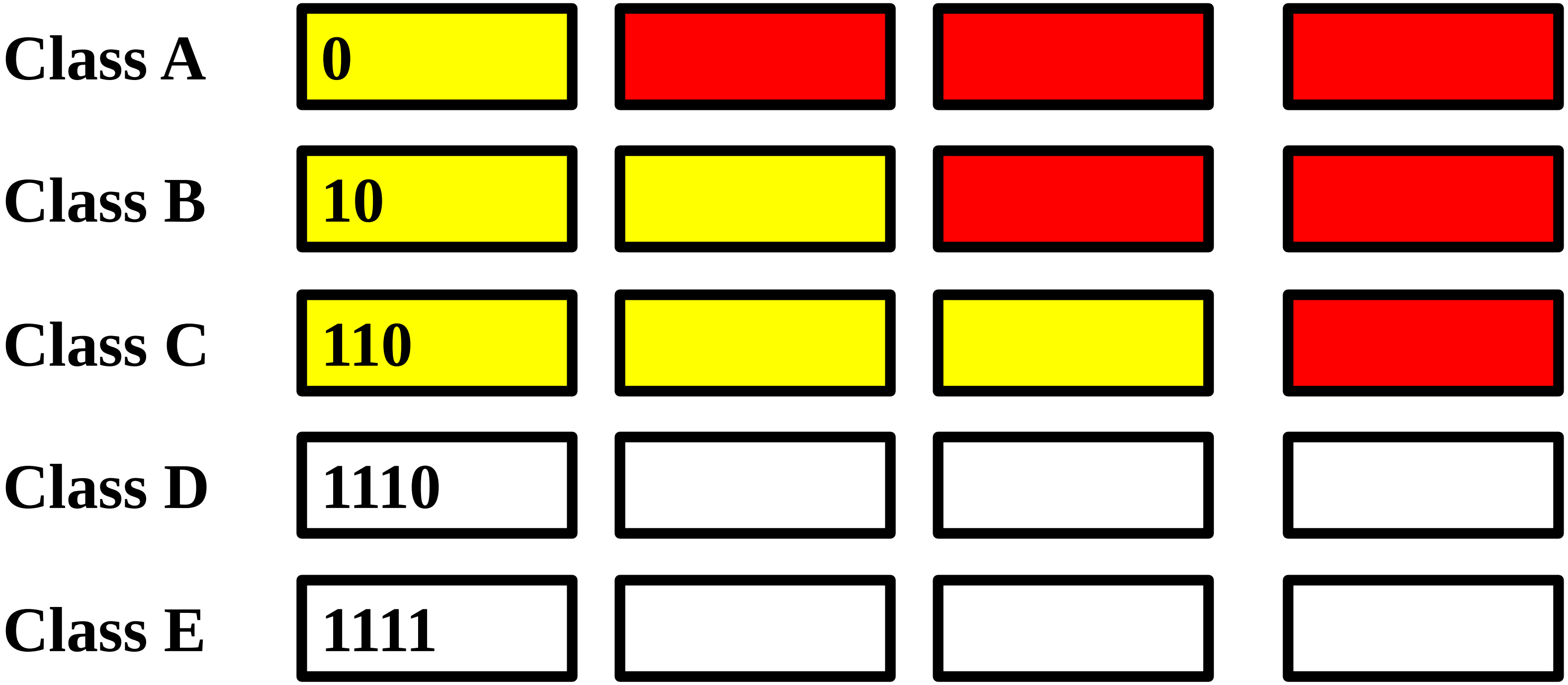
- IP address:
  - subnet part (high order bits)
  - host part (low order bits)
- *What's a subnet ?*
  - device interfaces with same subnet part of IP address
  - can physically reach each other without intervening router



network consisting of 3 subnets

How to identify the subnet/host parts?

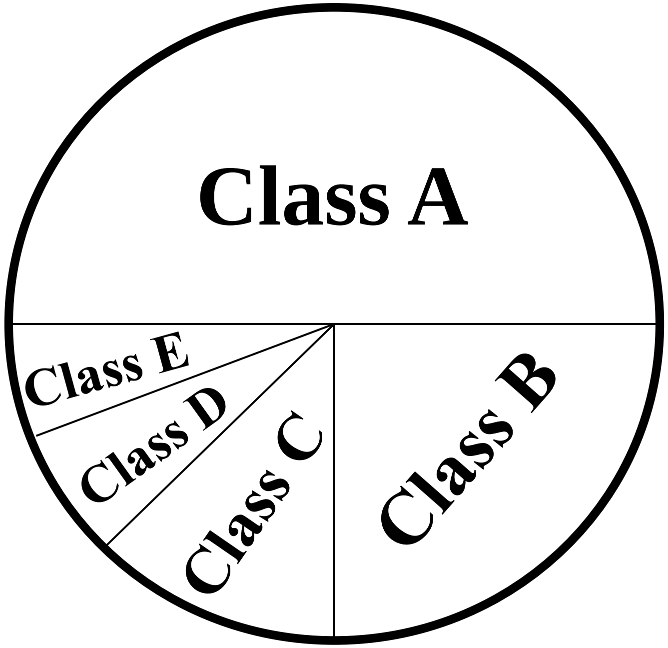
Classful Addresses



Which class does 192.168.0.1 belong to?

192 = $11000000_{(2)}$ ➔ Class C address

Classful Addresses Space



Class A: 2^{31} = 2,147,483,648 addresses, 50%

Class B: 2^{30} = 1,073,741,824 addresses, 25%

Class C: 2^{29} = 536,870,912 addresses, 12.5%

Class D: 2^{28} = 268,435,456 addresses, 6.25%

Class E: 2^{28} = 268,435,456 addresses, 6.25%

Total Addresses: 4,294,967,296

What is the problem here?

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 mask)

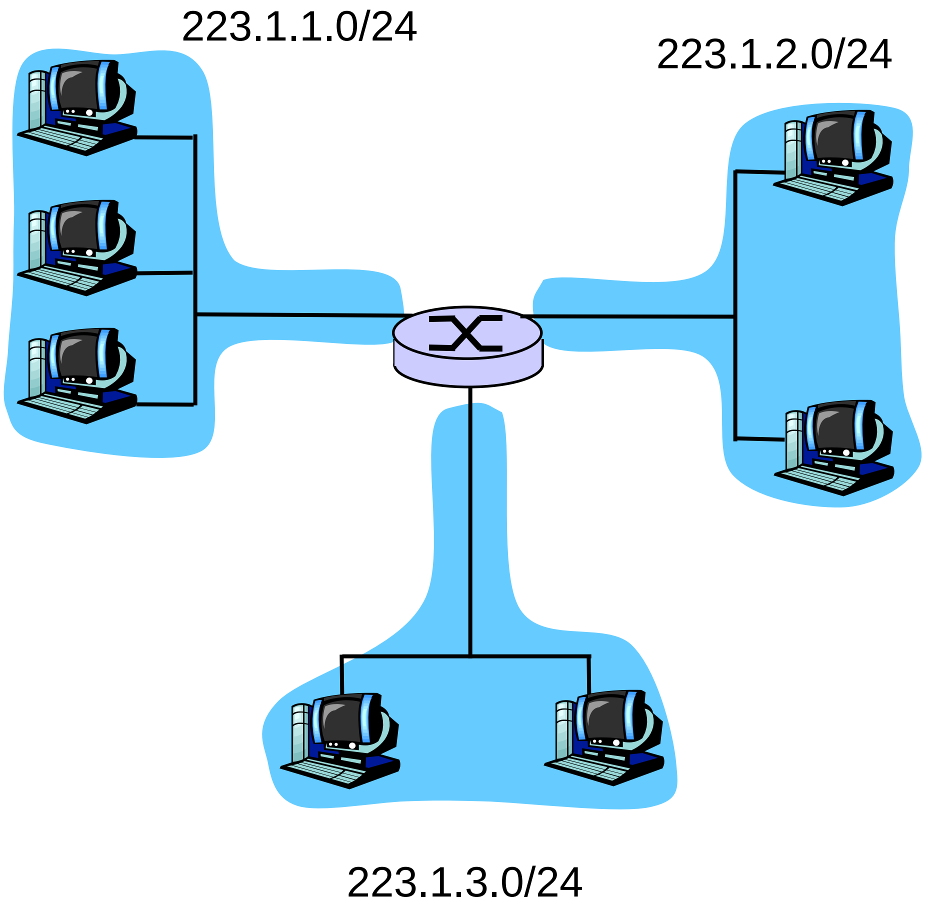
subnet part | host part

11001000 00010111 00010000 00000000

200.23.16.0/23

Subnetmask for class A, B and C addresses?

Subnets



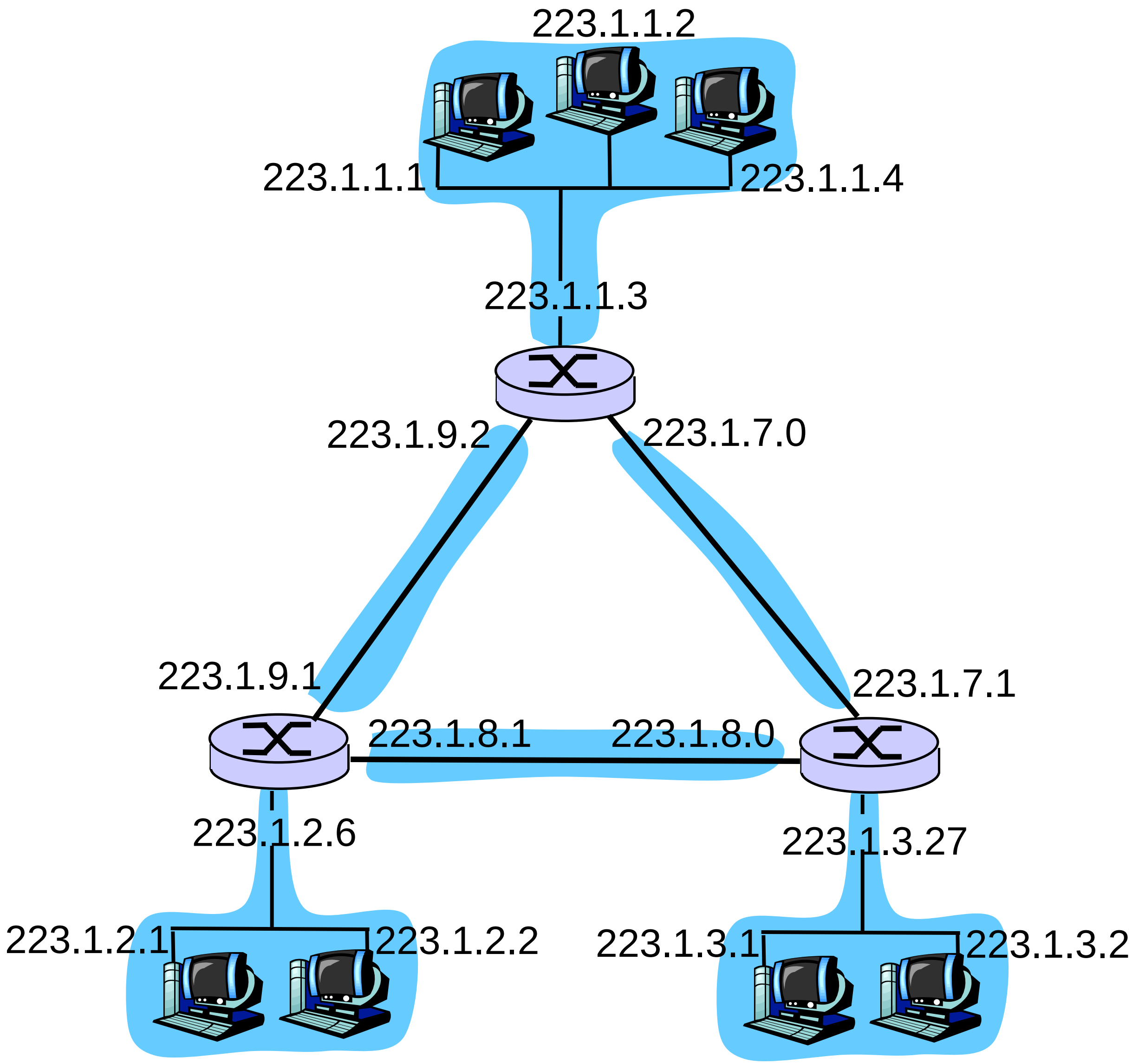
Subnet mask: /24

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.

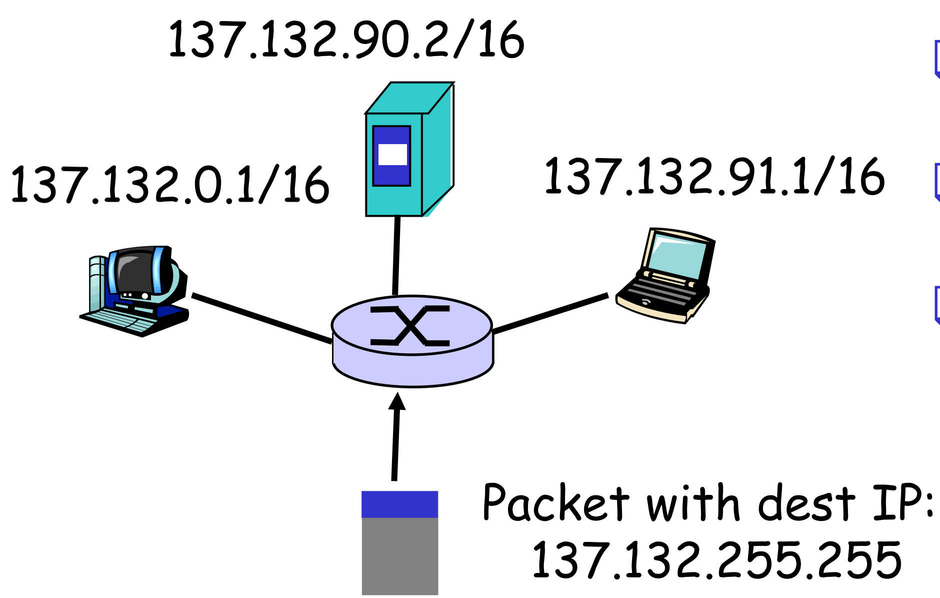
Subnets

How many?



Special IP Addresses

- 137.132.90.2
- 137.132.0.0
- 137.132.255.255



- Private addresses
  - 10.0.0.0/8 (Class A)
  - 172.16.0.0/12 (Class B)
  - 192.168.0.0/16 (Class C)
- 0.0.0.0
- 255.255.255.255
- 127.0.0.1

Example

- Find the first host address in the block if one of the addresses is 140.120.84.24/20

- Find the number of host addresses in the block if one of the addresses is 140.120.84.24/20

- Find the first host address in the block if one of the addresses is 140.120.84.24/24

- Find the number of host addresses in the block if one of the addresses is 140.120.84.24/24

IP addresses: how to get one?

Q: How does an ISP get block of addresses?

A: ICANN: Internet Corporation for Assigned Names and Numbers (https://www.icann.org)

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

IP addresses: how to get one?

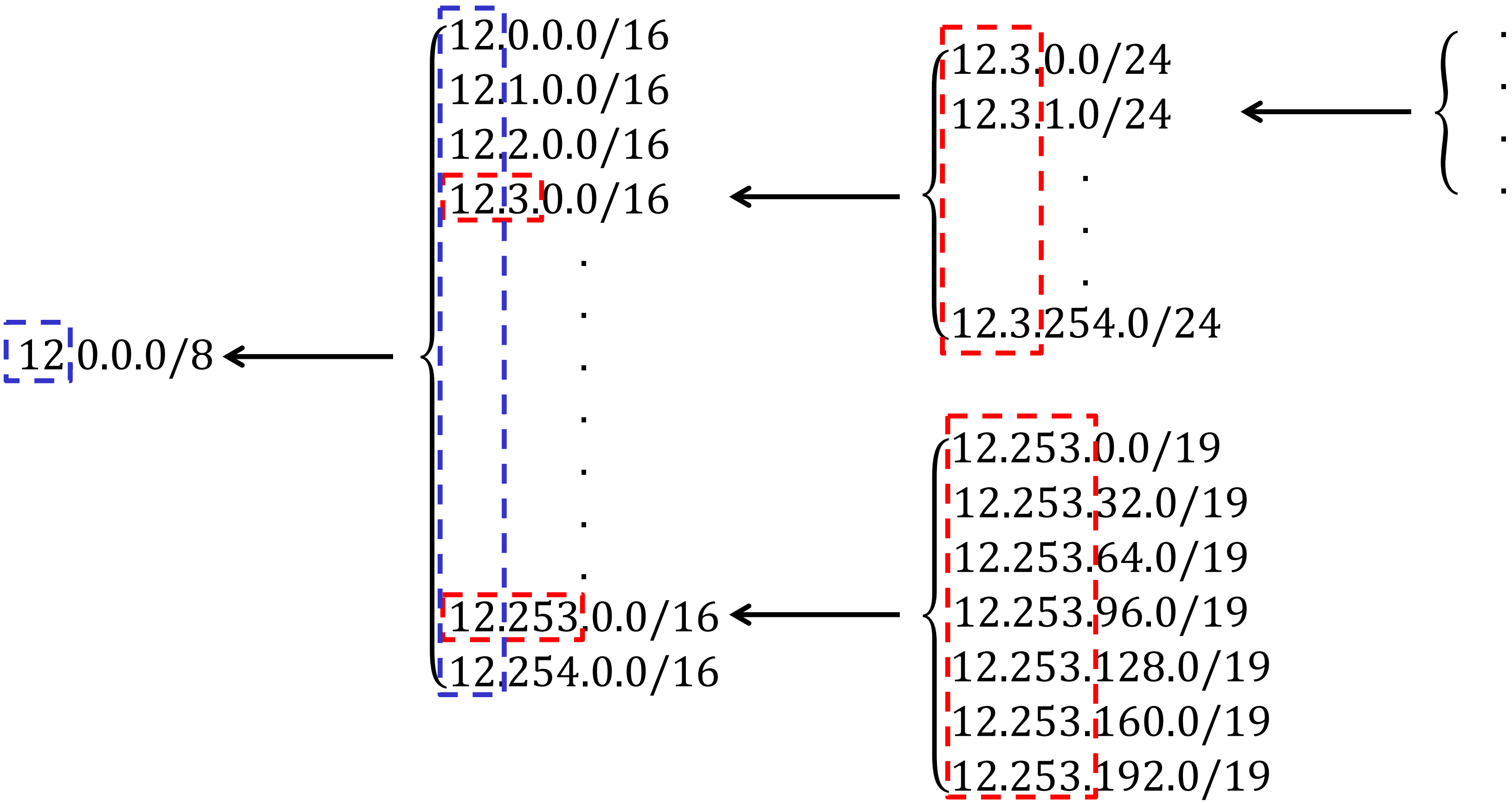
Q: How does *network* get subnet part of IP addr?

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

This is also called sub-netting!

CIDR: Hierarchical Address Allocation

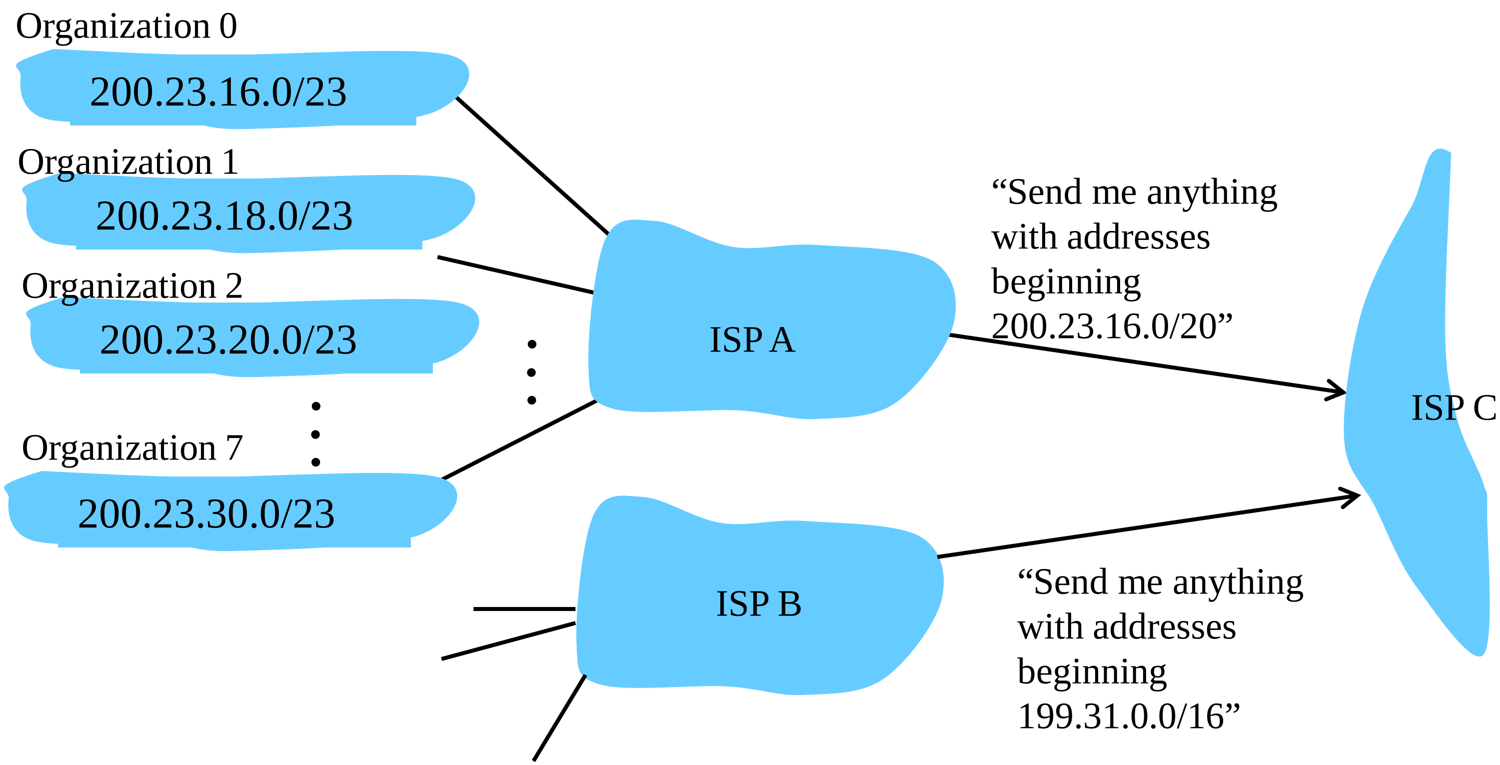


CIDR: Hierarchical Address Allocation

- Prefixes are key to Internet routing scalability
  - address allocation by ICANN, ARIN/RIPE/APNIC and by ISPs
  - routing protocols and packet forwarding based on prefixes
  - today, routing tables contain ~150,000 - 200,000 prefixes

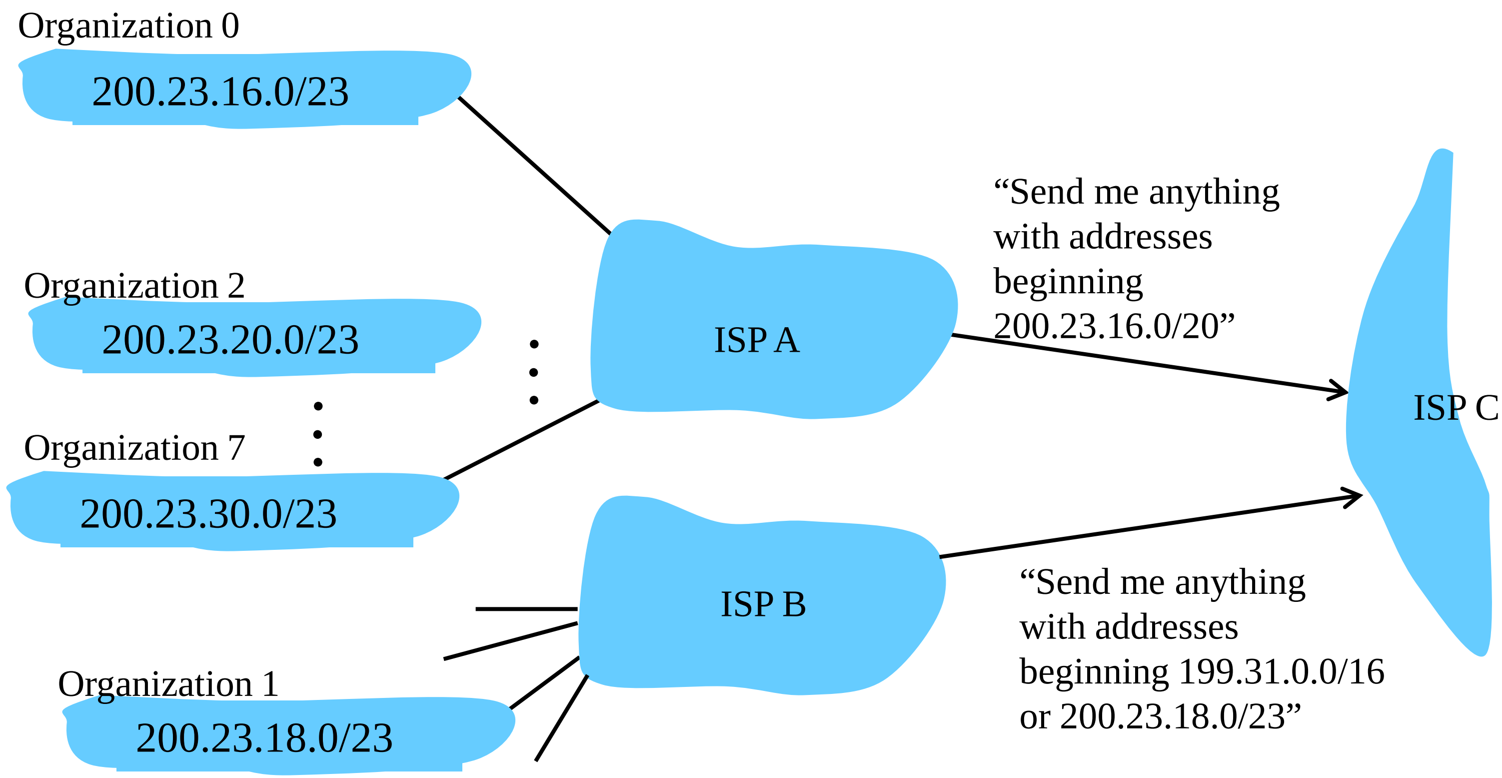
Hierarchical addressing: route aggregation

Allows efficient advertisement of routing information:



Hierarchical addressing: more specific routes

ISP B has a more specific route to Organization 1



How are packets forwarded?

- Routers have forwarding tables
  - maps each IP prefix to next-hop link(s)
  - entries can be statically configured
    - e.g., "map 12.34.158.0/24" to "Interface 1"
- Destination-based forwarding
  - Packet has a destination address
  - Router identifies longest-matching prefix

How are packets forwarded?

Routing table of ISP C:

destination

200.23.18.30/24

Prefix	Next Hop
126.255.103.0/24	Interface 3
200.23.18.0/23	Interface 2
200.23.16.0/20	Interface 1
199.31.0.0/16	Interface 2
4.0.0.0/8	Interface 4

outgoing link:

Interface 2