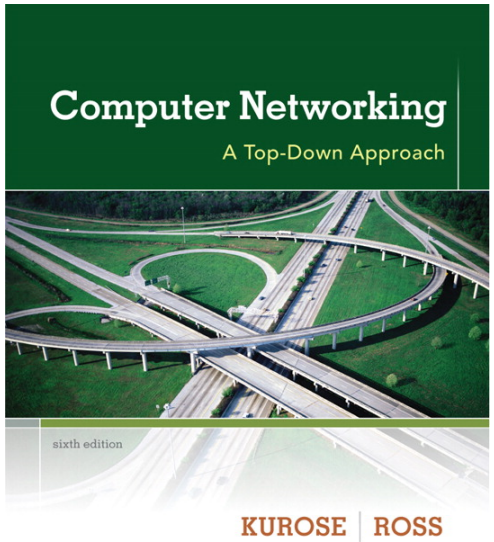
Chapter 1 Introduction



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Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
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Chapter 1: introduction

our goal:

- get "feel" and terminology
- more depth, detail *later* in course
- approach:
  - use Internet as example

overview:

- what's the Internet?
- what's a protocol?
- network edge; hosts, access net, physical media
- network core: packet/circuit switching, Internet structure
- performance: loss, delay, throughput
- protocol layers, service models

Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

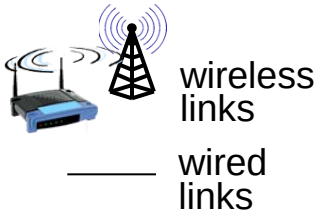
- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

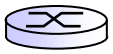
1.5 protocol layers, service models

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

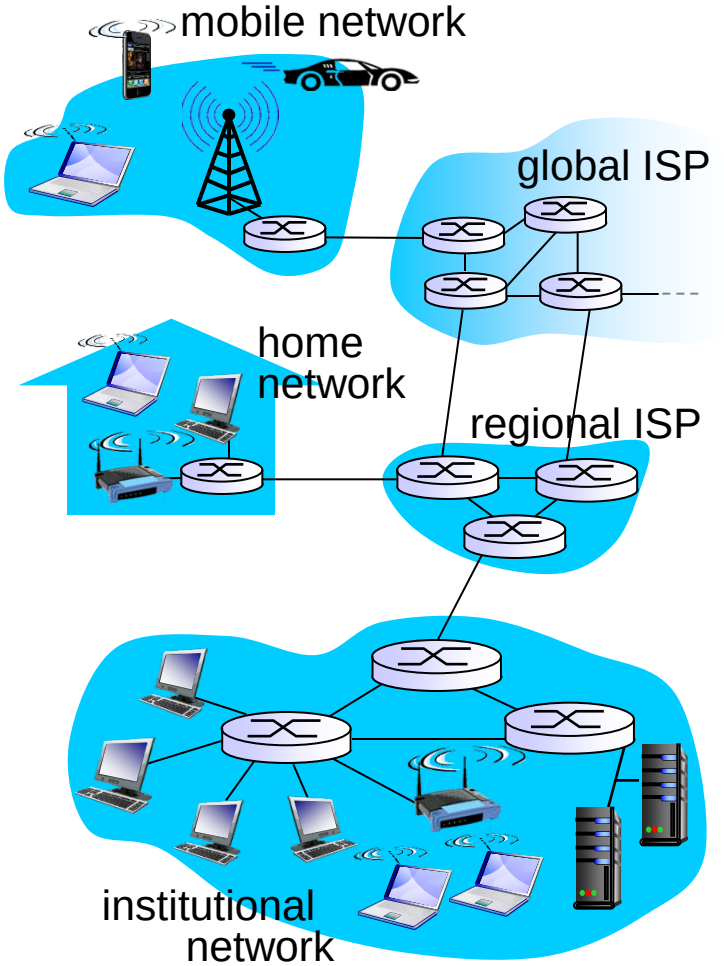
- millions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*



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



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



"Fun" internet appliances

IP picture frame
http://www.ceiva.com/

Web-enabled toaster +
weather forecaster

Tweet-a-watt:
monitor energy use

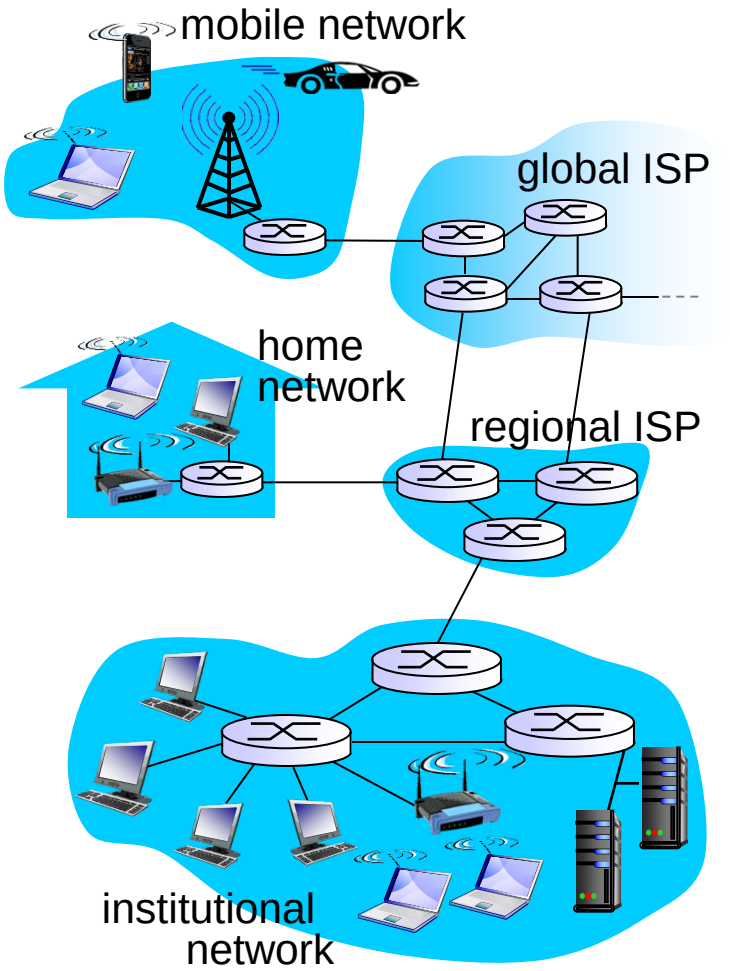
Internet
refrigerator

Slingbox: watch,
control cable TV remotely

Internet phones

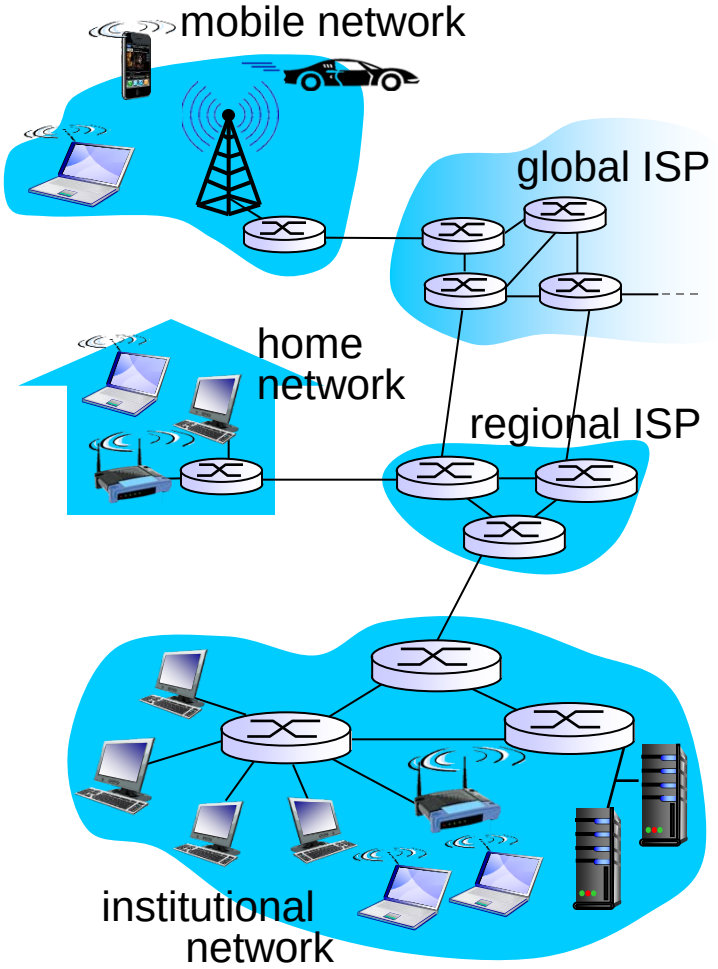
What's the Internet: "nuts and bolts" view

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



What's the Internet: a service view

- *Infrastructure that provides services to distributed applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - reliable data transfer between source and destination
  - "best effort" service, analogous to postal service

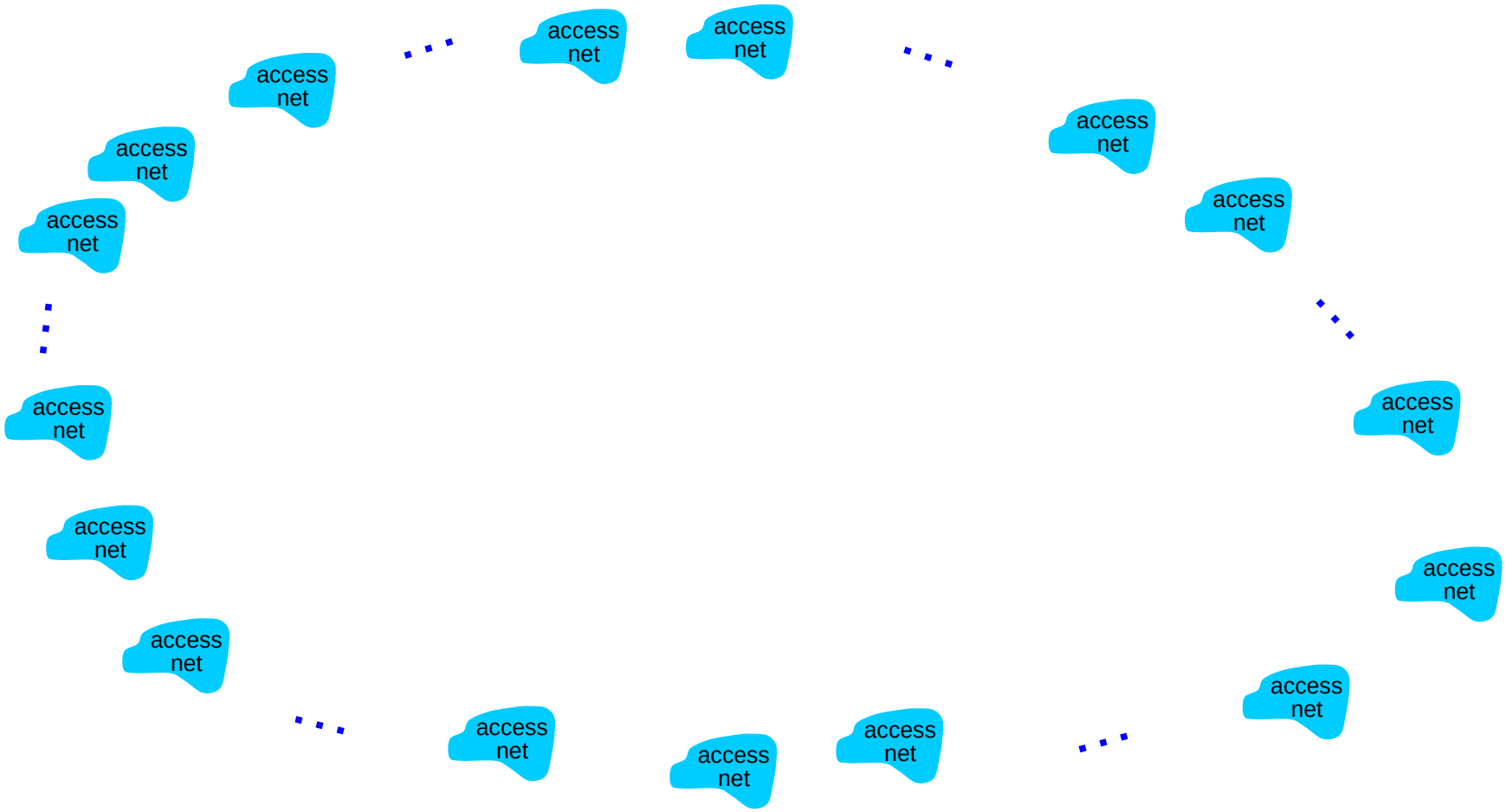


Internet structure: network of networks

- End systems connect to Internet via access ISPs (Internet Service Providers)
  - Residential, company and university ISPs
- Access ISPs in turn must be interconnected.
  - So that any two hosts can send packets to each other
- Resulting network of networks is very complex
  - Evolution was driven by economics and national policies
- Let's take a stepwise approach to describe current Internet structure

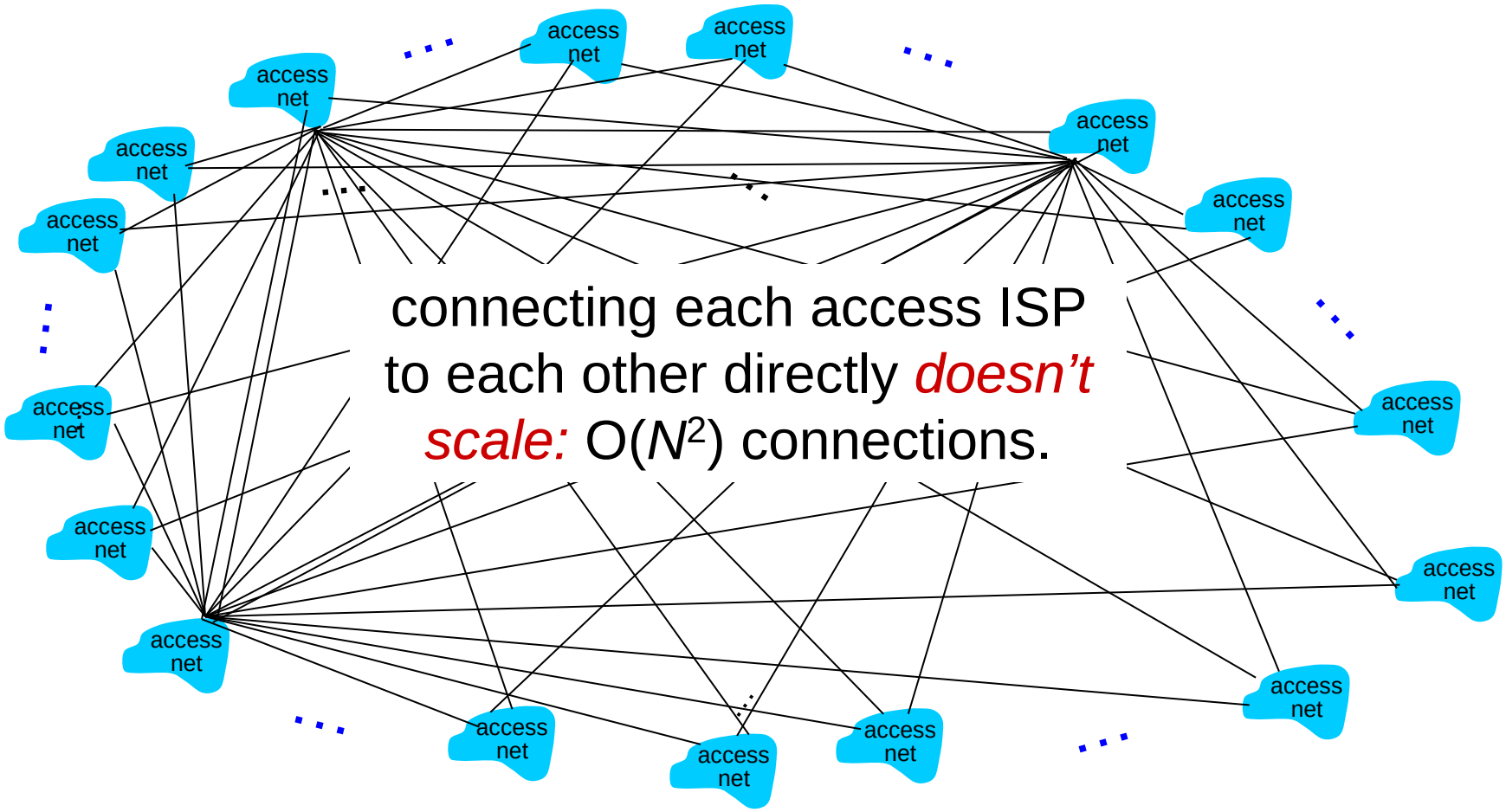
Internet structure: network of networks

Question: given *millions* of access ISPs, how to connect them together?



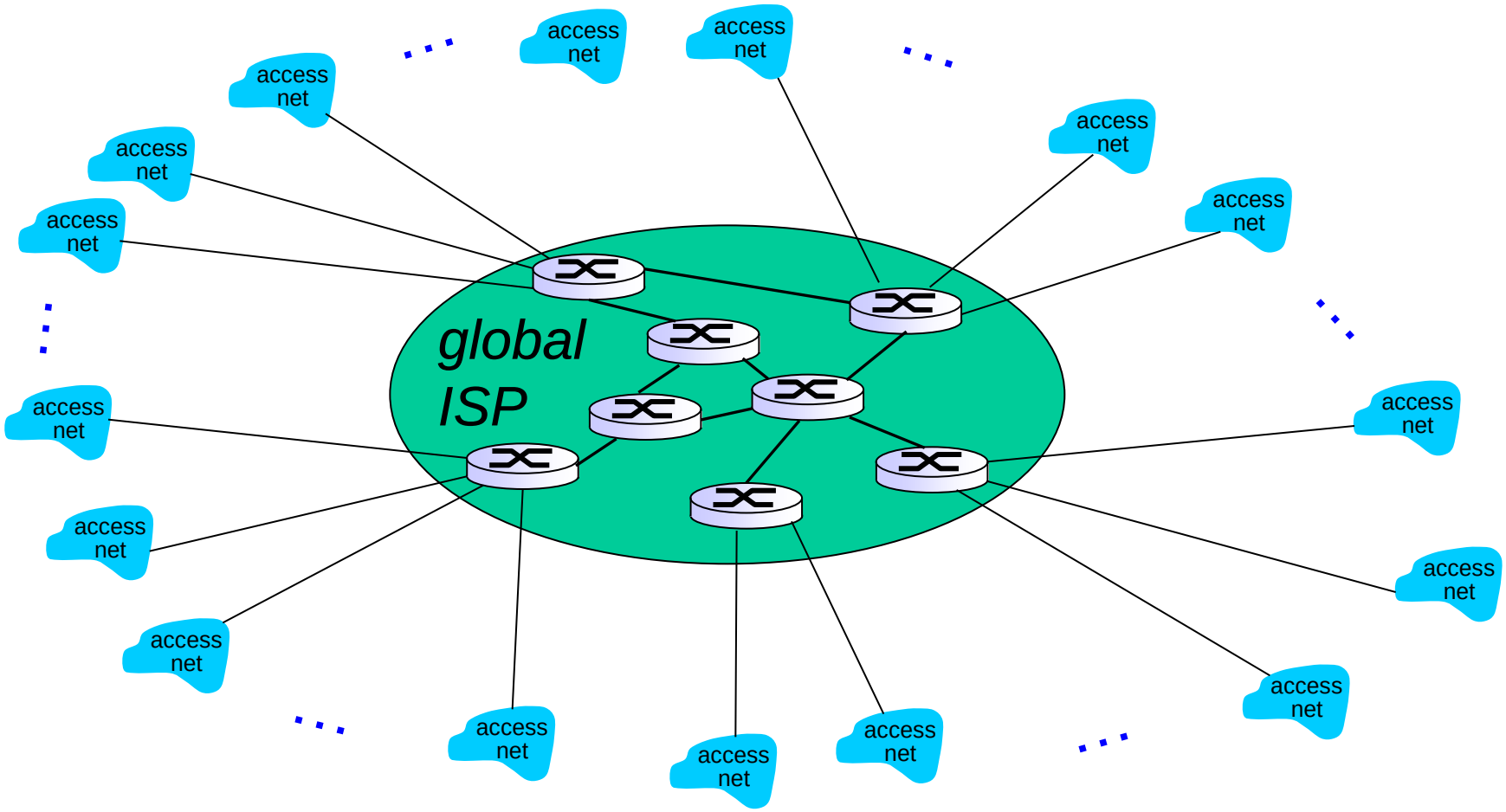
Internet structure: network of networks

Option: connect each access ISP to every other access ISP?



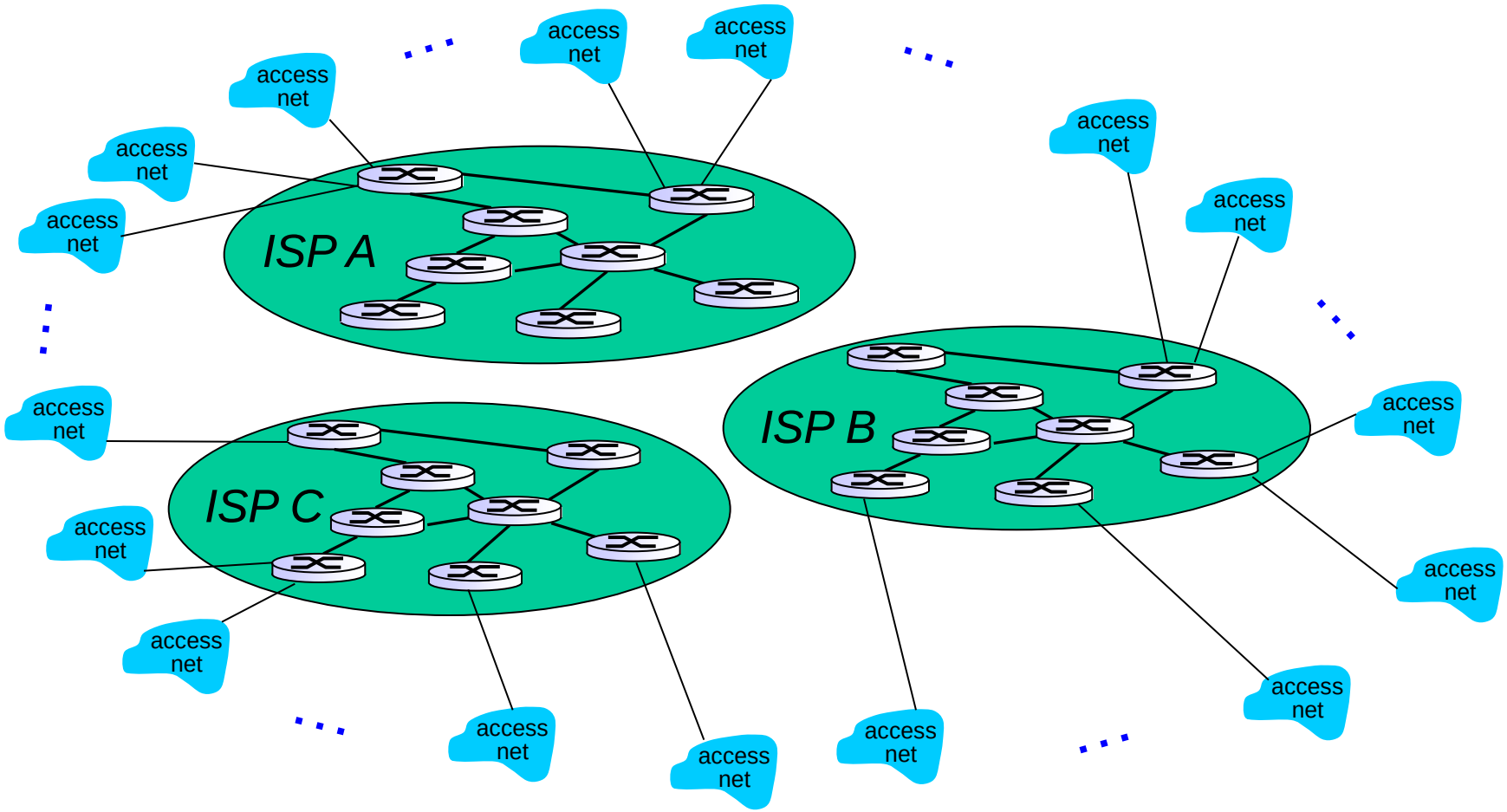
Internet structure: network of networks

Option: connect each access ISP to a global transit ISP? Customer and provider ISPs have economic agreement.



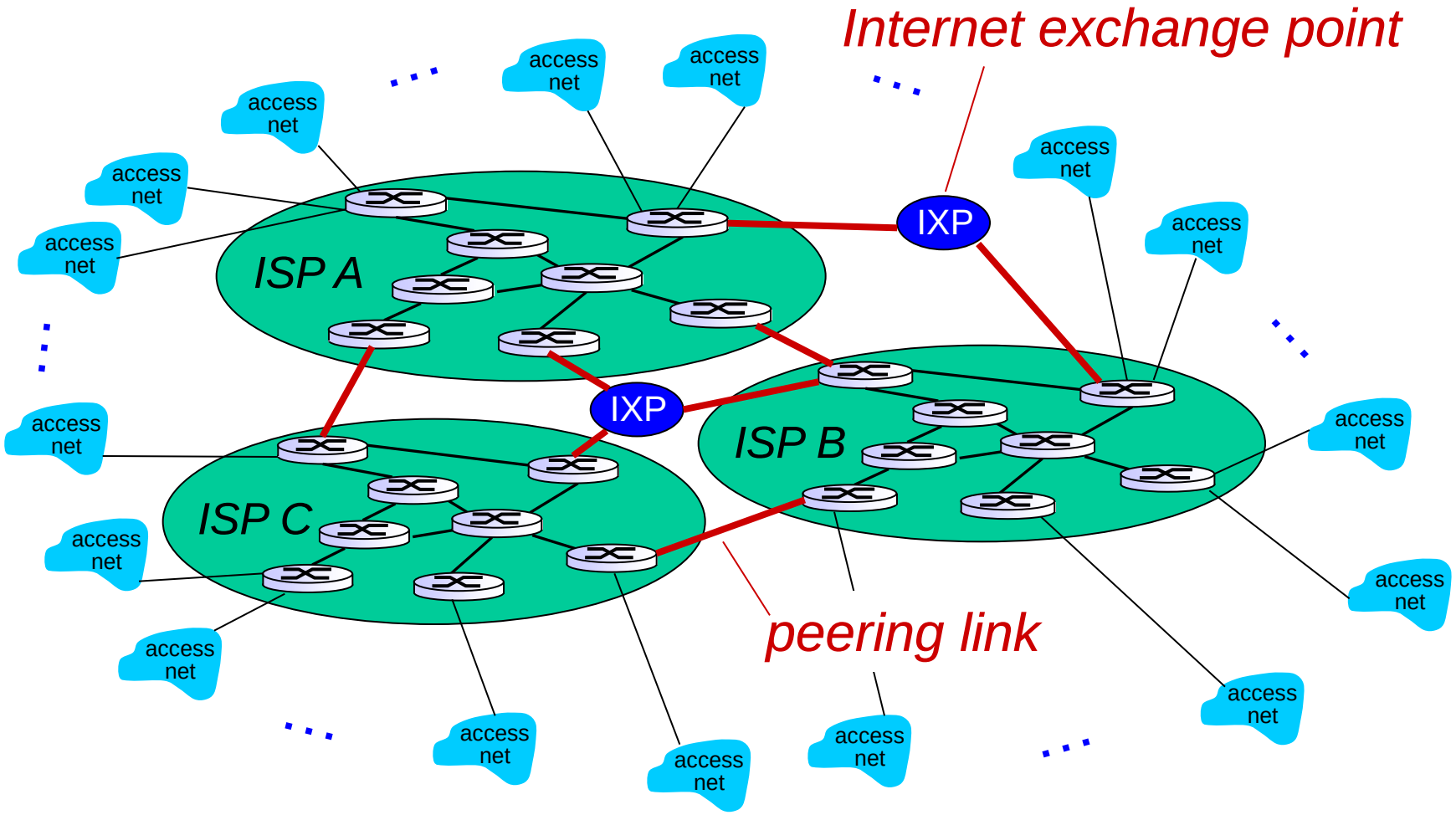
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors ….



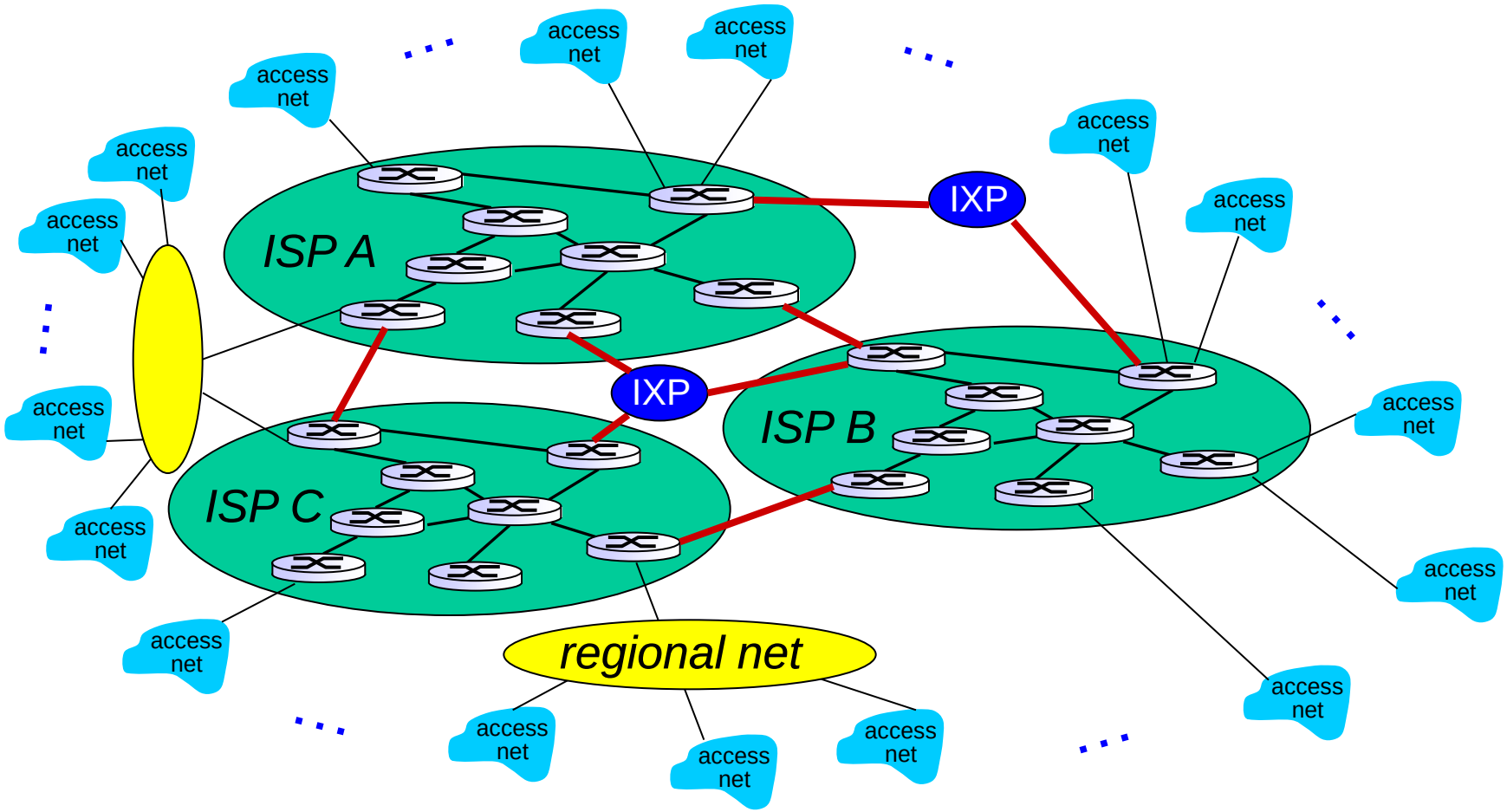
Internet structure: network of networks

But if one global ISP is viable business, there will be competitors …. which must be interconnected



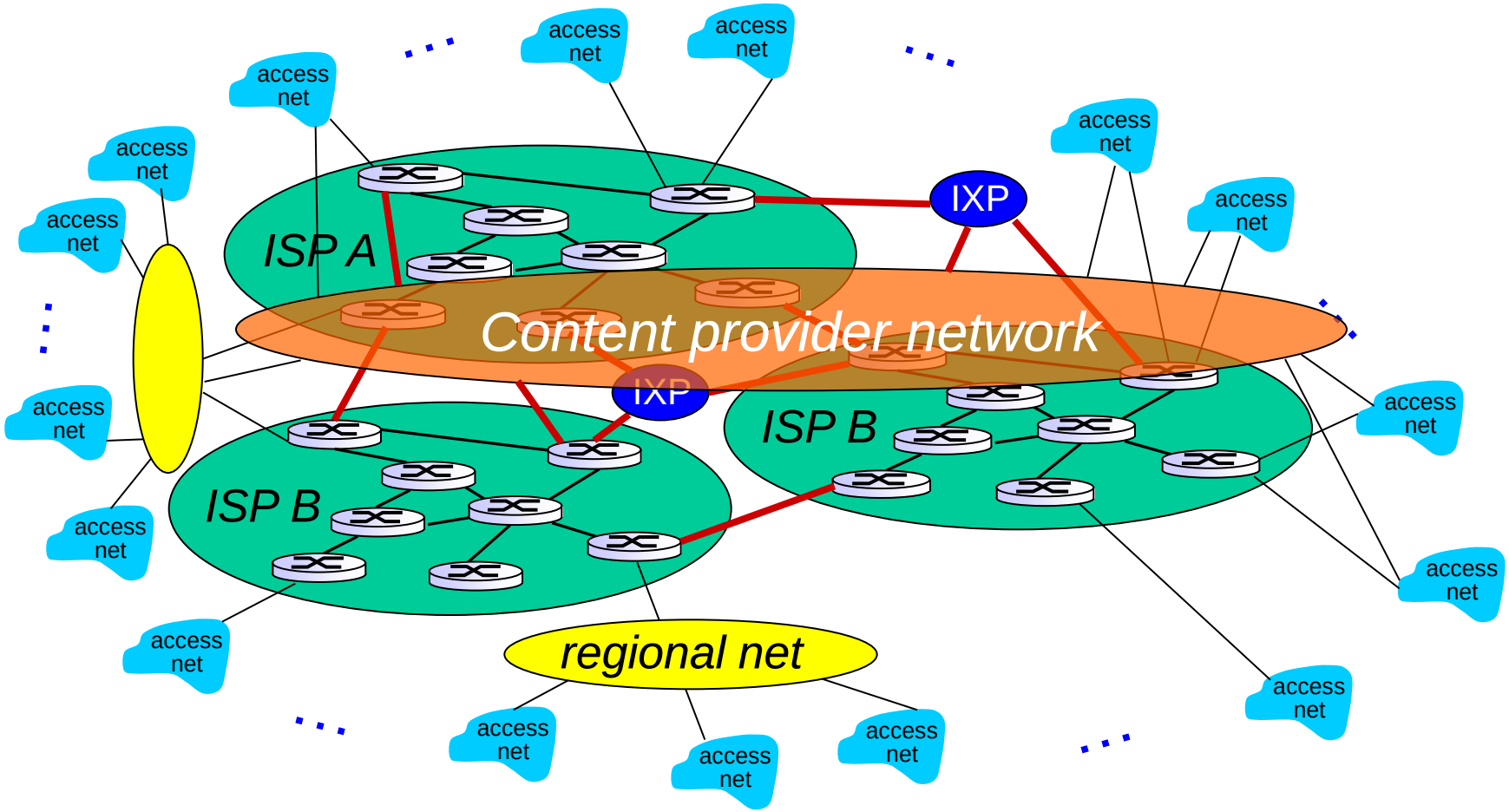
Internet structure: network of networks

… and regional networks may arise to connect access nets to ISPS

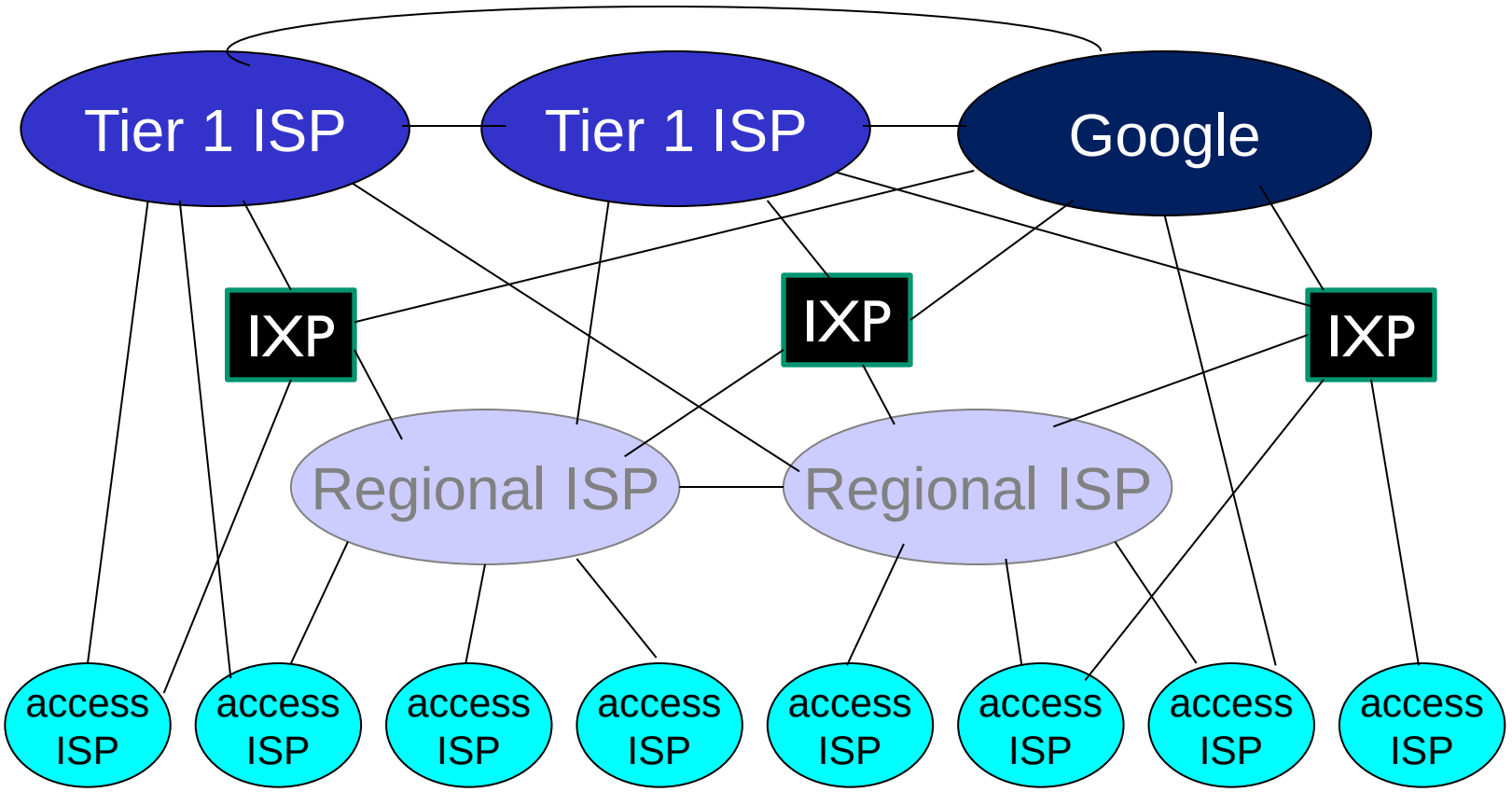


Internet structure: network of networks

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



Internet structure: 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 network (e.g, Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs

What's a protocol?

human protocols:

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

… specific msgs sent

… specific actions taken when msgs received, or other events

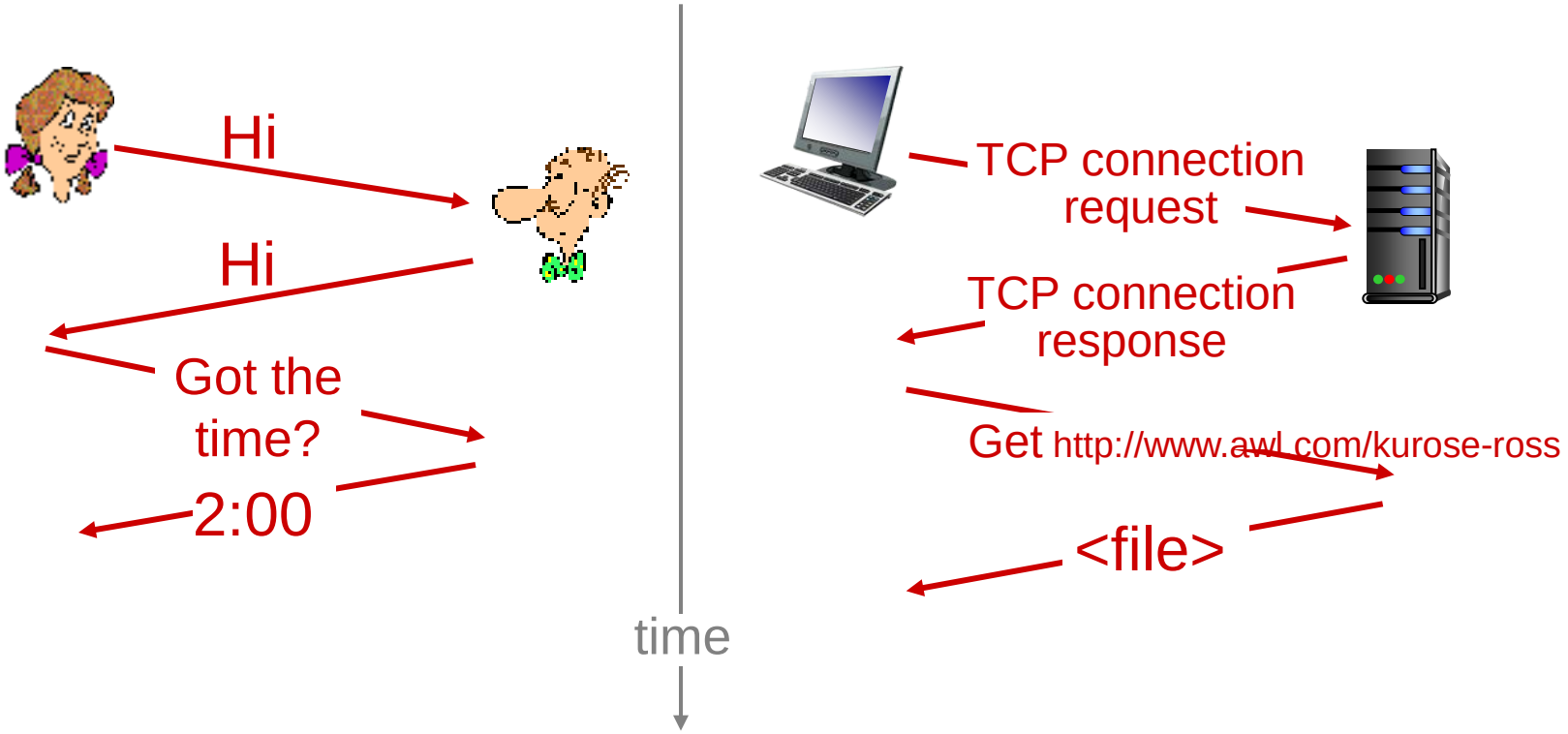
network protocols:

- machines rather than humans
- all communication activity in Internet governed by protocols

protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

What's a protocol?

a human protocol and a computer network protocol:



Q: other human protocols?

Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

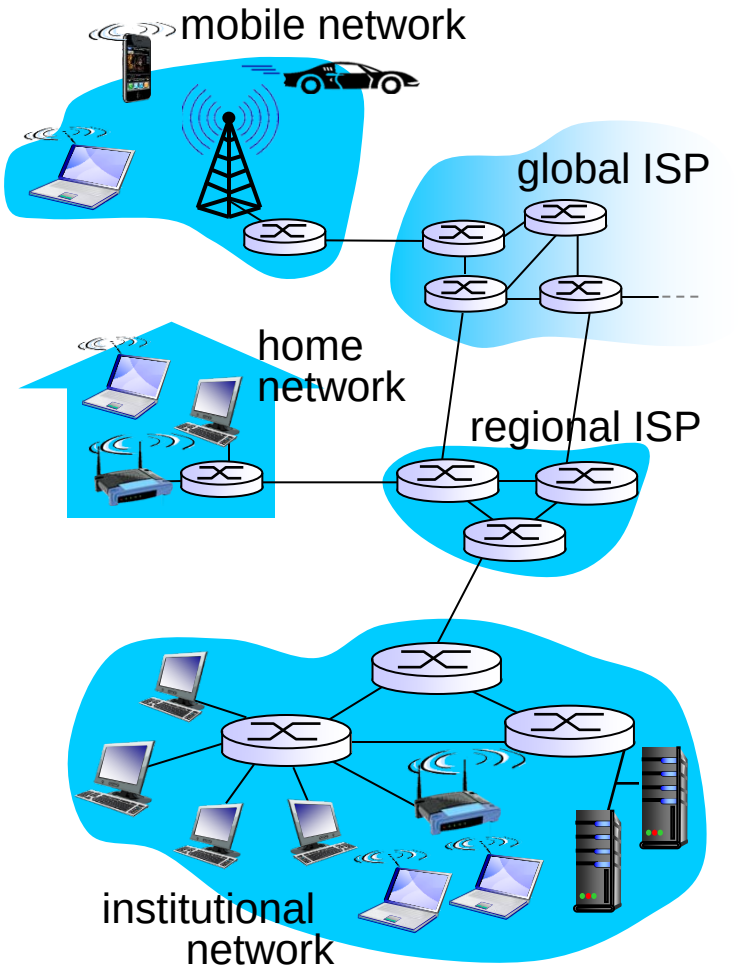
1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

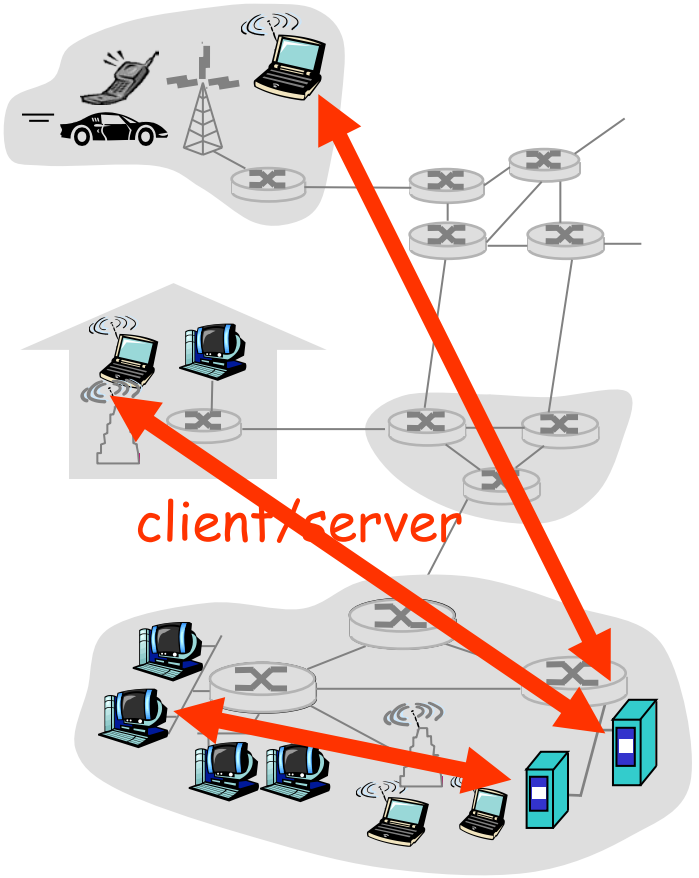
A closer look at network structure:

- *network edge:*
  - hosts: clients and servers
  - servers often in data centers
- *access networks, physical media:* wired, wireless communication links
- *network core:*
  - interconnected routers
  - network of networks



Network Edge

- End systems (or hosts):
  - run applications in network edge
- Client/Server Model:
  - Client request a service to a server (always running)
    - Example: Web -> browser/web server
- Peer-to-Peer Model
  - Host acting as a client and a server
  - Reduced use of dedicated servers
    - Example: Skype, BitTorrent



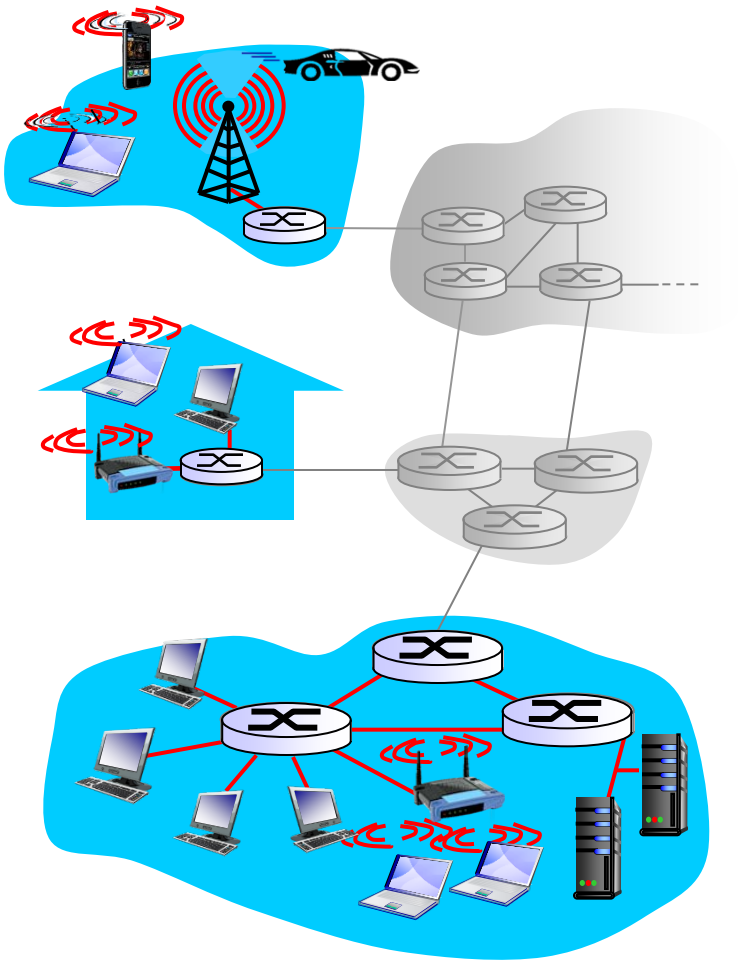
Access networks and physical media

Q: How to connect end systems to edge router?

- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

- bandwidth (bits per second) of access network?
- shared or dedicated?



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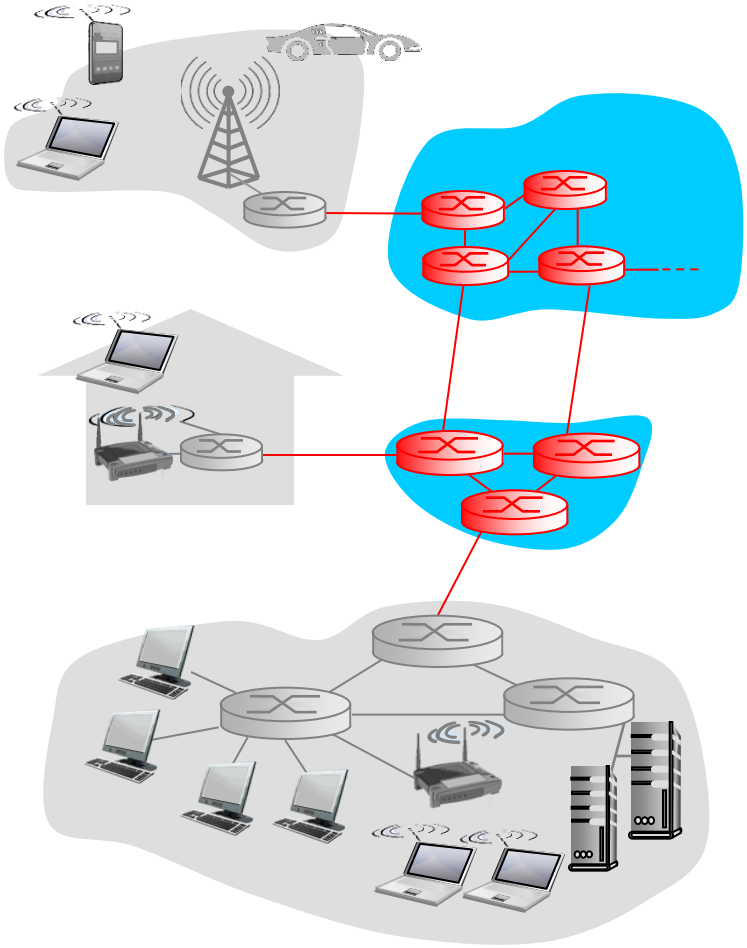
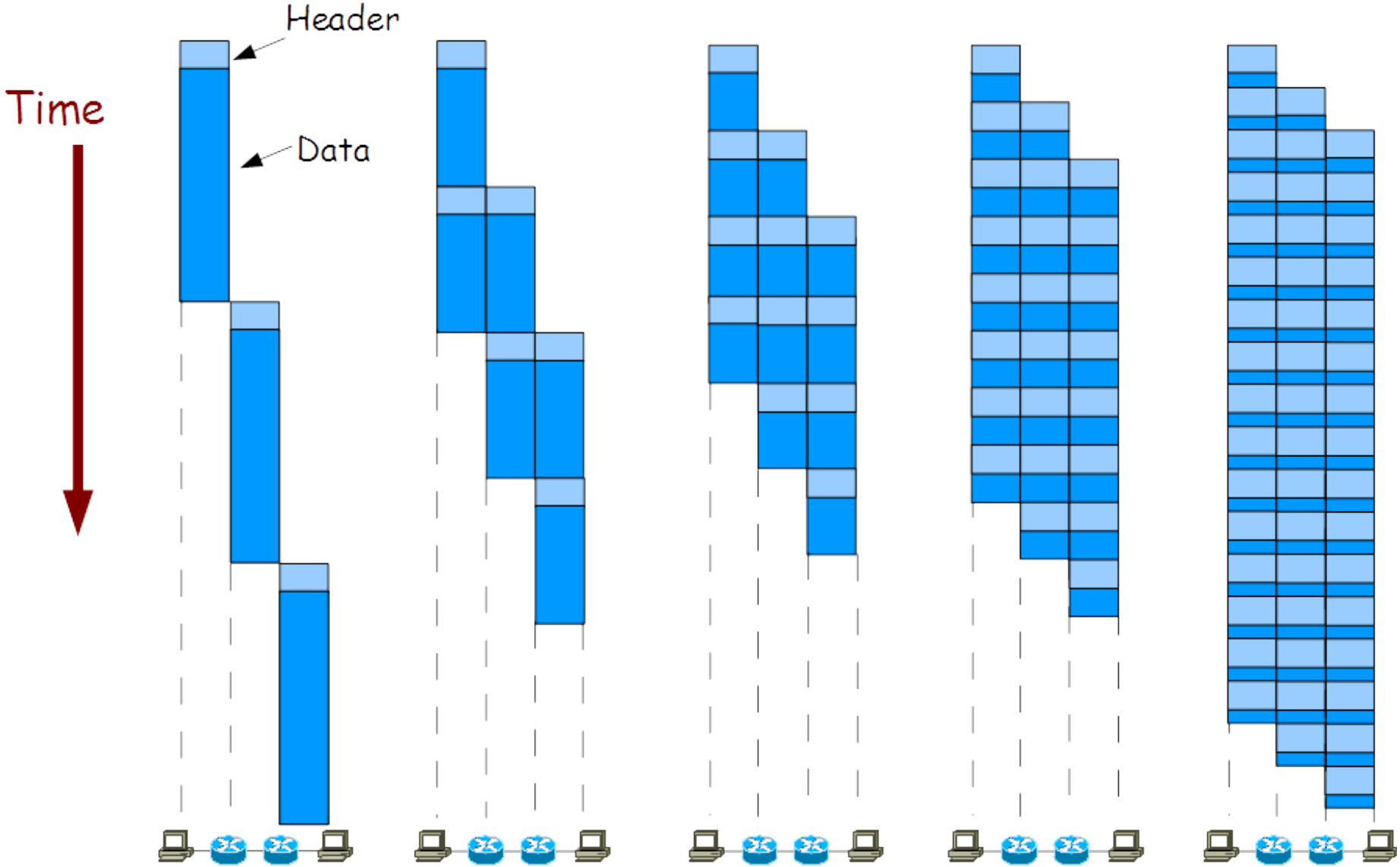
The network core

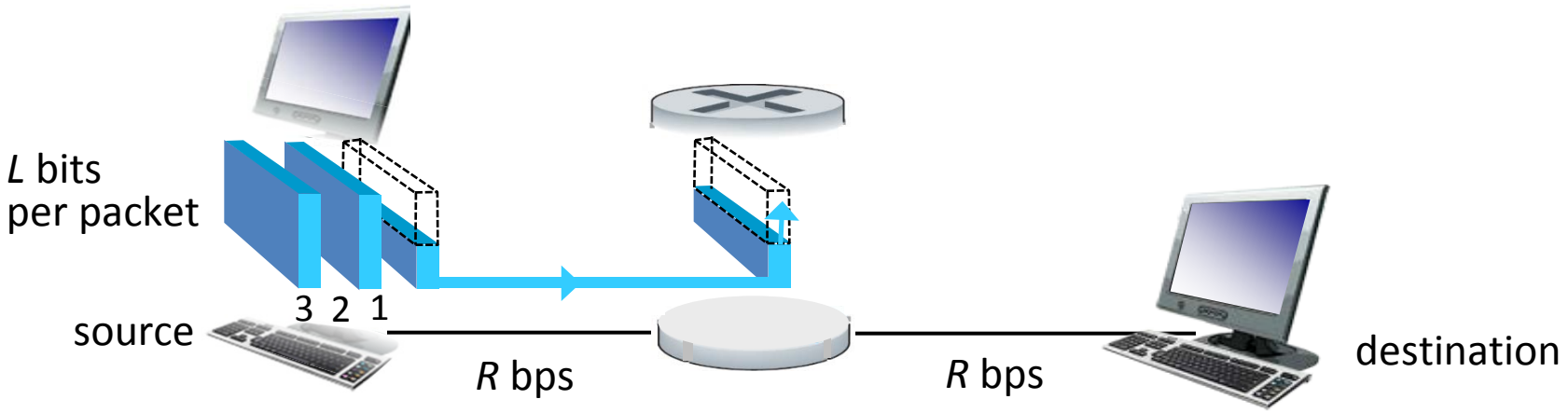
- mesh of interconnected routers
- packet-switching: hosts break application-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



Packet size and performances



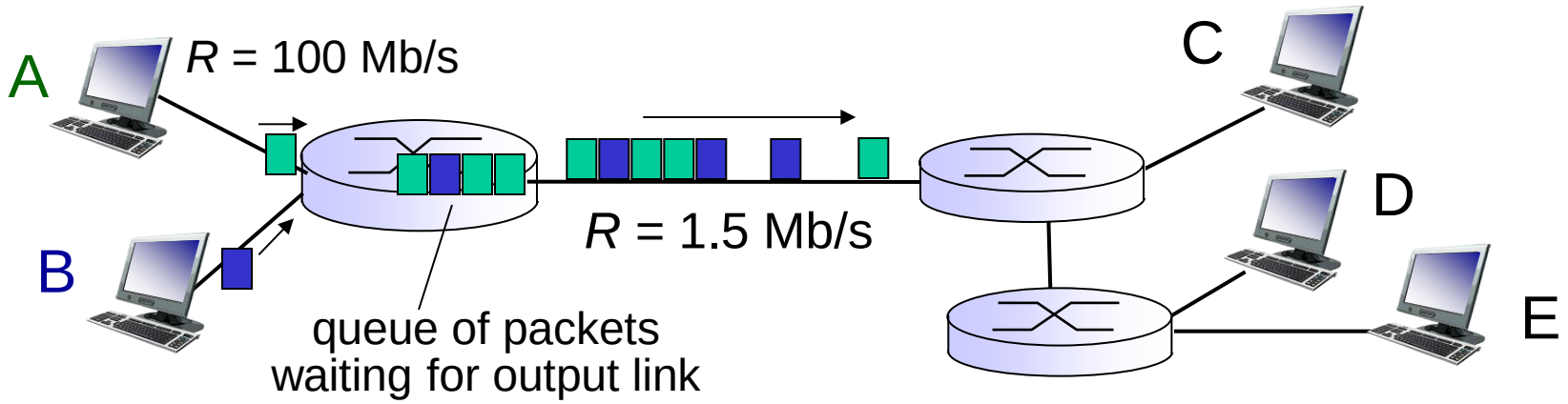
Packet-switching: store-and-forward



- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link
- end-end delay = 2*L*/*R* (assuming zero propagation delay)

more on delay shortly …

Packet Switching: queueing delay, loss



queuing and loss:

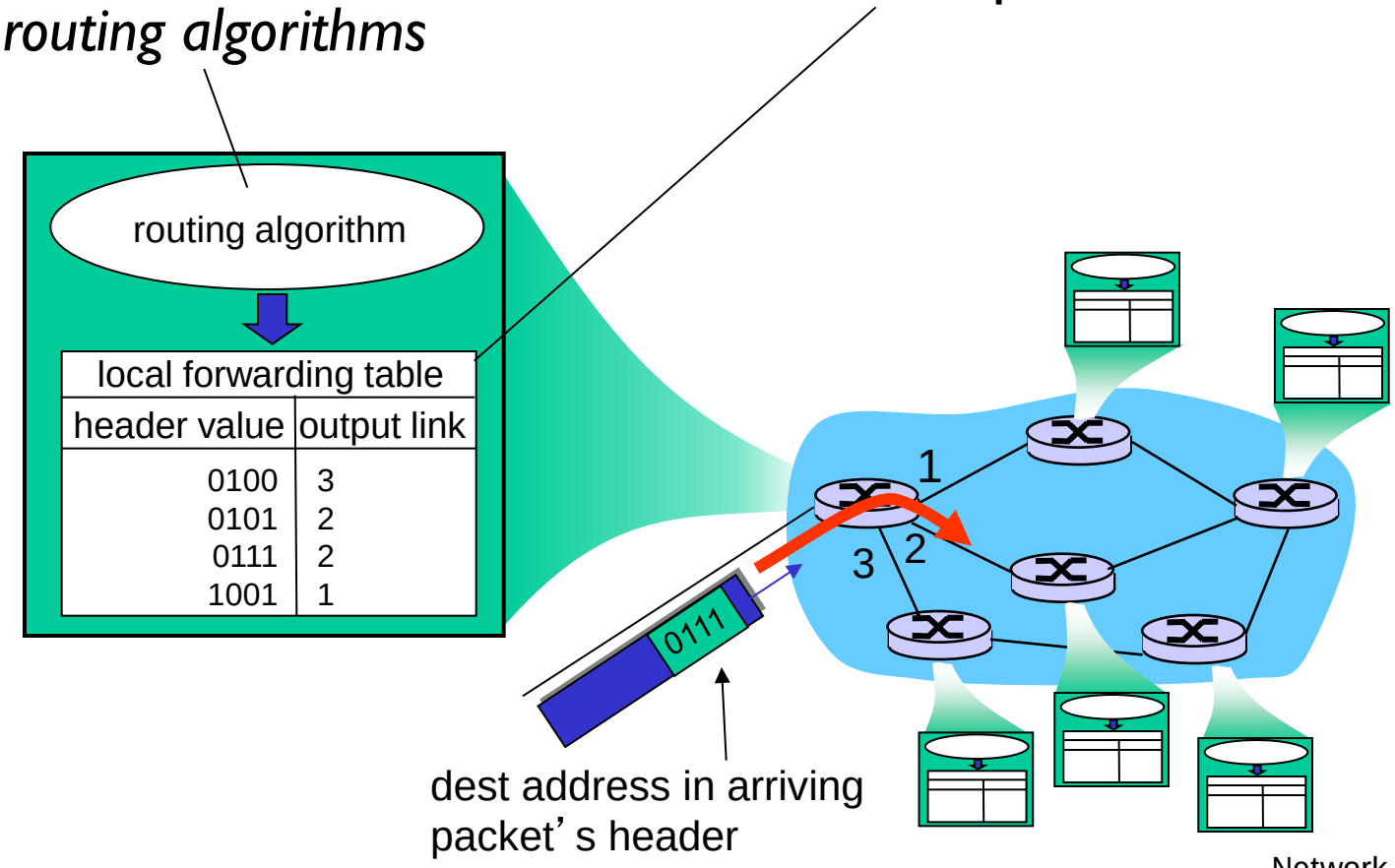
- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

Two key network-core functions

routing: determines source-destination route taken by packets

- *routing algorithms*

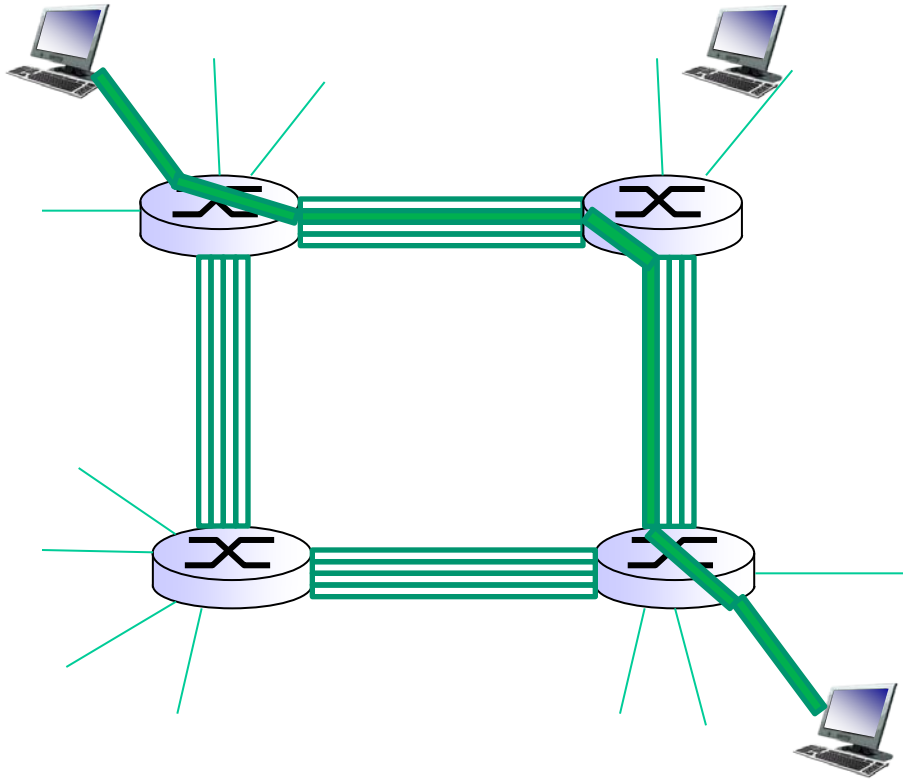
forwarding: move packets from router's input to appropriate router output



Alternative core: circuit switching

end-end resources allocated to, reserved for "call" between source & dest:

- In diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call *(no sharing)*
- Commonly used in traditional telephone networks

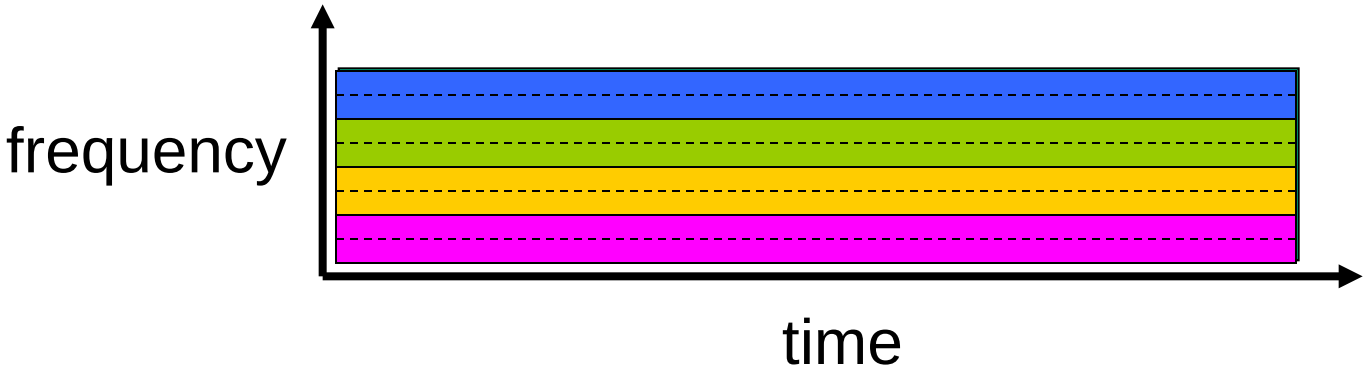


Circuit switching: FDM versus TDM

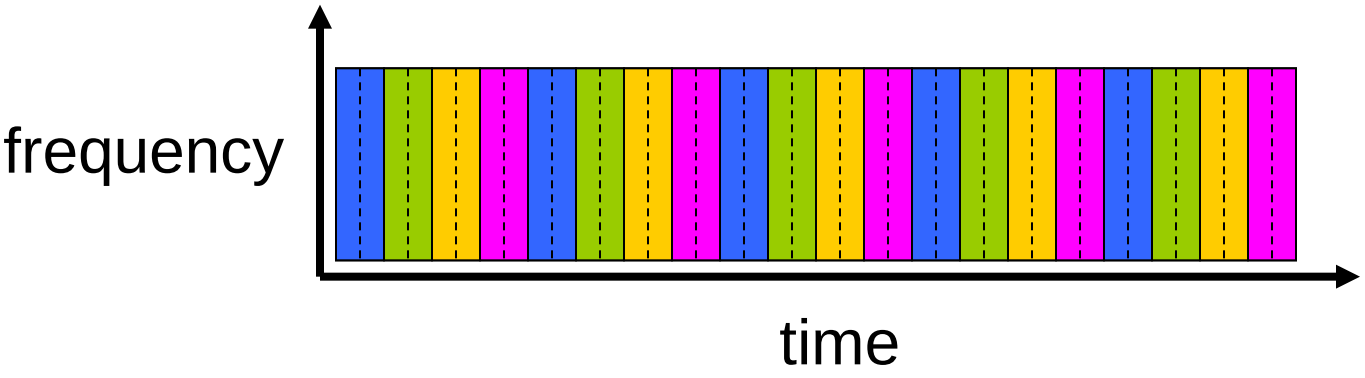
Example:

4 users

FDM



TDM



Packet switching versus circuit switching

- Circuits Switching
  - Static Reservation of links
  - Three phases:
    - circuit establishment , data transfer and circuit disconnect
  - After circuit establishment bandwidth is dedicated to this connection and remains available until the users terminate communication between the two nodes, even if they are not transmitting.
  - Used in normal telephone line, for voice communication.
- Packet Switching
  - Simpler, no call setup, no resource reservation
  - Resource sharing
  - Excessive congestion possible: packet delay and loss
    - protocols needed for reliable data transfer, congestion control
  - Better use of resources

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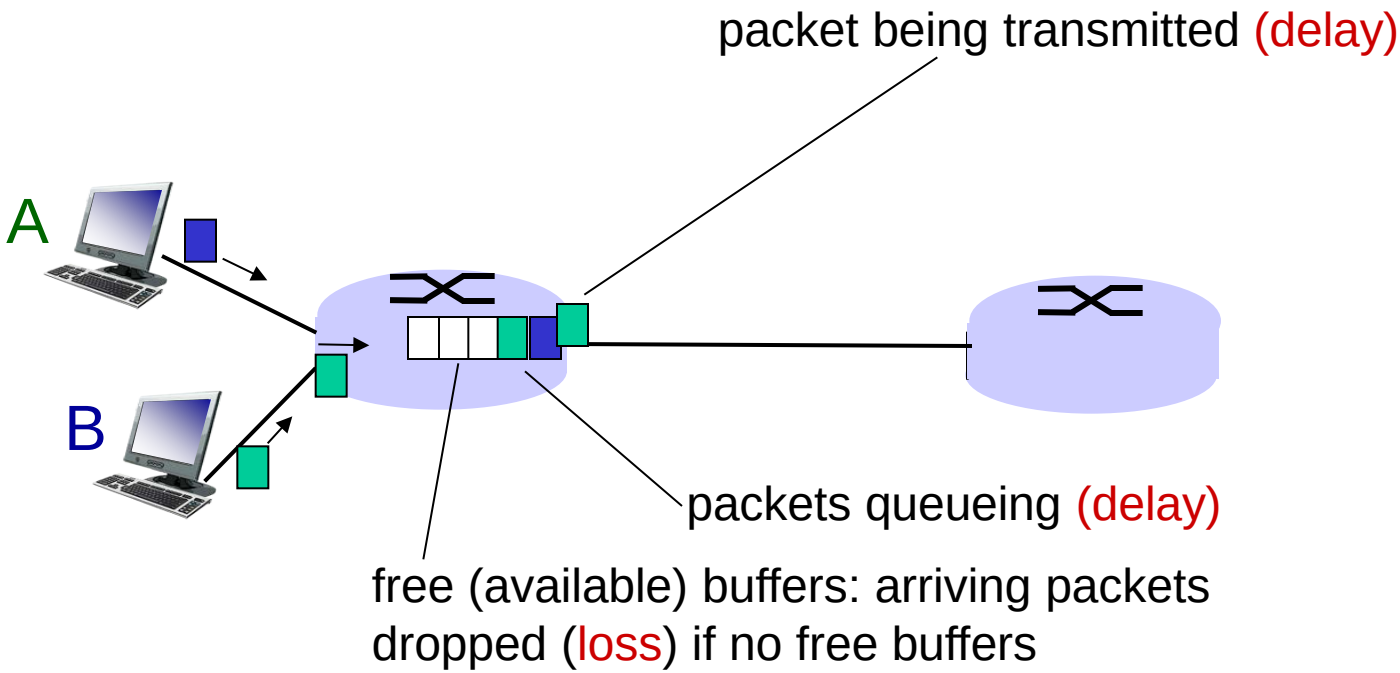
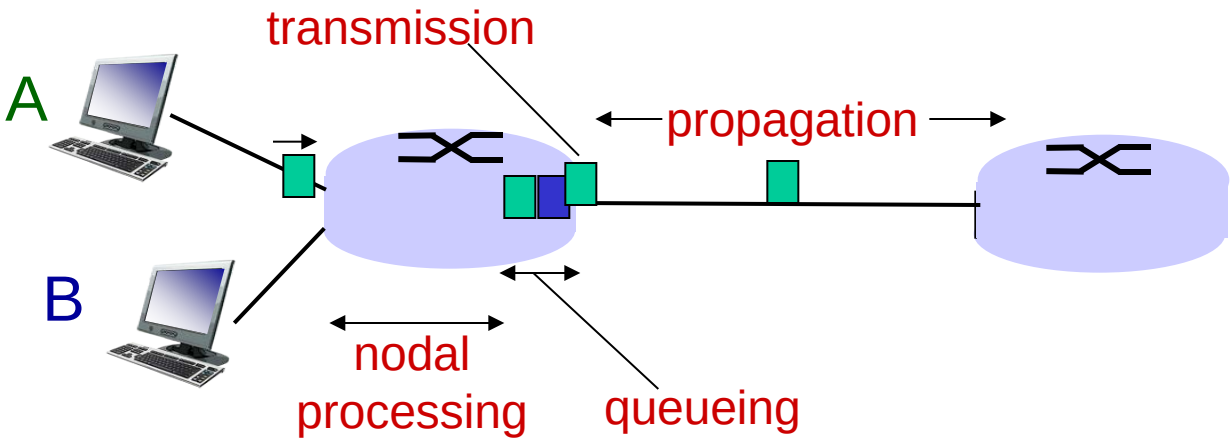
How do loss and delay occur?

packets *queue* in router buffers

- packet arrival rate to link (temporarily) exceeds output link capacity
- packets queue, wait for turn



Four sources of packet delay



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

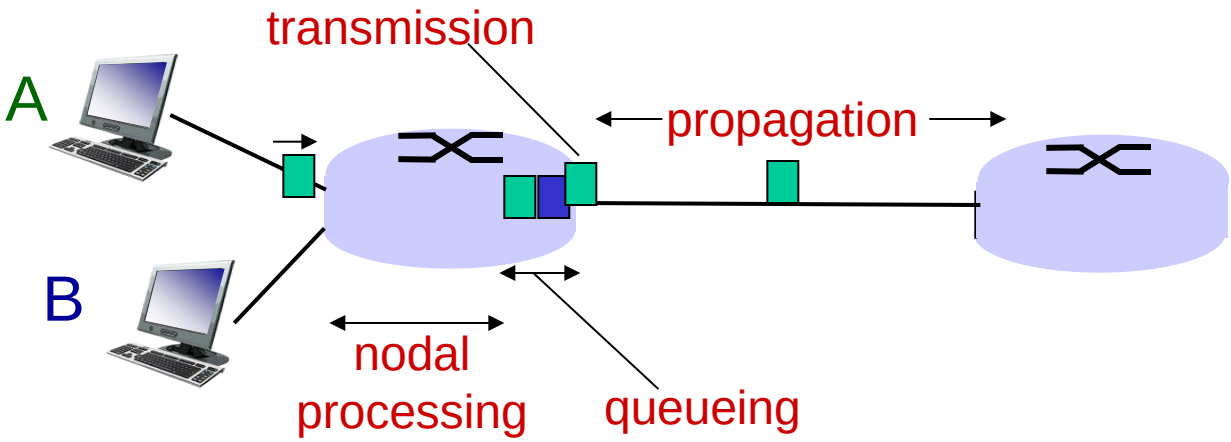
d_{proc}: nodal processing

- check bit errors
- determine output link
- typically < msec

d_{queue}: queueing delay

- time waiting at output link for transmission
- depends on congestion level of router

Four sources of packet delay



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

d_{trans}: transmission delay:

- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{prop}: propagation delay:

- d: length of physical link
- s: propagation speed in medium (~2×10^8 m/sec)
- $d_{prop} = d/s$

d_{trans} and d_{prop} *very* different

* Check out the Java applet for an interactive animation on trans vs. prop delay

Transmission & Propagation delay

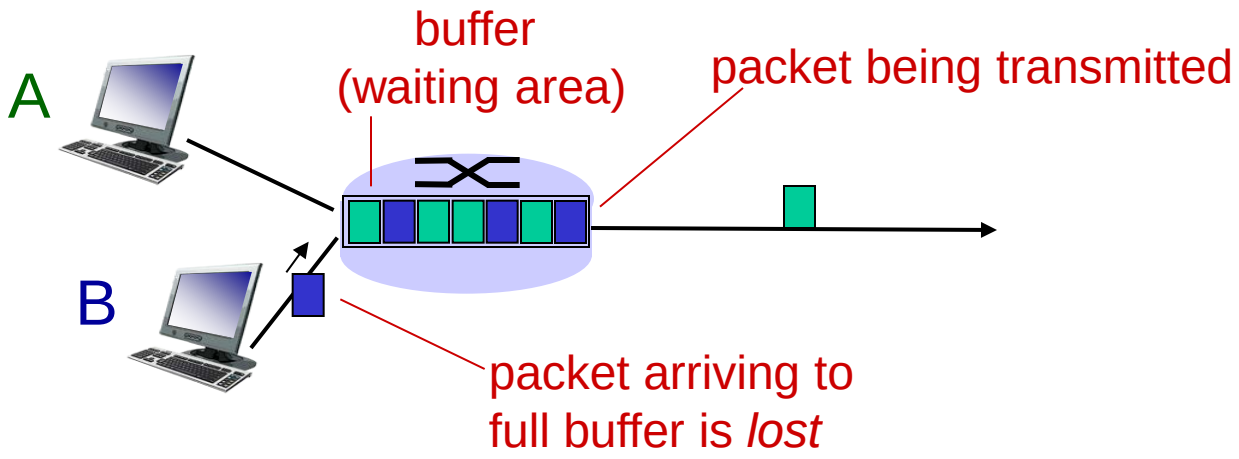
- **The transmission delay** is the amount of time required for the router to push out the packet.
- **The propagation delay**, is the time it takes a bit to propagate from one router to the next.

- the transmission and propagation delay are completely different! if denote the length of the packet by *L* bits, and denote the transmission rate of the link from first router to second router by *R* bits/sec. then transmission delay will be **L/R**. and this is depended to *transmission rate of link* and the *length of packet*.

- then if denote the distance between two routers **d** and denote the propagation speed **s**, the propagation delay will be **d/s**. it is a function of the *Distance* between the two routers, but has no dependence to the packet's length or the transmission rate of the link.

Packet loss

- queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all



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Protocol "layers"

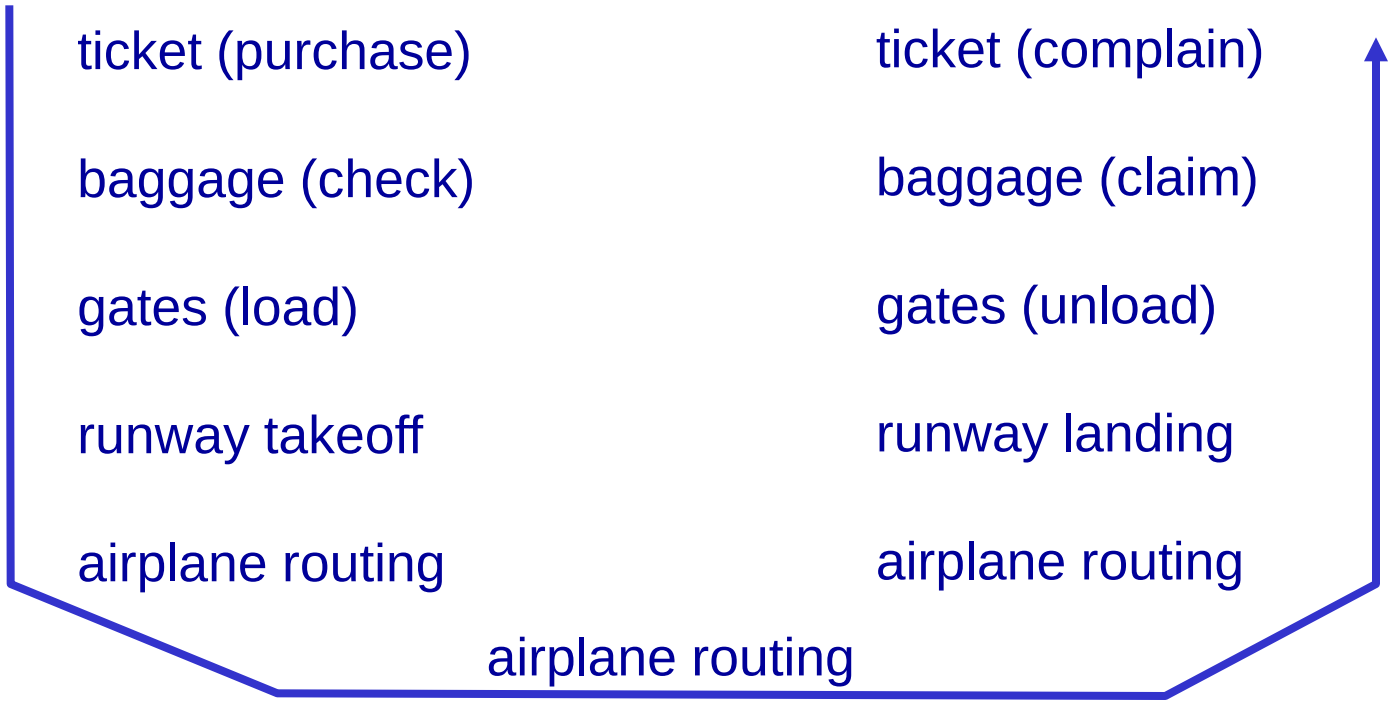
Networks are complex, with many "pieces":

- hosts
- routers
- links of various media
- applications
- protocols
- hardware, software

Question:

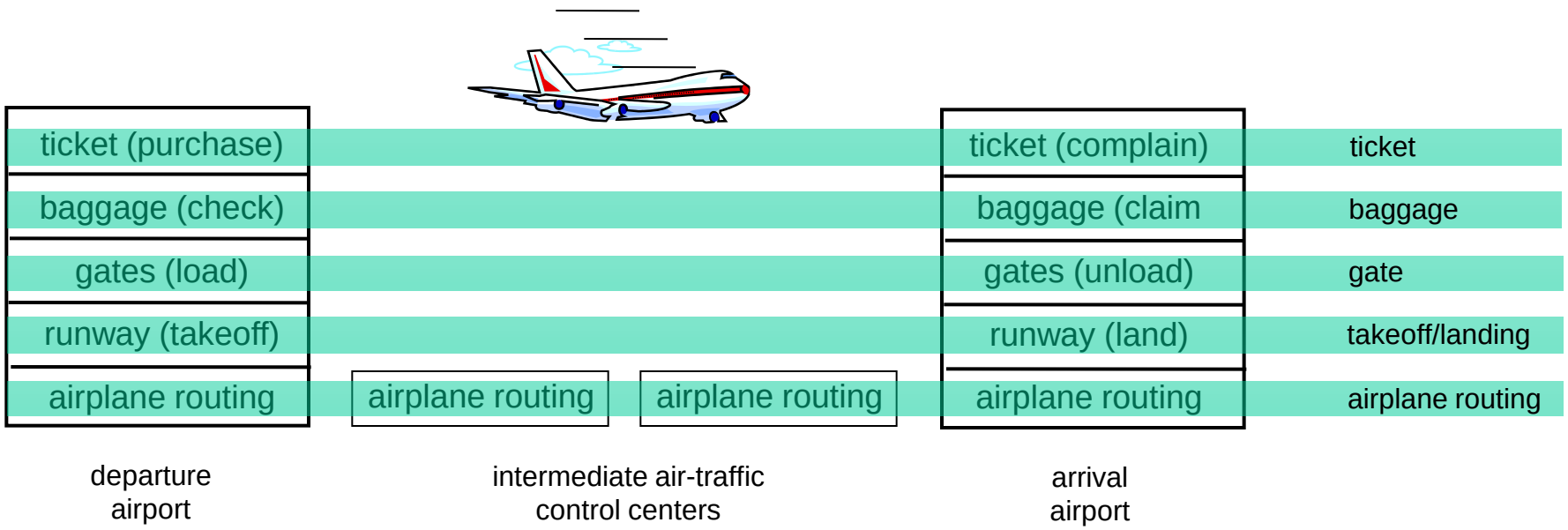
is there any hope of *organizing* structure of network?

Organization of air travel



- a series of steps

Layering of airline functionality



layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

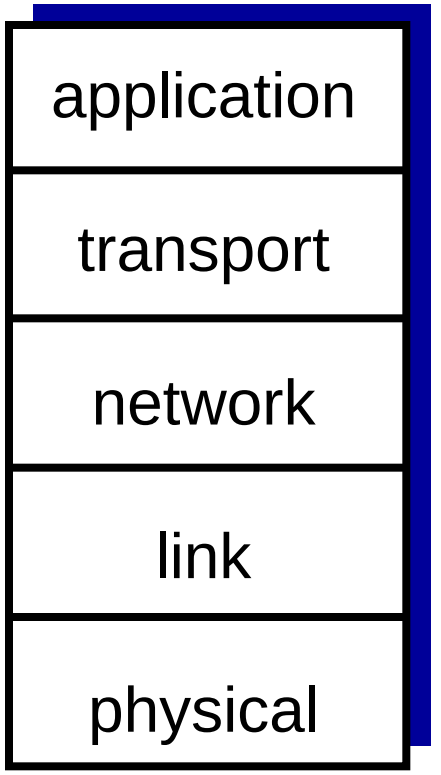
Why layering?

dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
  - layered *reference model* for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system
- layering considered harmful?

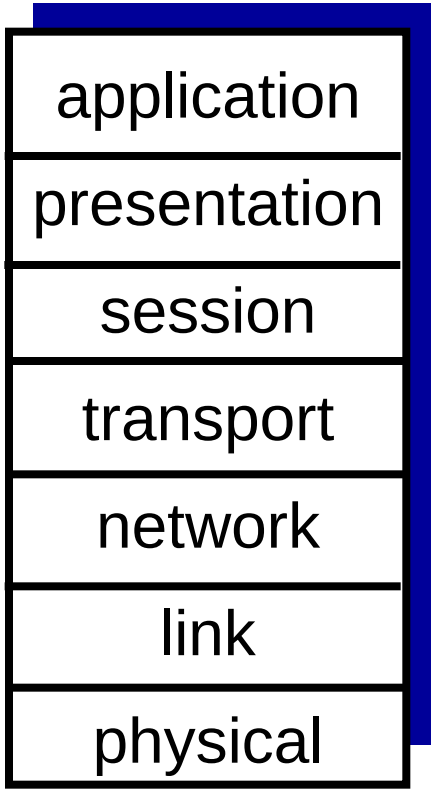
Internet protocol stack

- *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"

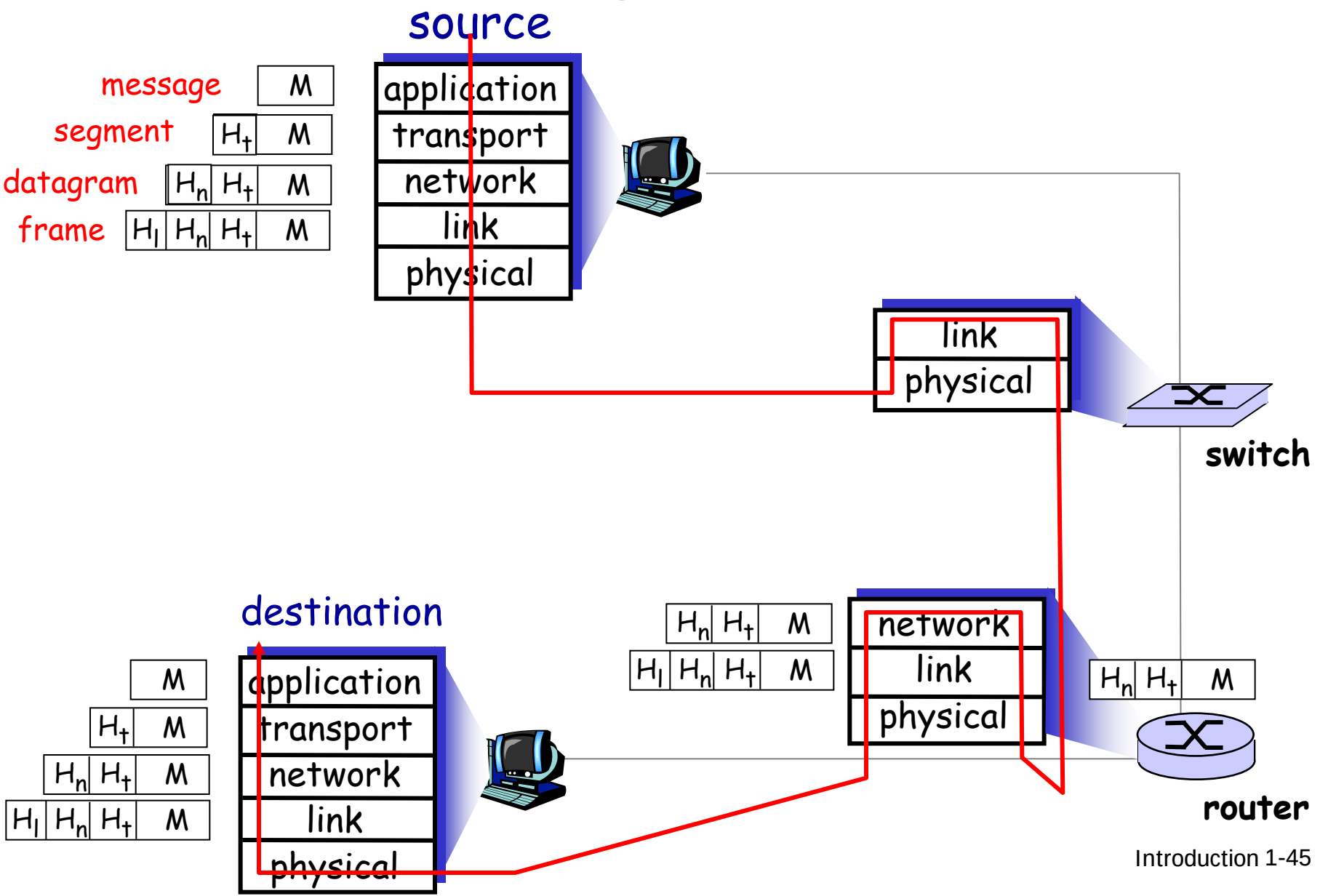


ISO/OSI reference model

- *presentation:* allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *session:* synchronization, checkpointing, recovery of data exchange
- Internet stack "missing" these layers!
  - these services, *if needed*, must be implemented in application



Encapsulation



Introduction: summary

covered a "ton" of material!

- Internet overview
- what's a protocol?
- Internet structure
- network edge, core, access network
  - packet-switching versus circuit-switching
- performance: loss, delay
- layering, service models

you now have:

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