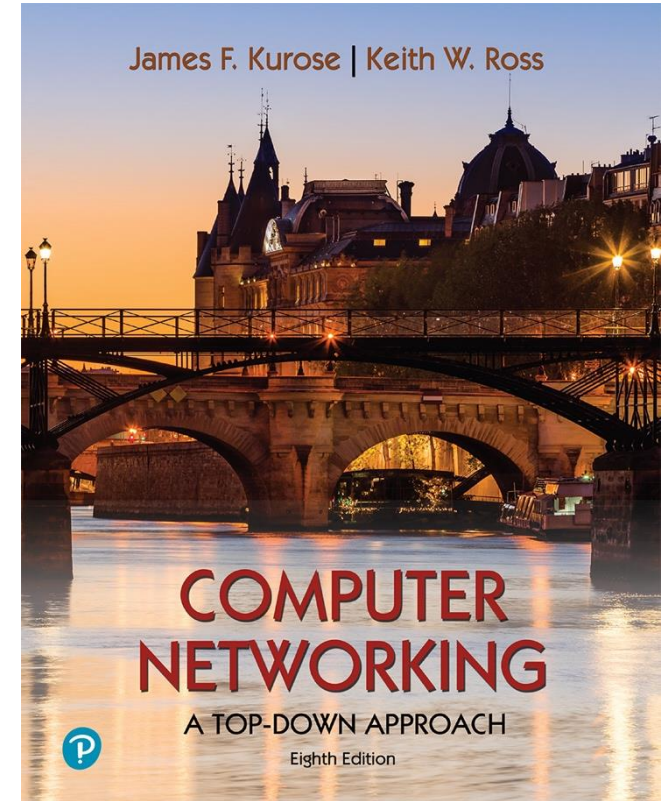# Chapter 1
Introduction

These slides have been adapted from

Computer Networking: A Top-Down Approach

8th edition
Jim Kurose, Keith Ross
Pearson, 2020

Chapter goal:

- Get "feel," "big picture," introduction to terminology
  - more depth, detail *later* in course

Overview:

- What *is* the Internet?
- Internet structure
  - From edge to core
- Protocol layers, service models
  - What *is* a protocol?
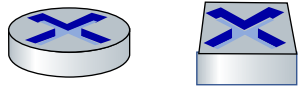 - Internet protocol stack

What *is* the Internet?

The Internet: a "nuts and bolts" view

Billions of connected computing *devices*:

- *hosts = end systems*
- running *network* *apps* at Internet's "edge"

Packet switches: forward packets (chunks of data)
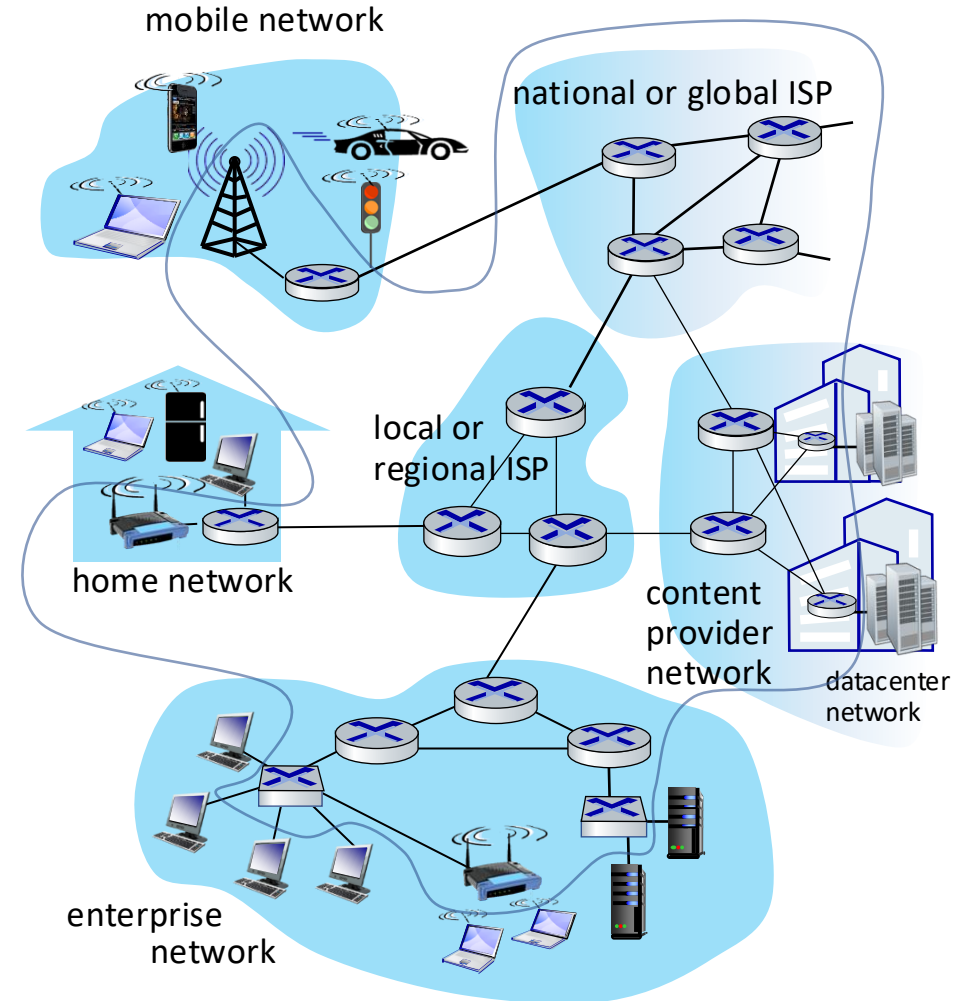
- *routers, switches*

Communication links

- fiber, copper, radio, satellite
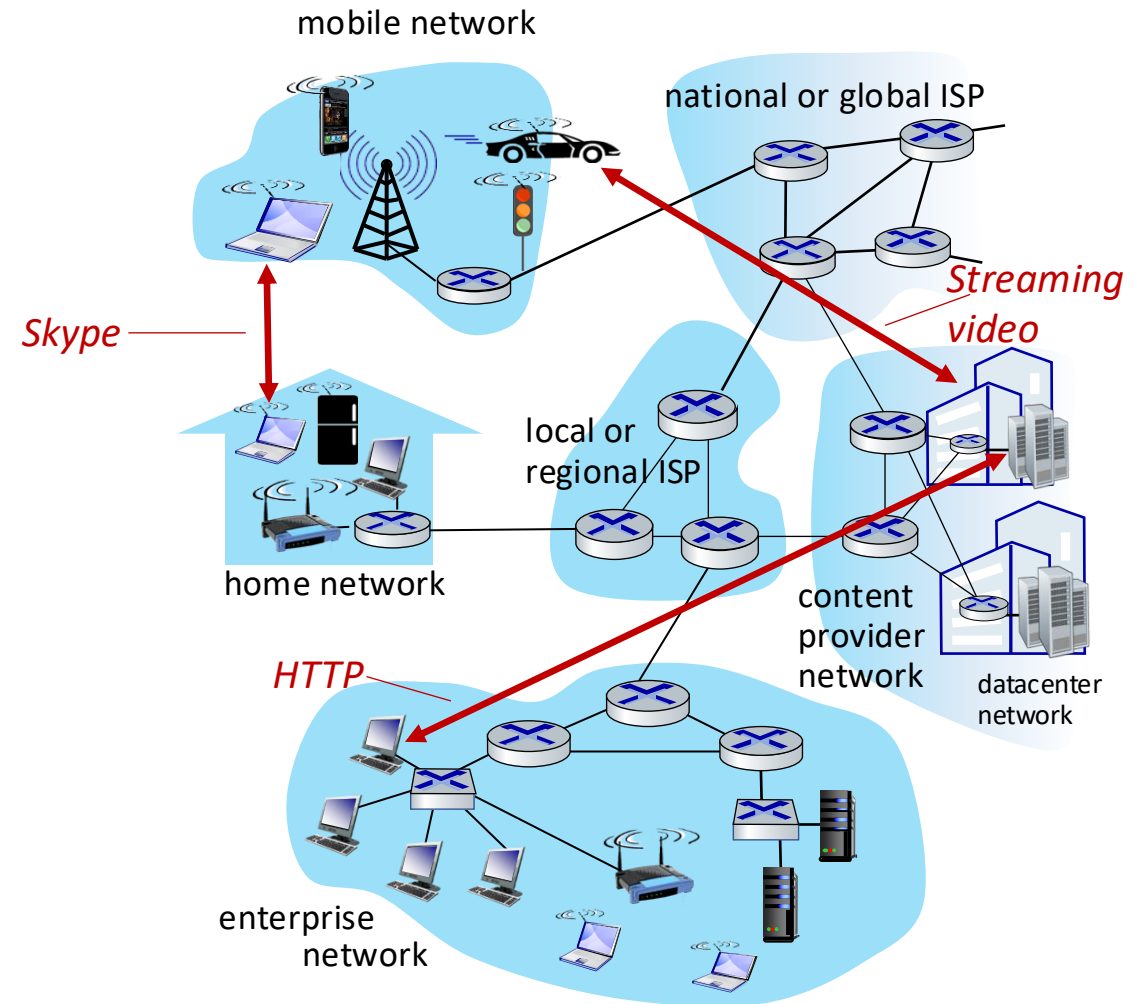- transmission rate: *bandwidth*

Networks

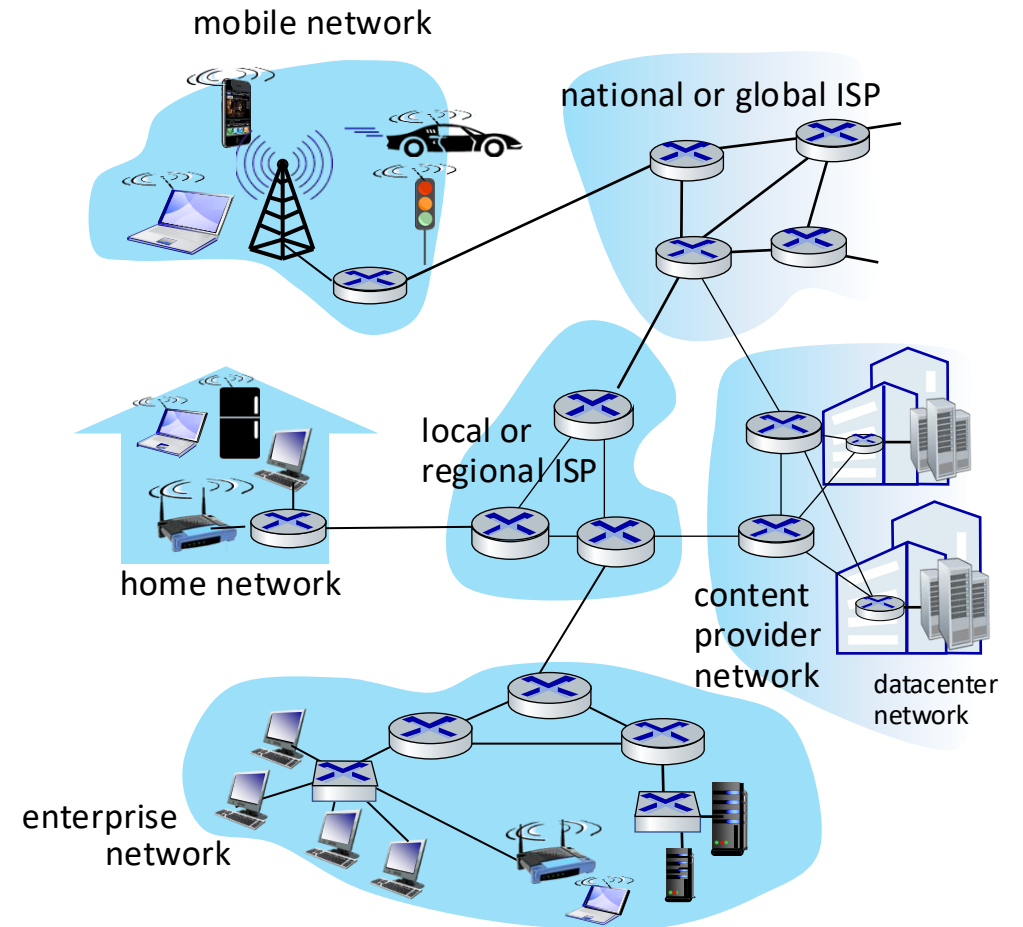- collection of devices, routers, links: managed by an organization

mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

The Internet: a "services" view

- *Infrastructure* that provides "transport" service to applications:
  - Web, streaming video, multimedia teleconferencing, email, games, e-commerce, social media, inter-connected appliances, …
  - "hooks" allowing sending/receiving apps to "connect" using Internet transport service
  - different transport service options, analogous to postal service

mobile network

national or global ISP

Skype

Streaming video

local or regional ISP

home network

content provider network

datacenter network

HTTP

enterprise network

The Internet: a "network of networks" view

- hosts connect to Internet via access network

- access networks in turn must be interconnected
  - so that *any* two hosts *(anywhere!)* can send packets to each other

- resulting network of networks is very complex
  - evolution driven by economics, national policies

mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

Internet structure

A closer look at Internet structure
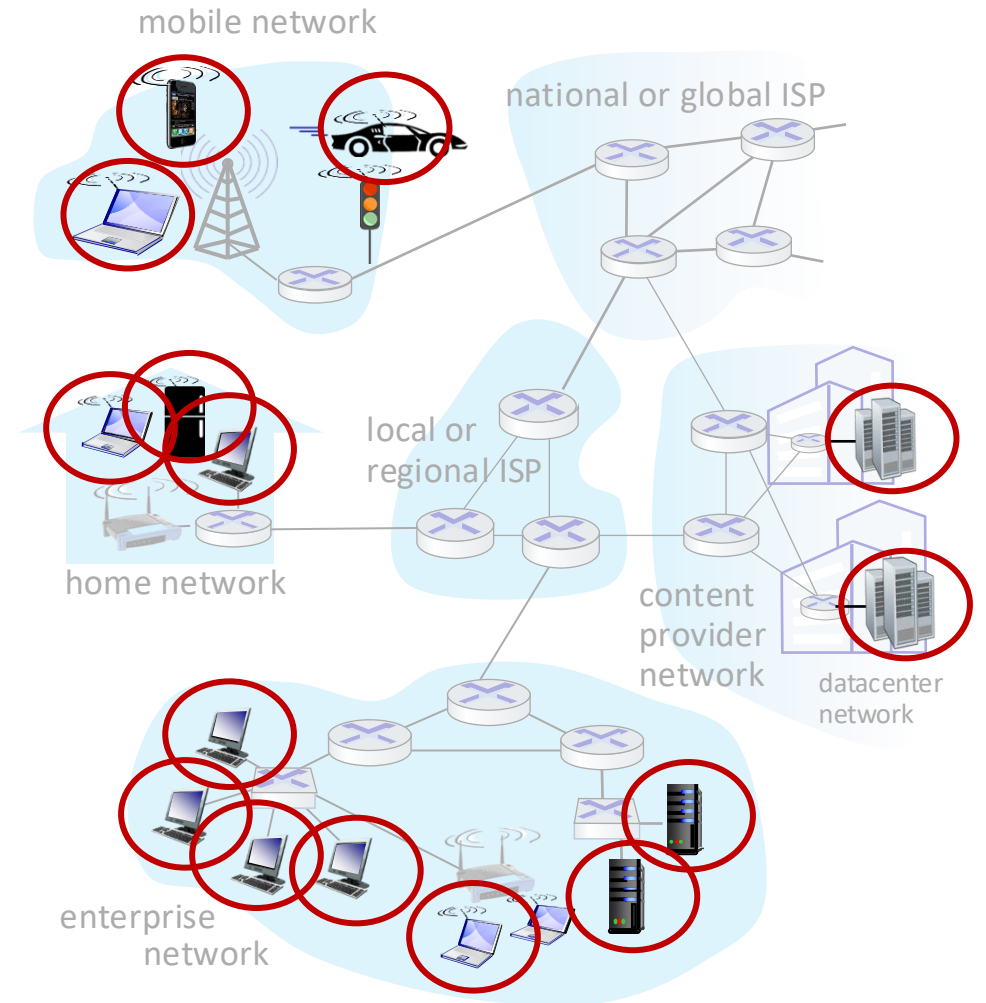
Network edge:

- hosts: clients and servers
- servers often in data centers

Access networks:

- residential access nets
- institutional access networks (school, company)
- mobile access networks (WiFi, 4G/5G)

Network core:

- interconnected routers

mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

A closer look at Internet structure
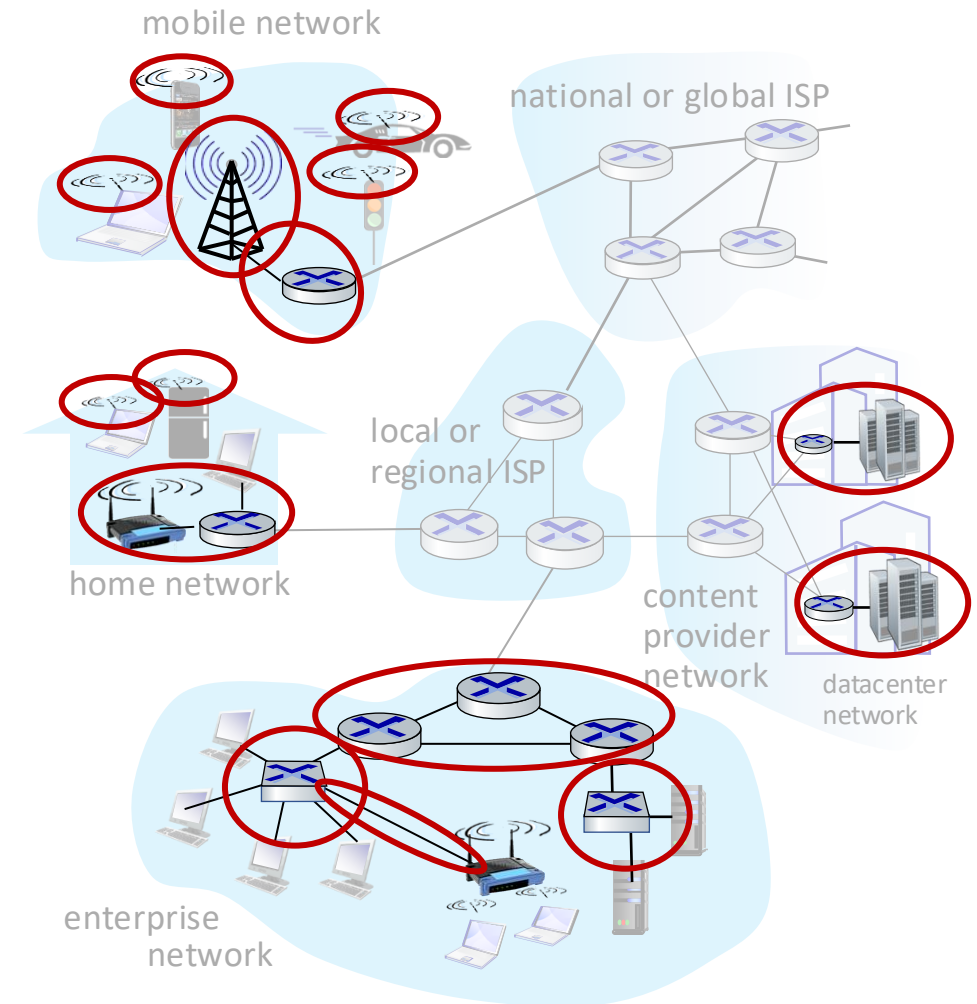
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mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

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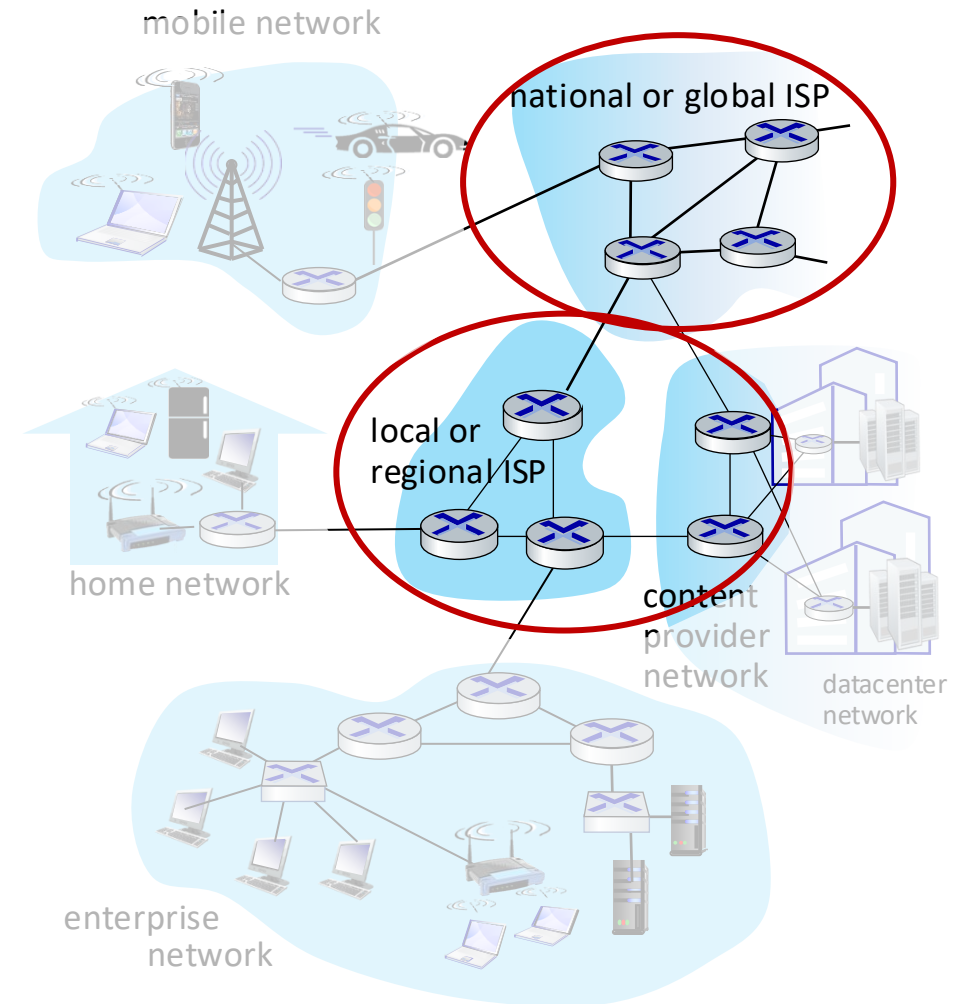
Network edge:
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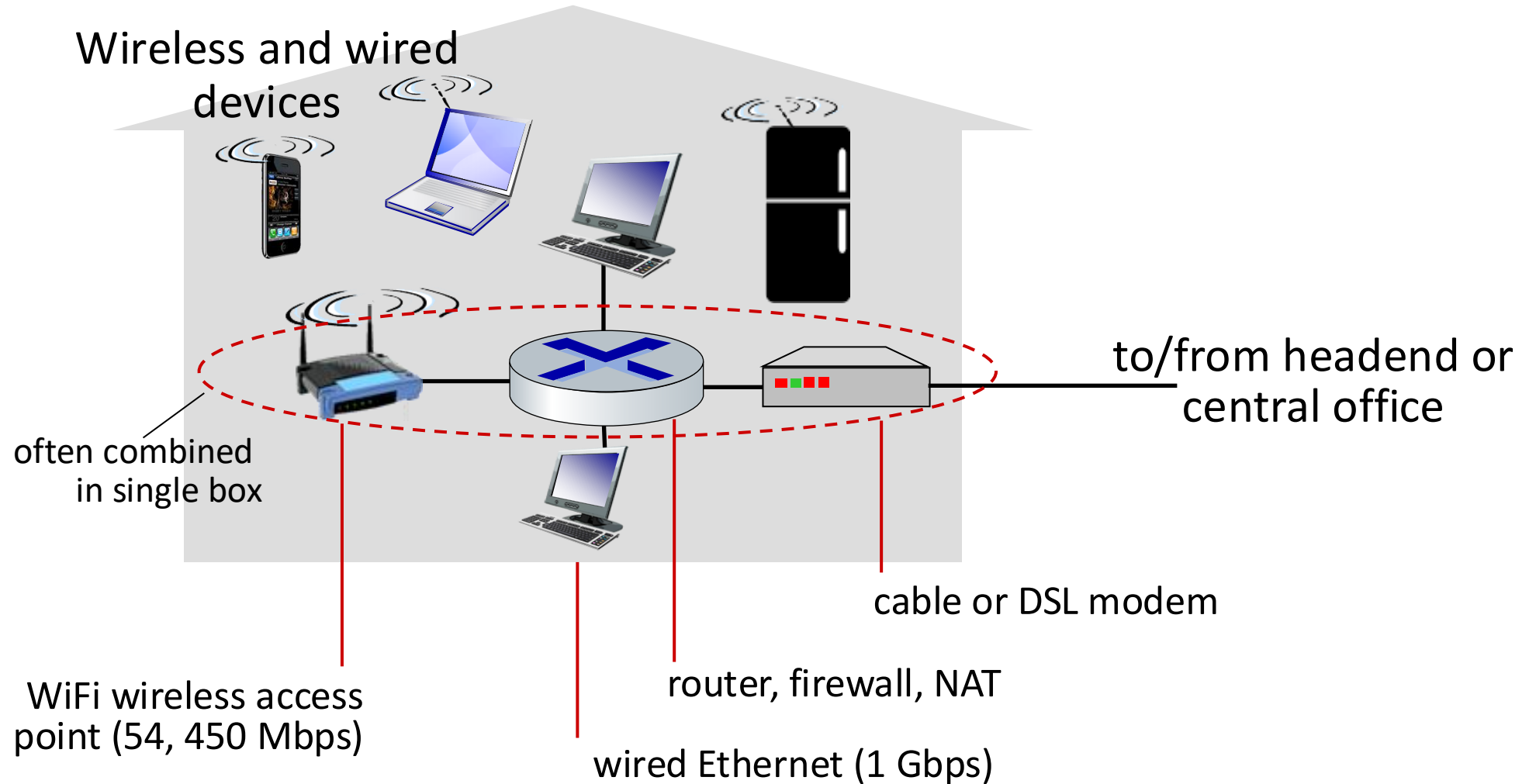- servers often in data centers

Access networks:
- residential access nets
- institutional access networks (school, company)
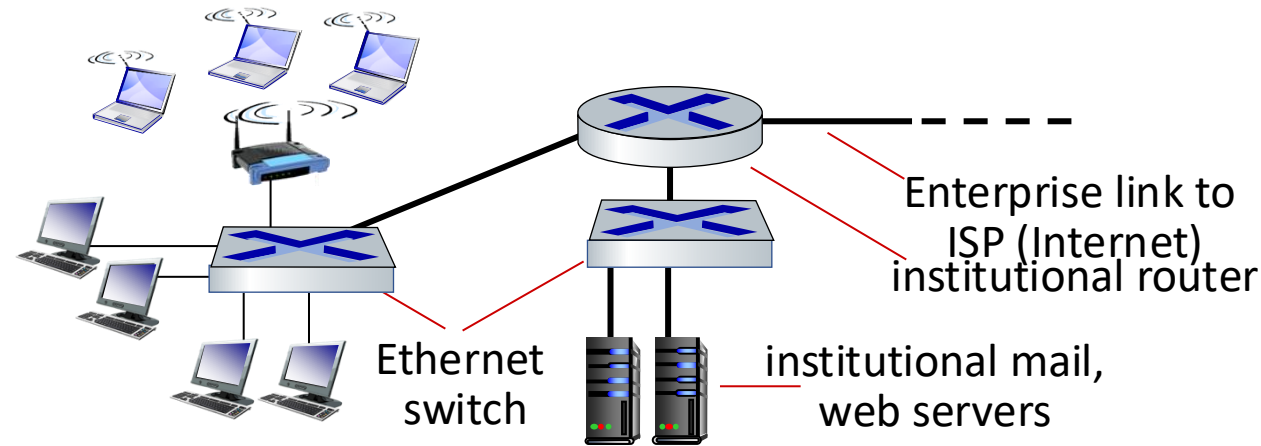- mobile access networks (WiFi, 4G/5G)

Network core:
- interconnected routers

mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

Access networks: home networks

Wireless and wired devices

often combined in single box

to/from headend or central office

WiFi wireless access point (54, 450 Mbps)

router, firewall, NAT

wired Ethernet (1 Gbps)

cable or DSL modem
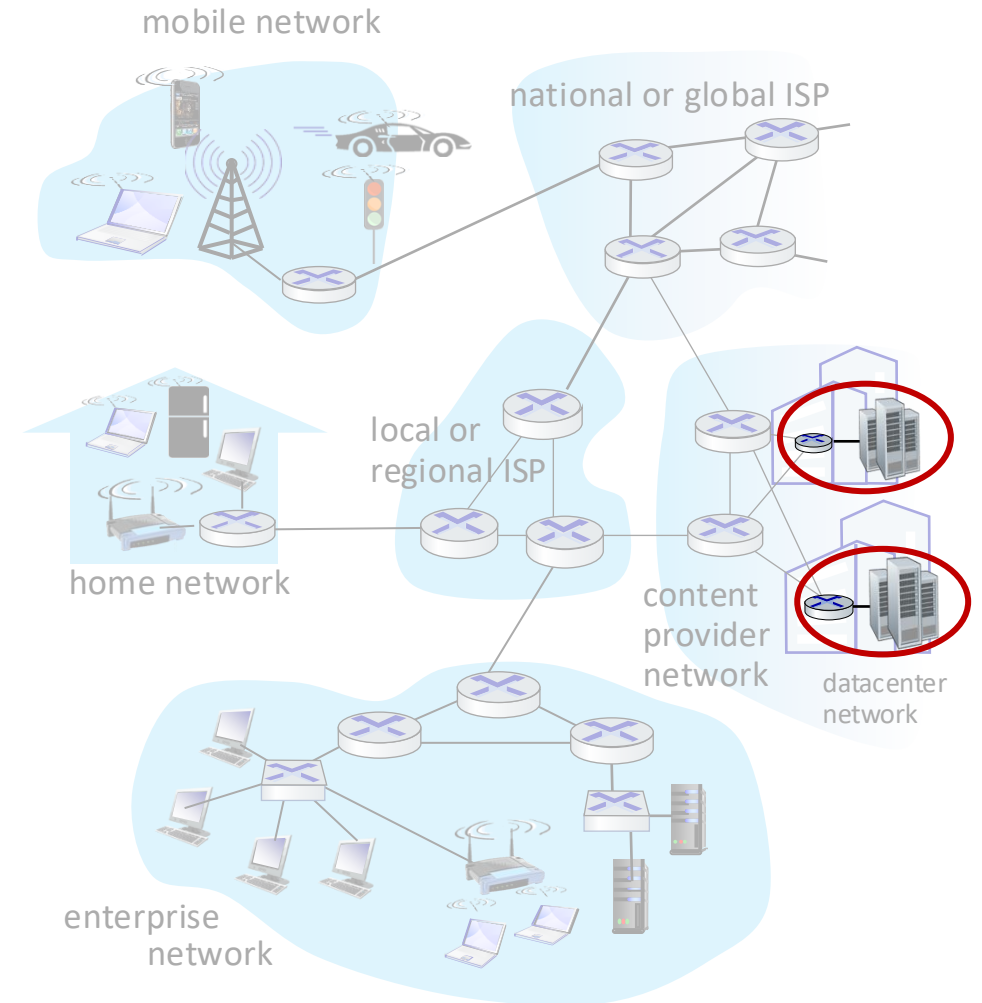
Access networks: enterprise networks

- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
  - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps
- Visit https://ns-info.uwaterloo.ca/netstats/core.php for UW core Network look and stats

Access networks: data center networks

- high-bandwidth links (10s to 100s Gbps) connect hundreds to thousands of servers together, and to Internet
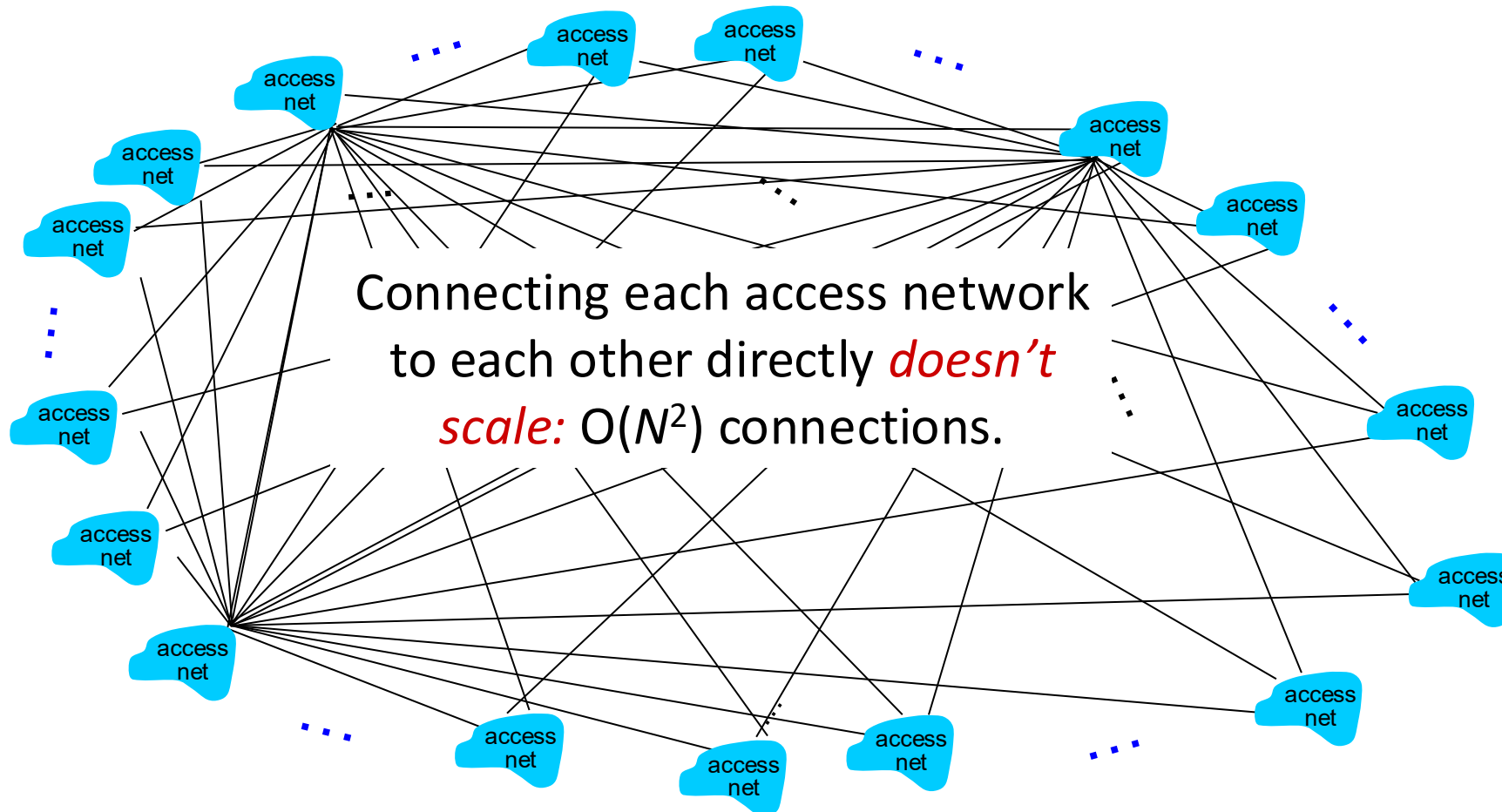

Courtesy: Massachusetts Green High Performance Computing Center (mghpcc.org)

Internet core network
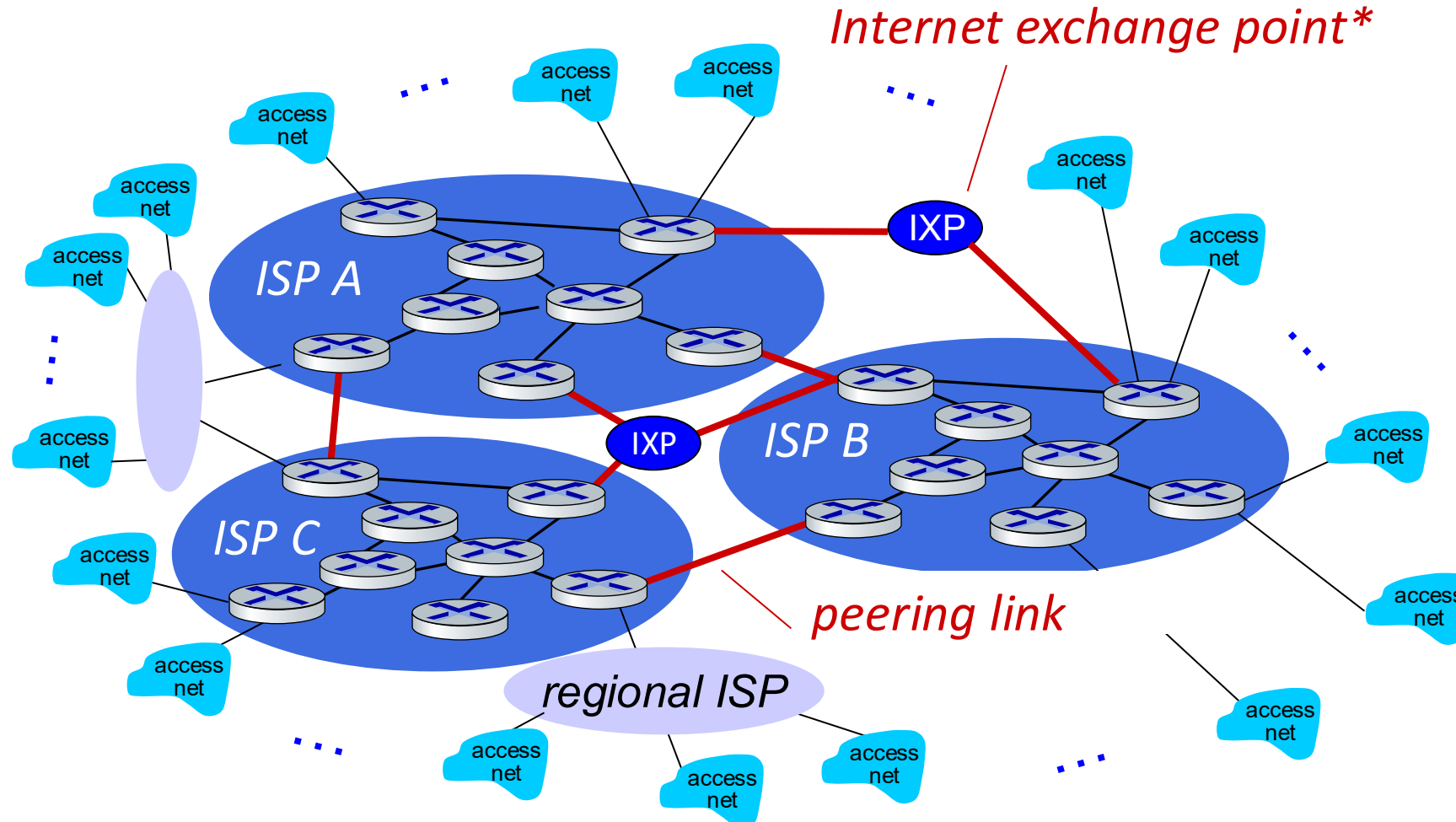
Question: given *millions* of access networks, how do we connect them together?

Connecting each access network to each other directly *doesn't scale:* O(N^2) connections.

Internet core network

international, national and regional interconnect access nets

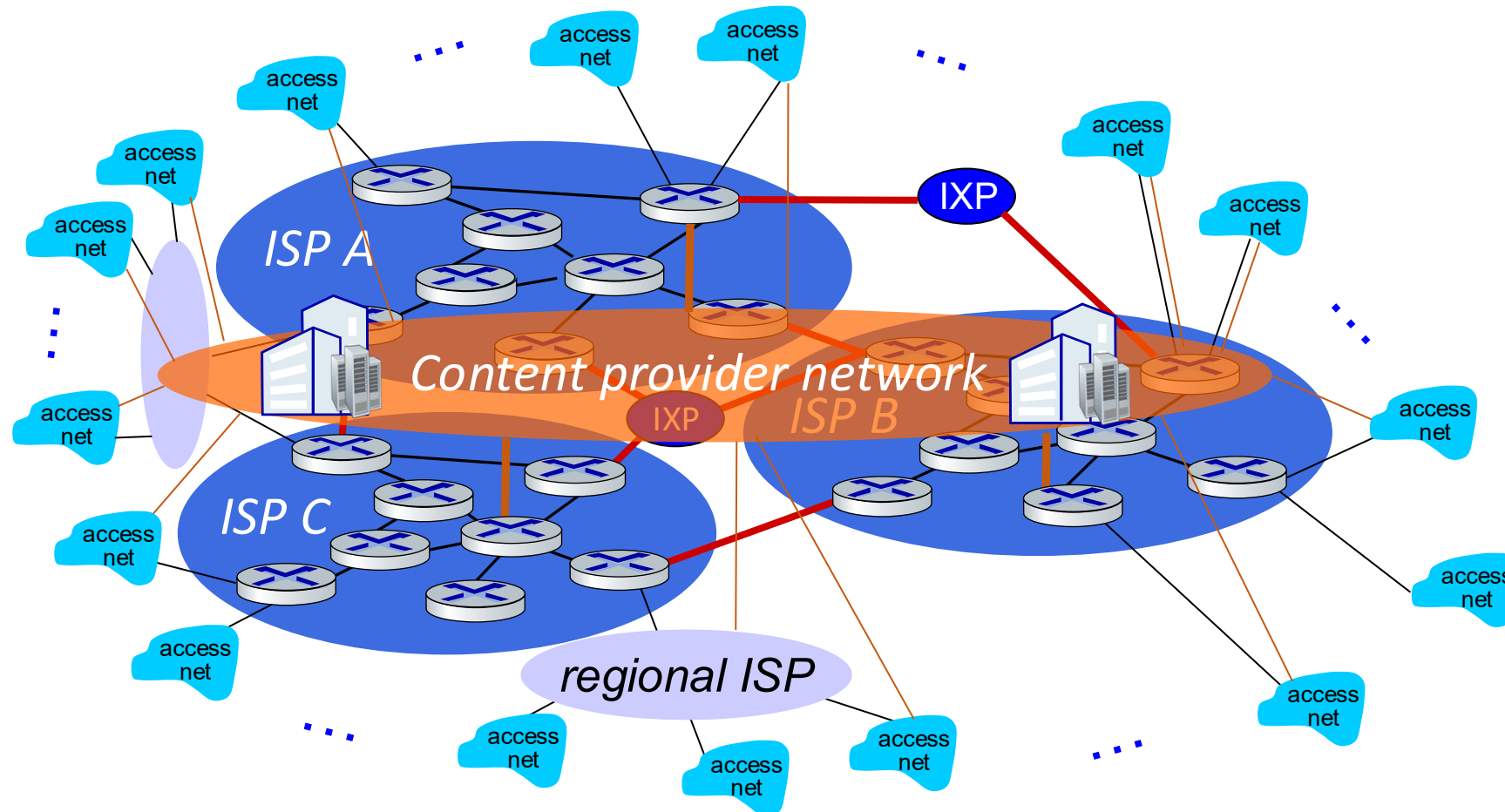*Internet exchange point**

peering link

- e.g., Toronto Internet Exchange, Canada's largest IXP, one of the largest in the world https://www.torix.ca/
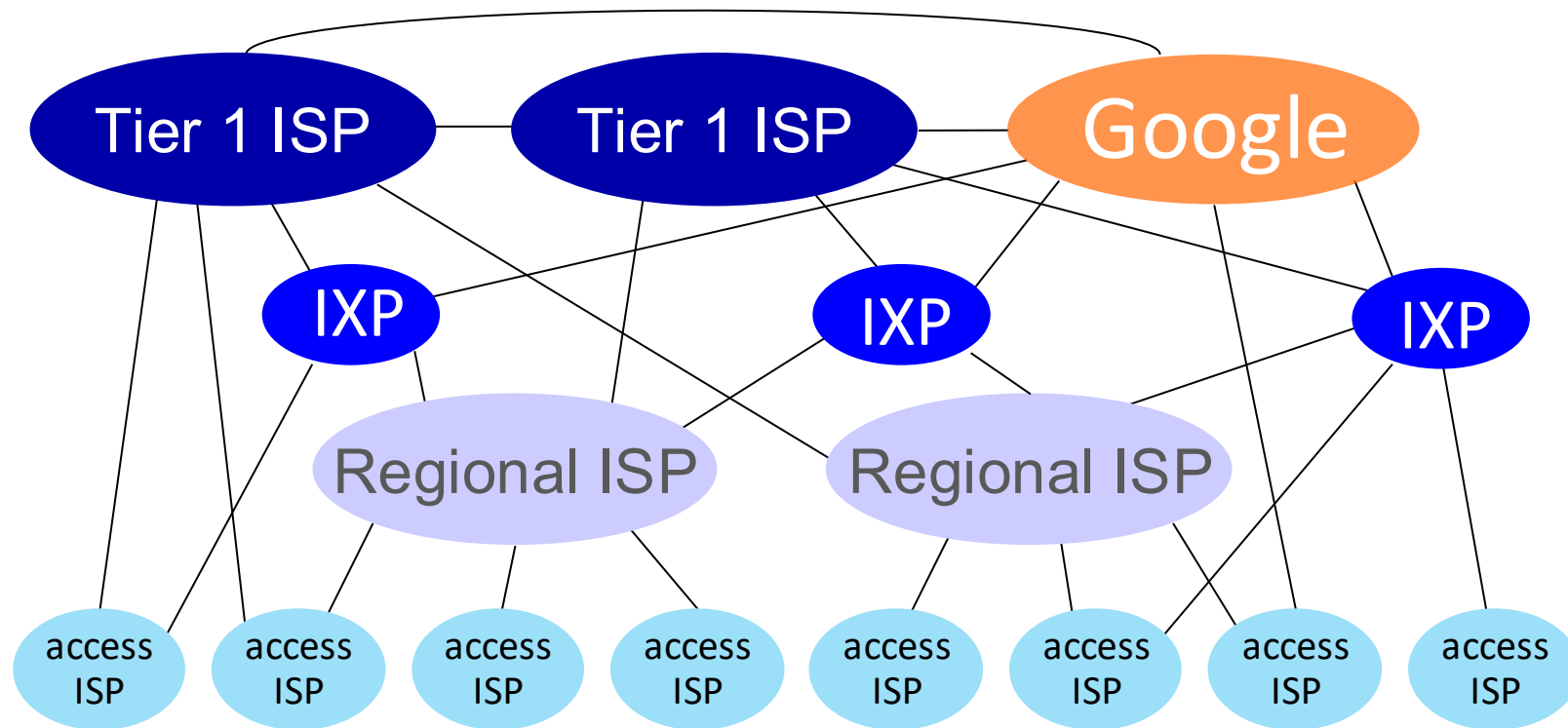
Internet structure: a "network of networks"

... and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users

Internet structure: a "network of networks"

At "center": small # of well-connected large networks

- "tier-1" commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
- content provider networks (e.g., Google, Facebook): private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs

Protocol layers
Service models

What's a protocol?

Human protocols:

- "what's the time?"
- "I have a question"
- introductions

Rules for:

… specific messages sent

… specific actions taken when message received, or other events
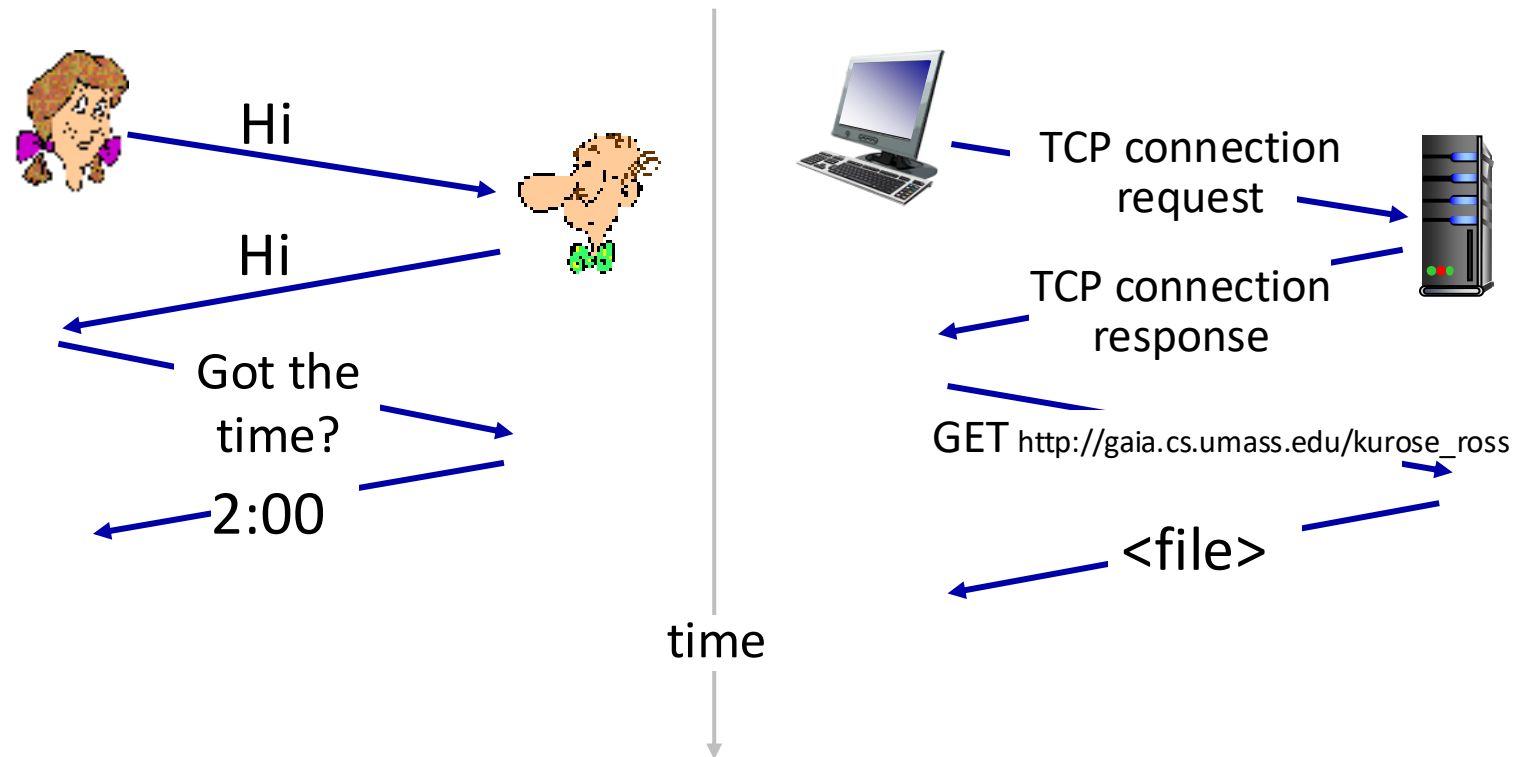
Network protocols:

- computers (devices) rather than humans
- all communication activity in Internet governed by protocols

Protocols define the format, order of messages sent and received among network entities, and actions taken on message transmission, receipt
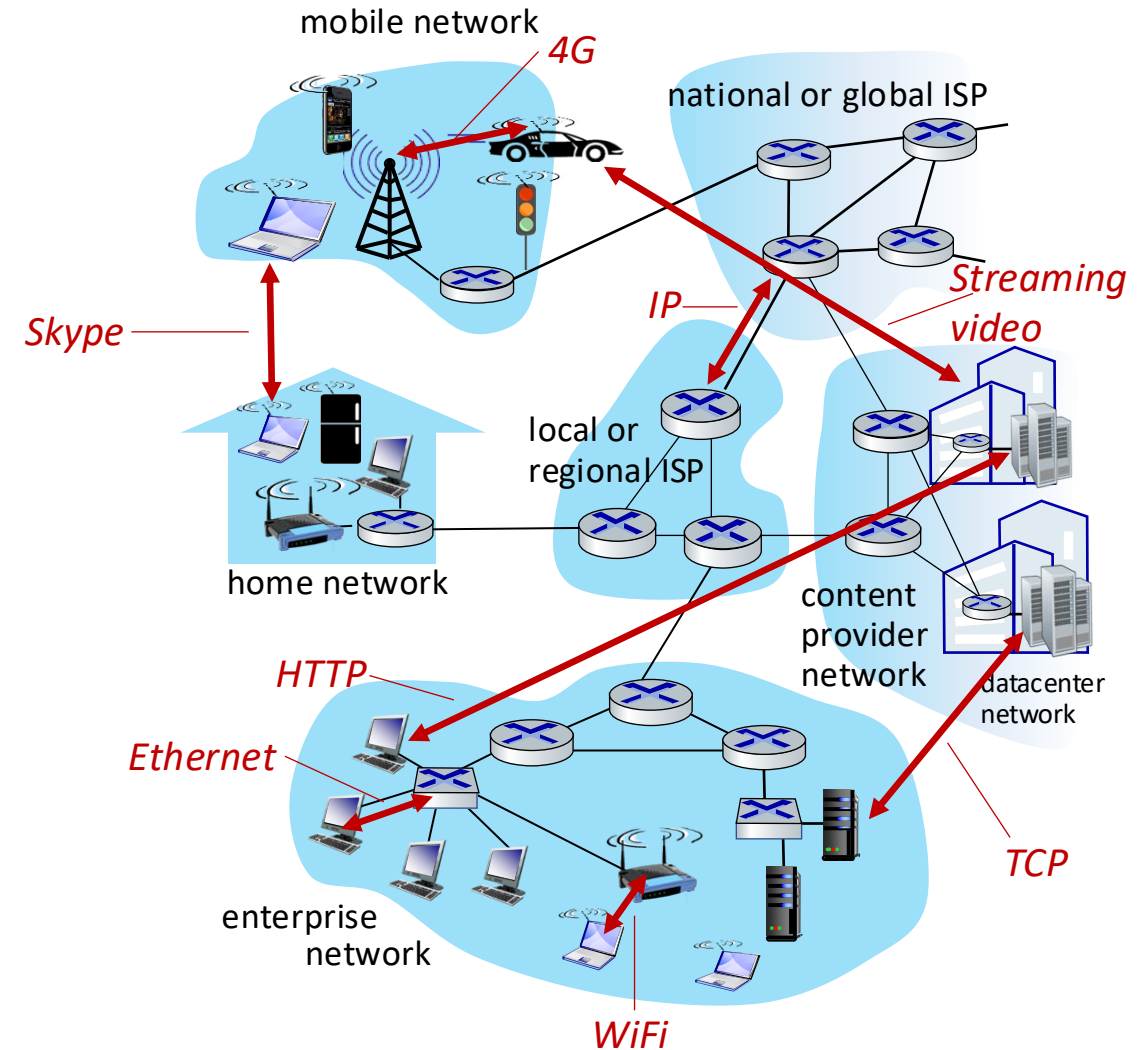
What's a protocol?

A human protocol and a computer network protocol:

Q: other human protocols?

The Internet: a "protocols" view

- *protocols* are *everywhere*
  - control sending, receiving of messages
  - e.g., HTTP (Web), streaming video, Skype, TCP, IP, WiFi, 4/5G, Ethernet

- Internet standards
  - RFC: Request for Comments
  - IETF: Internet Engineering Task Force

Layered Internet protocol stack

- *application:* supporting network applications
  - HTTP, IMAP, SMTP, DNS
- *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, 802.11 (WiFi), PPP
- *physical:* bits "on the wire"

| application |
| transport |
| network |
| link |
| physical |
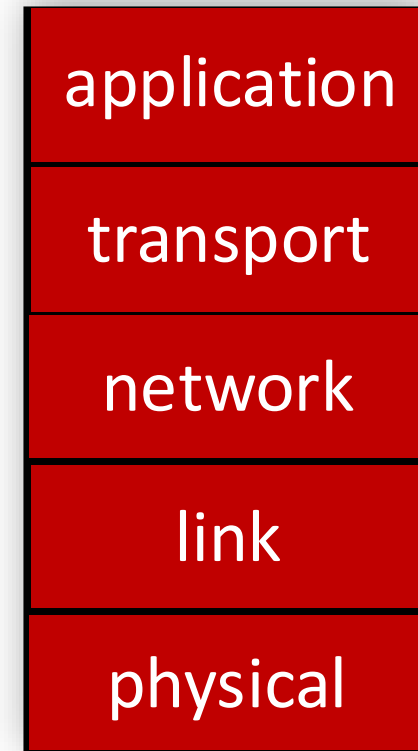
Encapsulation

Matryoshka dolls (stacking dolls)

message   segment   datagram   frame
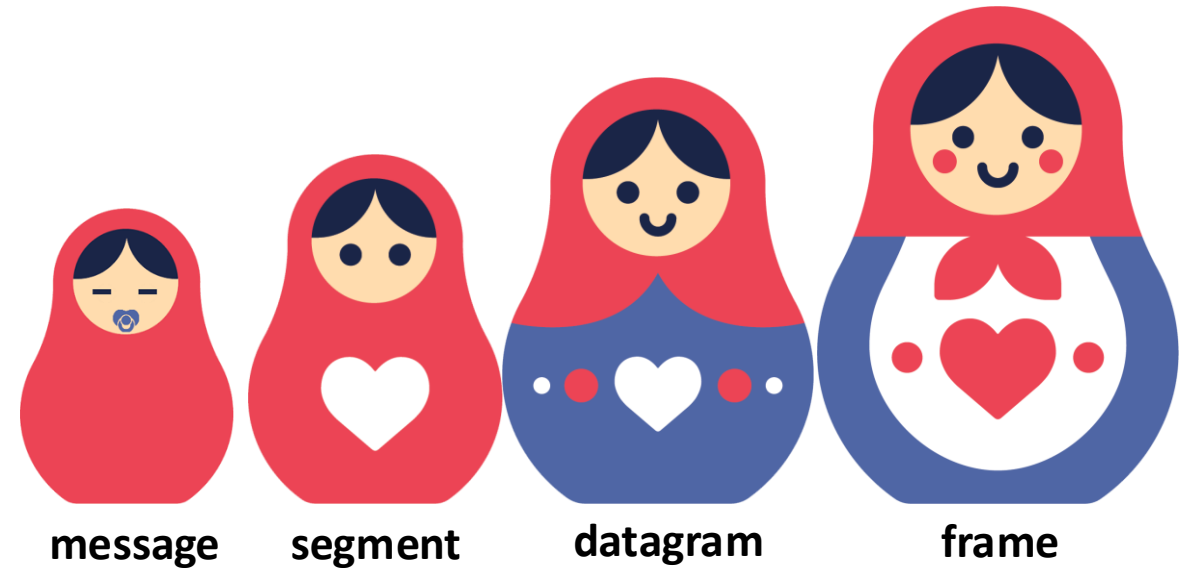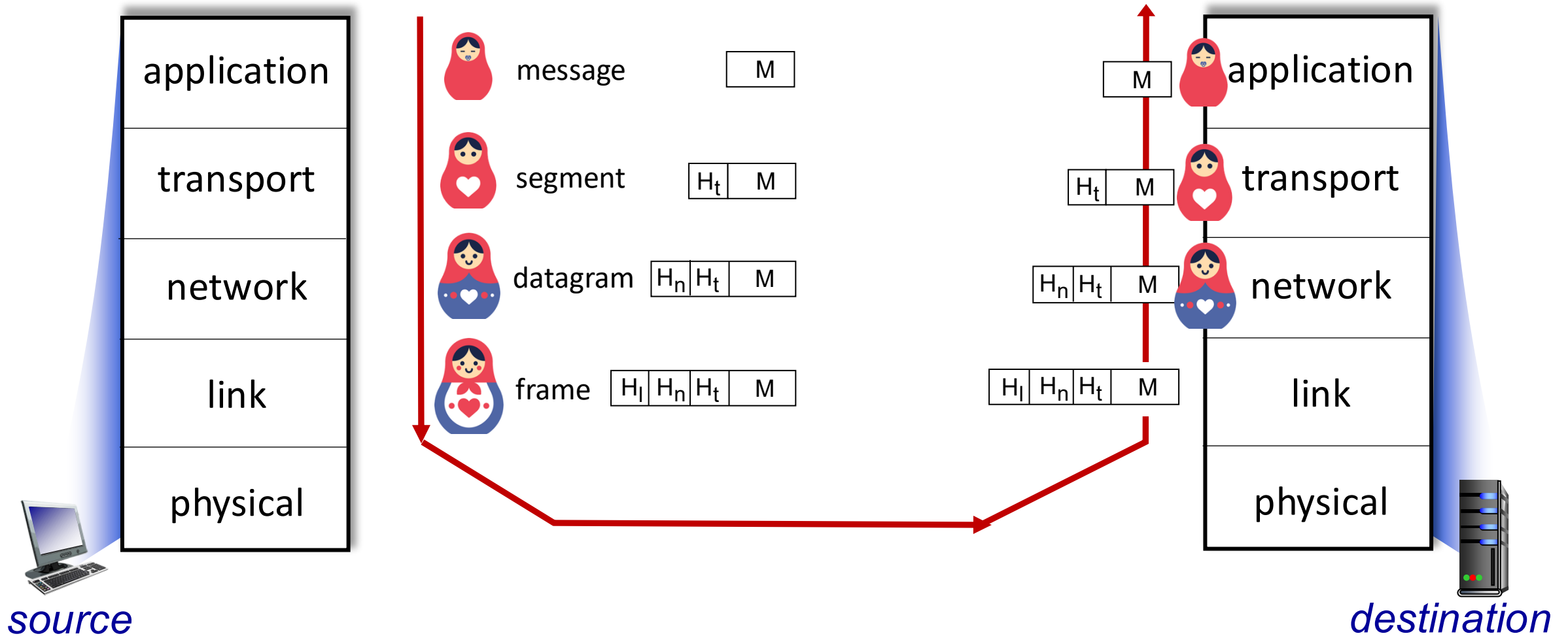
Services, Layering and Encapsulation

Services, Layering and Encapsulation

| M |

Application exchanges messages to implement some application service using *services* of transport layer

source

destination

Services, Layering and Encapsulation

M

H$_t$ | **M**

Transport-layer protocol transfers M (e.g., reliably) from one *process* to another, using services of network layer

- transport-layer protocol encapsulates application-layer message, M, with *transport* layer-layer header H$_t$ to create a transport-layer segment
  - H$_t$ used by transport layer protocol to implement its service

source

destination

Services, Layering and Encapsulation

| M |

application

| H_t | M |

transport

| H_n | H_t | M |

network

Network-layer protocol transfers transport-layer segment [H_t | M] from one *host* to another, using link layer services

link

- network-layer protocol encapsulates transport-layer segment [H_t | M] with network layer-layer header H_n to create a network-layer datagram
  - H_n used by network layer protocol to implement its service

physical

source

application

transport

network

link

physical

destination

Services, Layering and Encapsulation

Link-layer protocol transfers datagram [H_n| [H_t |M] from *host* to neighboring *host*, using network-layer services

- link-layer protocol encapsulates network datagram [H_n| [H_t |M], with link-layer header H_l to create a link-layer frame

source

destination

Encapsulation: an end-end view

message | M |

segment | H_t | M |

datagram | H_n | H_t | M |

frame | H_l | H_n | H_t | M |

source

| application |
| transport |
| network |
| link |
| physical |

| link |
| physical |

switch

destination

| M |

| H_t | M |

| H_n | H_t | M |

| H_l | H_n | H_t | M |

| application |
| transport |
| network |
| link |
| physical |

| H_n | H_t | M |

| H_l | H_n | H_t | M |

| network |
| link |
| physical |

| H_n | H_t | M |

router
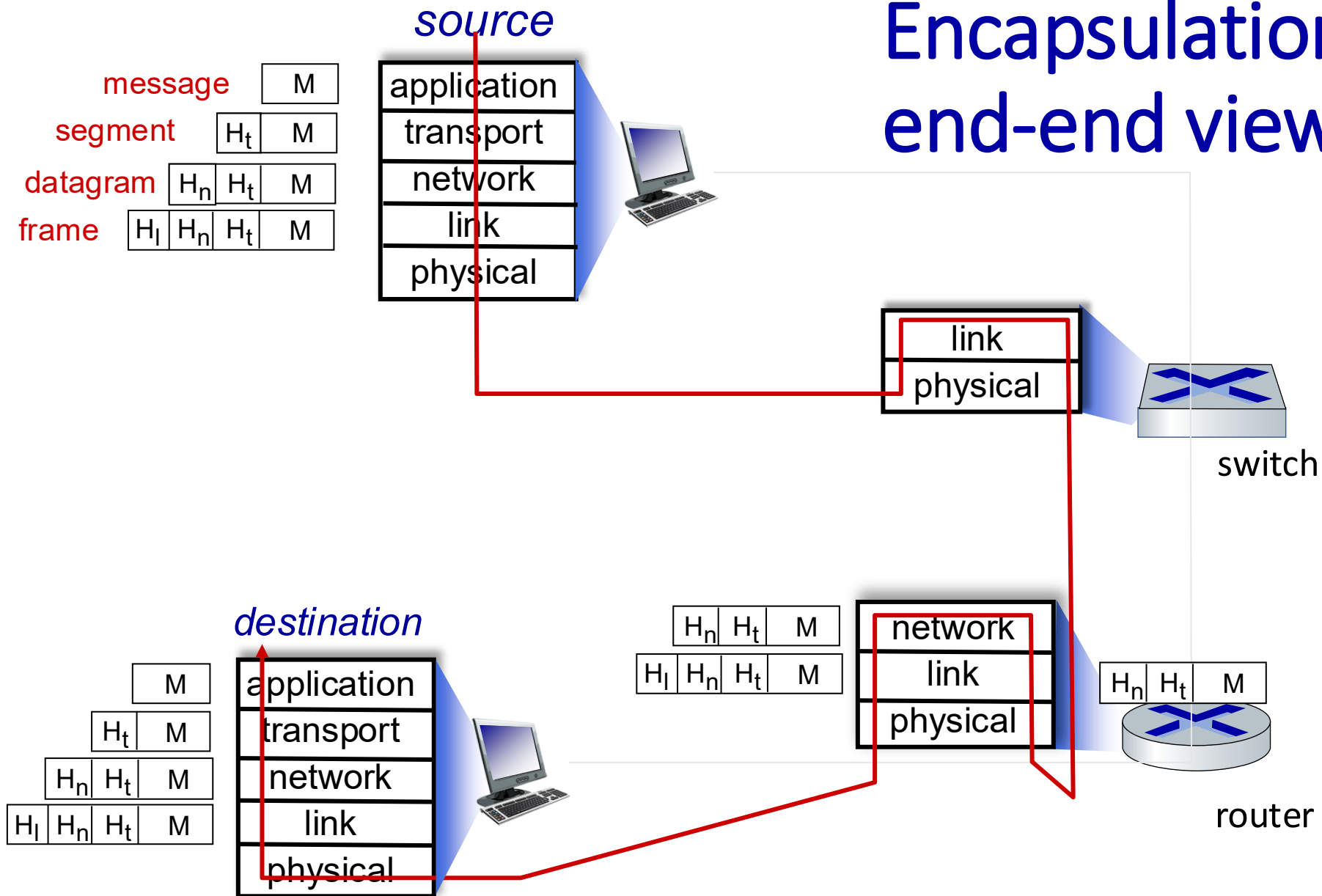
Summary

We've covered

- Internet overview
- Internet structure
- network edge, access network, core
- what's a protocol?
- layering, service models

You now have:

- context, overview, vocabulary, "feel" of networking
- more depth, detail, *and fun* to follow*!*