Information Network

Lecture 1 : Introduction

Holger Thies

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Course Information

- This course is an introduction to Networks
- Focus on the Internet
- Learn how devices communicate across networks
- Learn the most important protocols used for the Internet
- Basics of Information Security

Course Information

- Instructor
  - Holger Thies
  - Email: thies.holger.5c@kyoto-u.ac.jp
  - Office: Yoshida-South Campus Academic Center Bldg. (South Wing)
    Room 230
- Time and Place:
  - Wednesday, 5th period (16:45—18:15)
  - 32, Yoshida-South Campus Bldg. No. 1

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Exercises

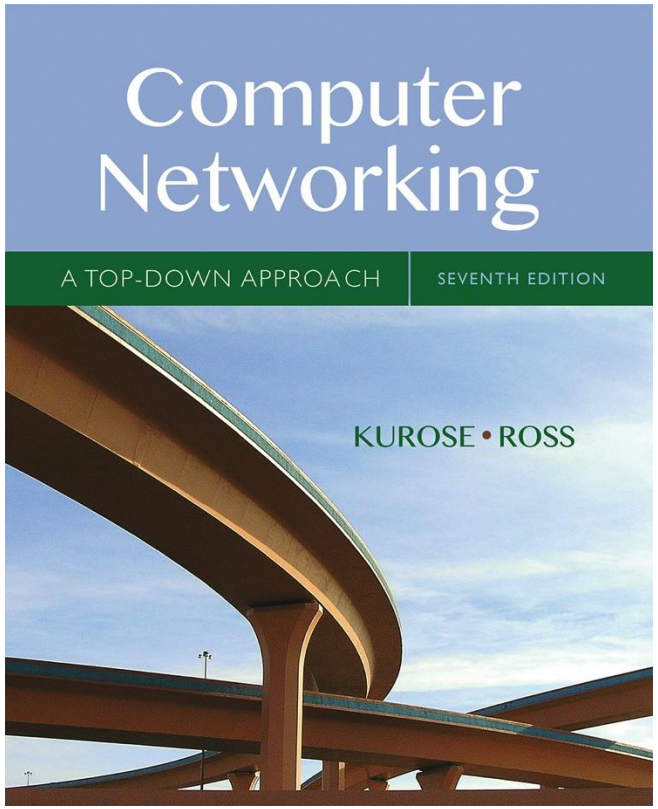
- There will be homework exercises approximately every two weeks.
- There also will a be a short tests in the last lecture.
- Depending on progress some details might change.
  - Changes will be announced on the **lecture slides** which are available on PandA.
  - Always study the lecture slides to make sure not to miss important information.
- There will be a final report at the end of the semester which has to be submitted on PandA.
  - Details will be announced later.
- Grading: In-class and homework exercises (40%), Final report (60%)

Textbook and Sources

You do not need to buy a textbook for this class.

However, the class closely follows the book by Kurose and Ross.

Many of the slides are taken or adapted from their officially provided power point slides.



Computer Networking: A Top Down Approach

7th edition
Jim Kurose, Keith Ross
Pearson/Addison Wesley
April 2016

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Computer Networks

- An interconnected collection of computers that can exchange information
- May be linked through cables, telephone line, radio wave, satellite, etc.
- Most common example: The Internet
- Computer Networks are large → layered architecture used
  - Divide and Conquer approach
  - Modularity
  - Independent layers can be changed without affecting other layers
  - Independent testing of layers

Syllabus

1. Overview of the Internet
2. Application Layer (World Wide Web, e-mail, etc.)
3. Transport Layer (sockets, TCP and UDP)
4. Network Layer (IP addresses and routing)
5. Link Layer (LANs and Ethernet)
6. Wireless and mobile networks
7. Security
8. Rules of Internet usage

Today's lecture

Today's lecture is an overview lecture.

We will discuss the topics in more detail in later lectures.

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

Network

- A network connects devices (nodes) via communication links
- Node: Computer, smartphone, printer, …
- One of the largest networks is the internet
- The Internet is a computer network interconnecting billions of computing devices throughout the world

Internet-connected devices

Amazon Echo

Internet refrigerator

IP picture frame

Pacemaker & Monitor

bikes

cars

Security Camera

Slingbox: remote control cable TV

Web-enabled toaster weather forecaster

AR devices

scooters

Internet phones

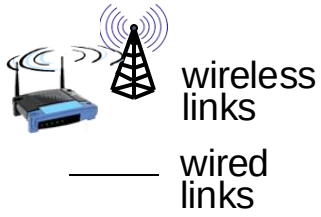
Gaming devices

sensorized, bed mattress

Fitbit

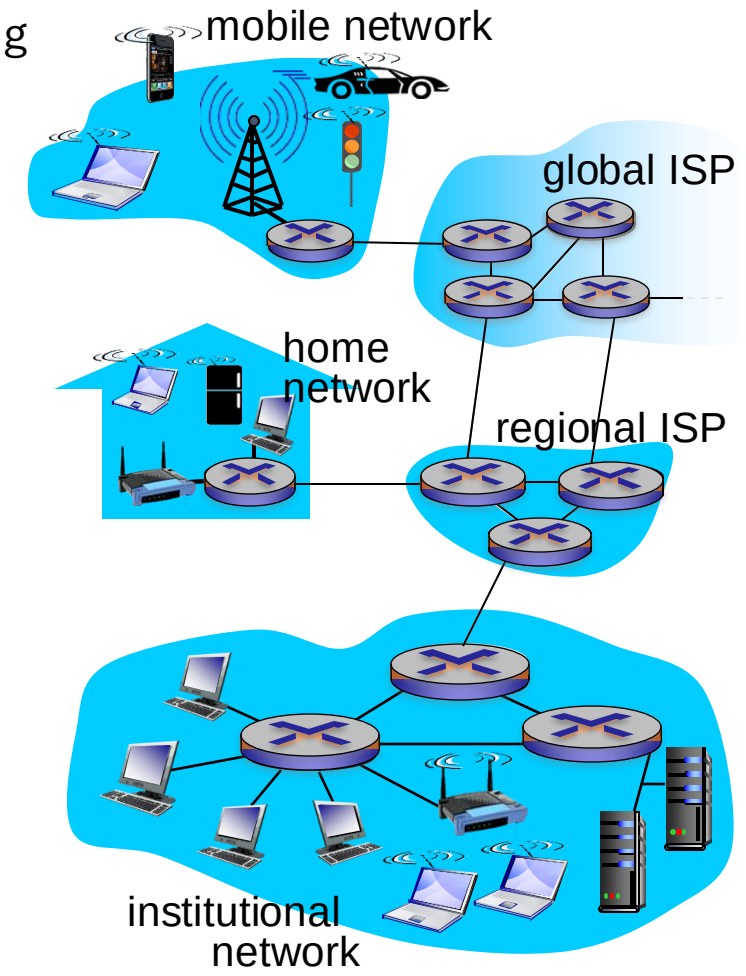
What is the Internet?

- billions 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*



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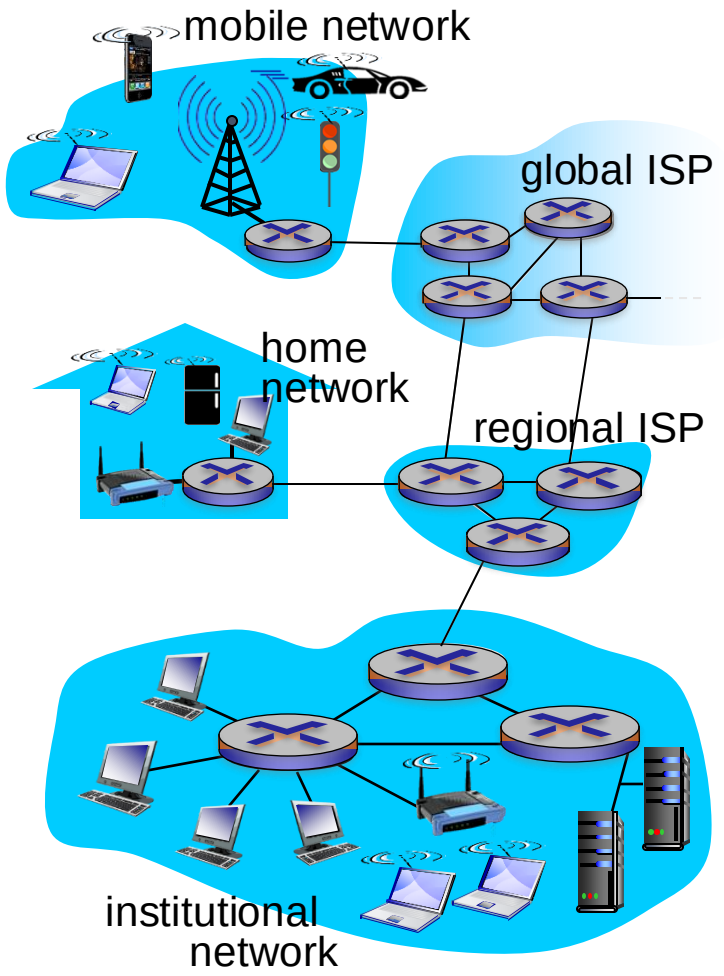
Internet

- Devices connected to the internet are called **hosts** or **end systems.**
- End systems are connected by a network of **communication links** and **packet switches.**
- Transmission rate of a data link is measured in bits/second
- A packet is a segment of data with header bytes
- A packet switch takes an arriving packet and forwards it to one of its outgoing communication links
  - Most prominent: Routers and Link-Layer switches
- The sequence of communication links and packet switches from source to destination is called **route** or **path**

What is the Internet?

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of messages
  - e.g., TCP, IP, HTTP, Skype, 802.11



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Internet Service Provider (ISP)

- End systems access the internet through Internet Service Providers
  - residential ISPs, corporate ISPs, university ISPs, etc.
- Each ISP is a network of packet switches and communication links
- ISPs provide a variety of types of network access
  - Residential broadband access such as DSL
  - High-speed local area network access
  - Mobile wireless access
- ISPs connect Web sites and video servers directly to the internet
- ISPs also must be interconnected

Protocols

human protocols:

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

… specific messages sent

… specific actions taken when messages received, or other events

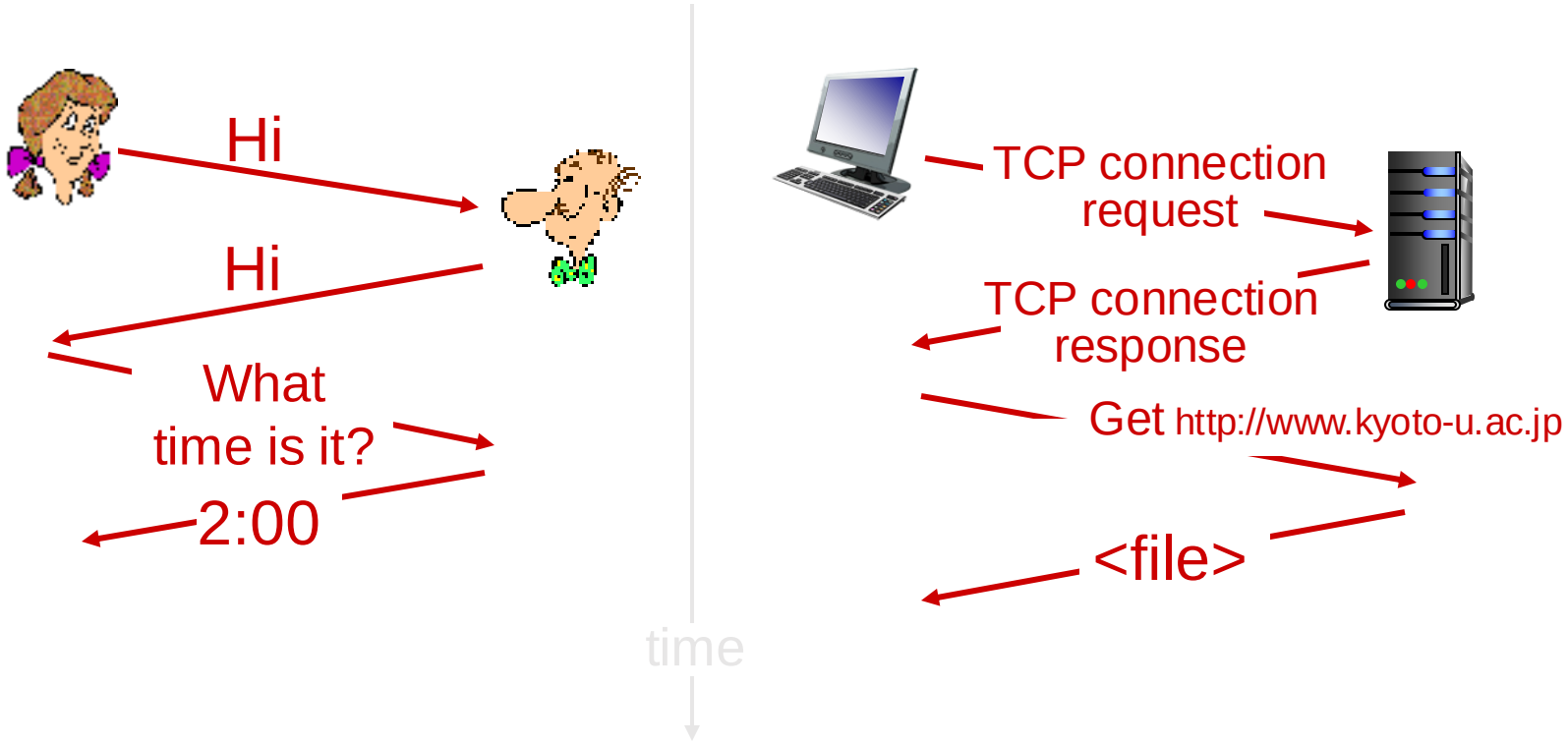
network protocols:

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

protocols define 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:



Protocols

- Protocols are rules for sending and receiving messages.
- To agree on what each protocol does, standards are developed.
- Standards help people to create systems and products that interoperate.
- Internet Standards are developed by the Internet Engineering Task Force (IETF).
- Standard documents are called **request for comments (RFCs).**

Today's lecture

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

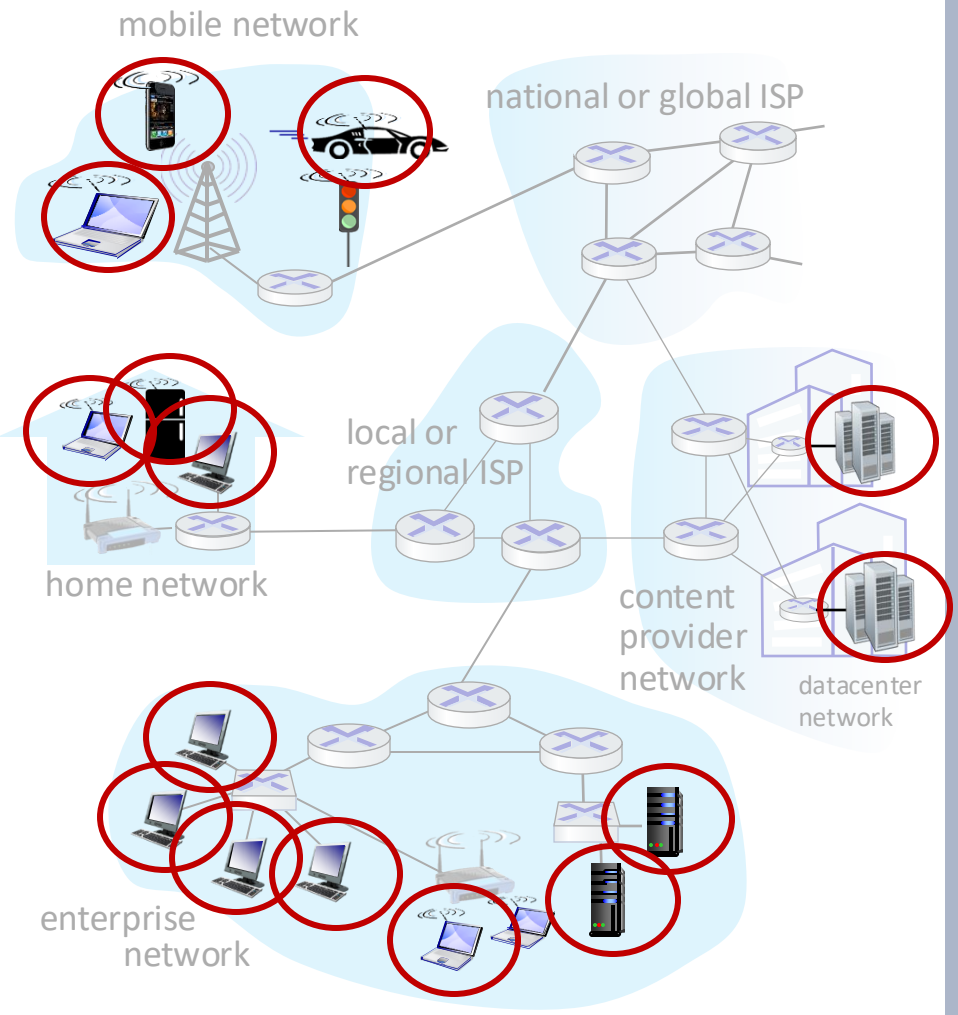
The network edge

- After the high-level overview of the Internet, we are now going to take a deeper look at the components of a network
- We start with the edge of a network – computers, smartphones and other devices that we use daily
- The computers and other devices connected to the Internet are often referred to as end systems.
- They are also referred to as hosts because they host application programs such as Web browsers, Web server programs or e-mail client programs.
- Remember: End-system and host means the same.

A closer look at Internet structure

Network edge:

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



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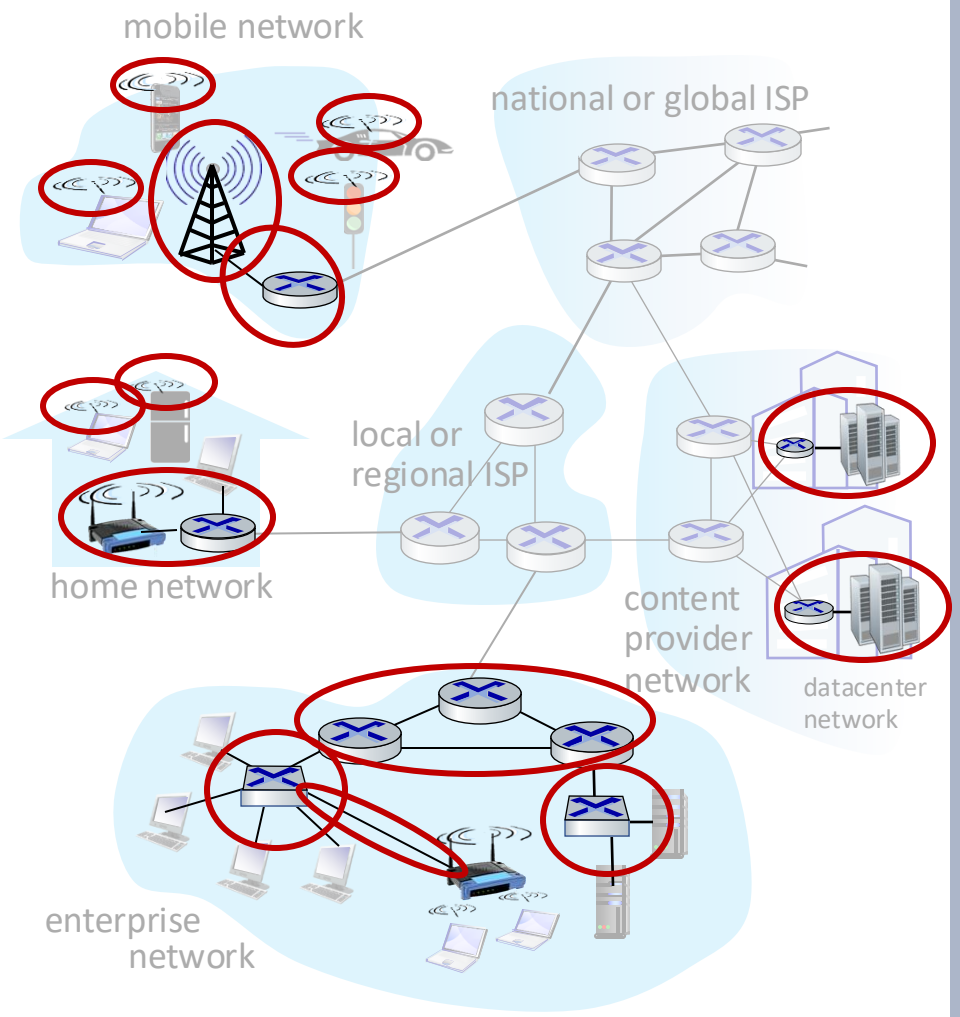
A closer look at Internet structure

Network edge:

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

Access networks, physical media:

- wired, wireless communication links



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A closer look at Internet structure

Network edge:

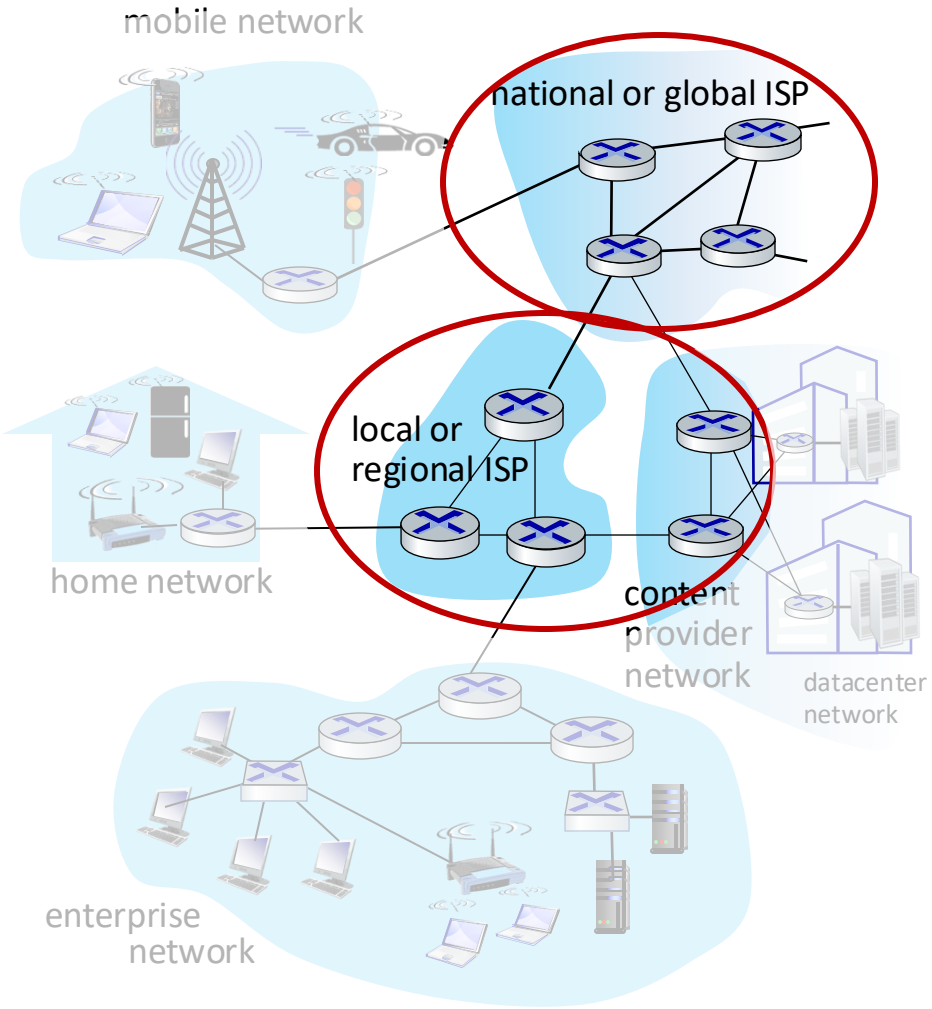
- hosts: clients and servers
- servers often in data centers

Access networks, physical media:

- wired, wireless communication links

Network core:

- interconnected routers
- network of networks



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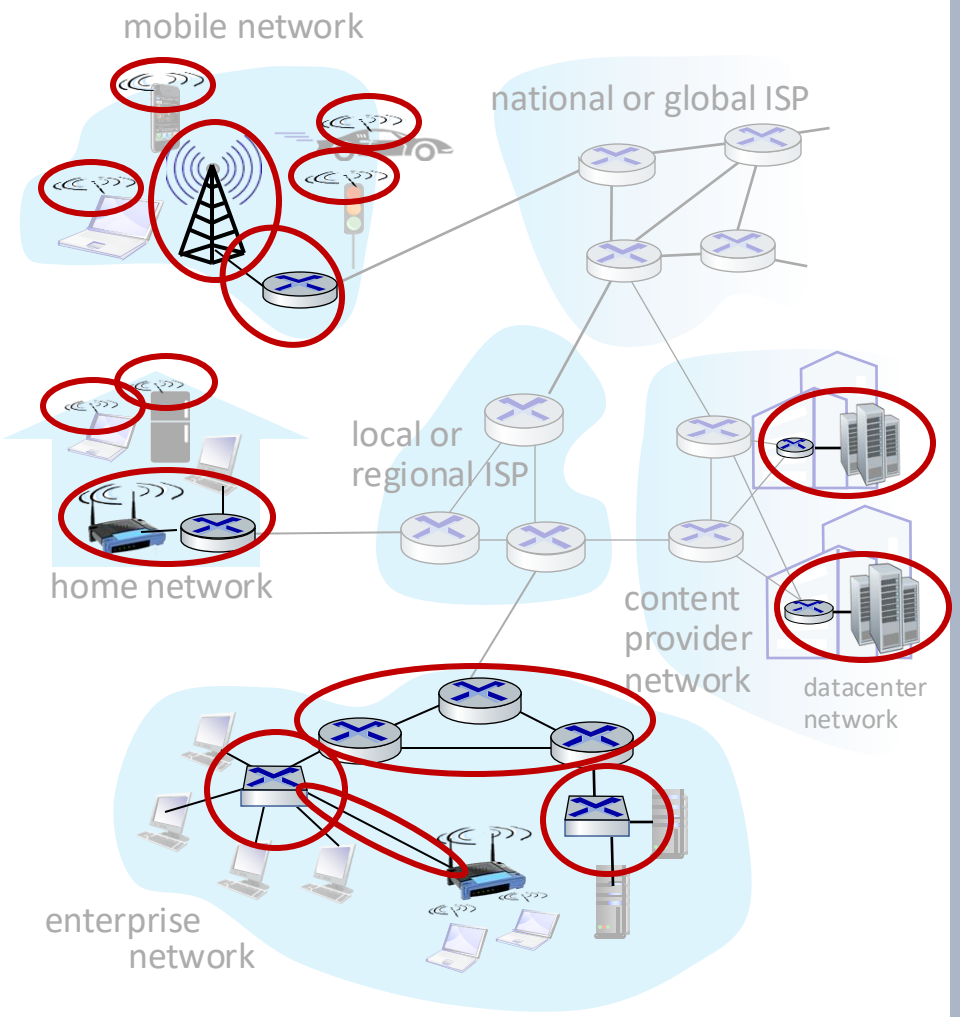
The network edge

- End systems (hosts) run application programs
- Hosts are divided into two types: **clients** and **servers**
- Clients are desktop PCs, laptops, smartphones, …
- Servers are more powerful machines that store and distribute web pages, stream video, relay e-mail, and so on.
- **Access networks** physically connect an end system to the first router

Access networks and physical media

How to connect end systems to the first router on a path from an end-system to another distant end-system?

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



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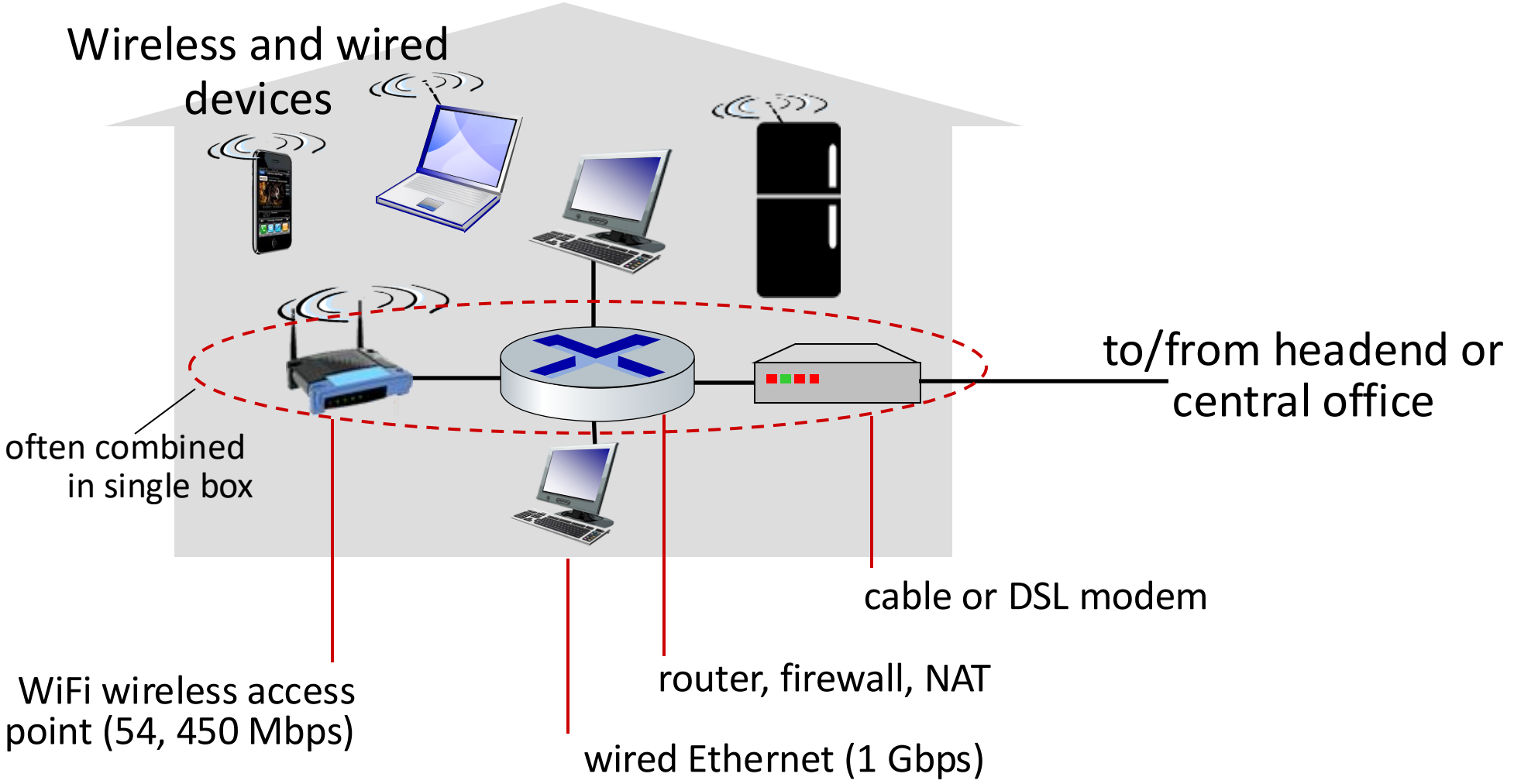
Access networks: home networks



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Home network

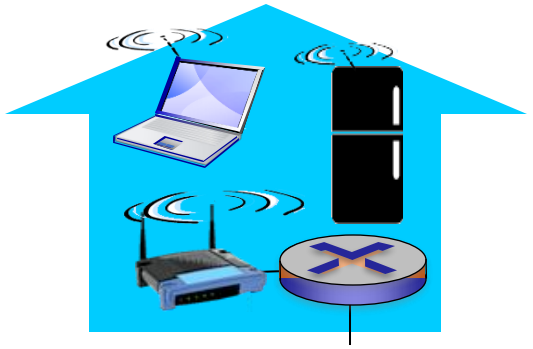
- A home network is a group of devices (computers, game consoles, printers, cell phones, etc.) that are connected to each other and to the internet.
- The router connects the devices to each other and the internet.
- The modem (often integrated in the router) connects the home network to the internet service provider.

Wireless access networks

- shared *wireless* access network connects end system to router
  - via base station aka “access point”

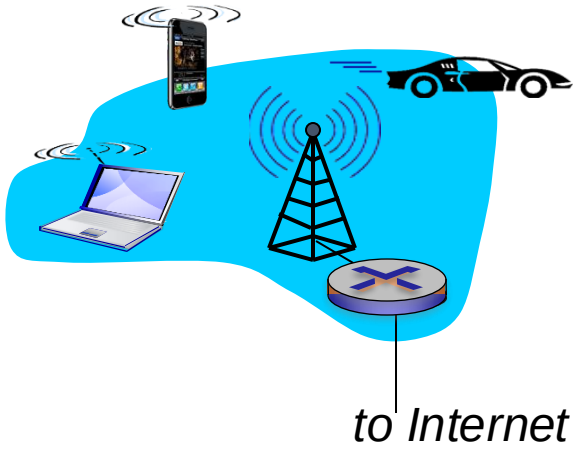
wireless LANs:

- within building



wide-area wireless access

- provided by telecommunication operator, 10’s km
- 3G, 4G, 5G



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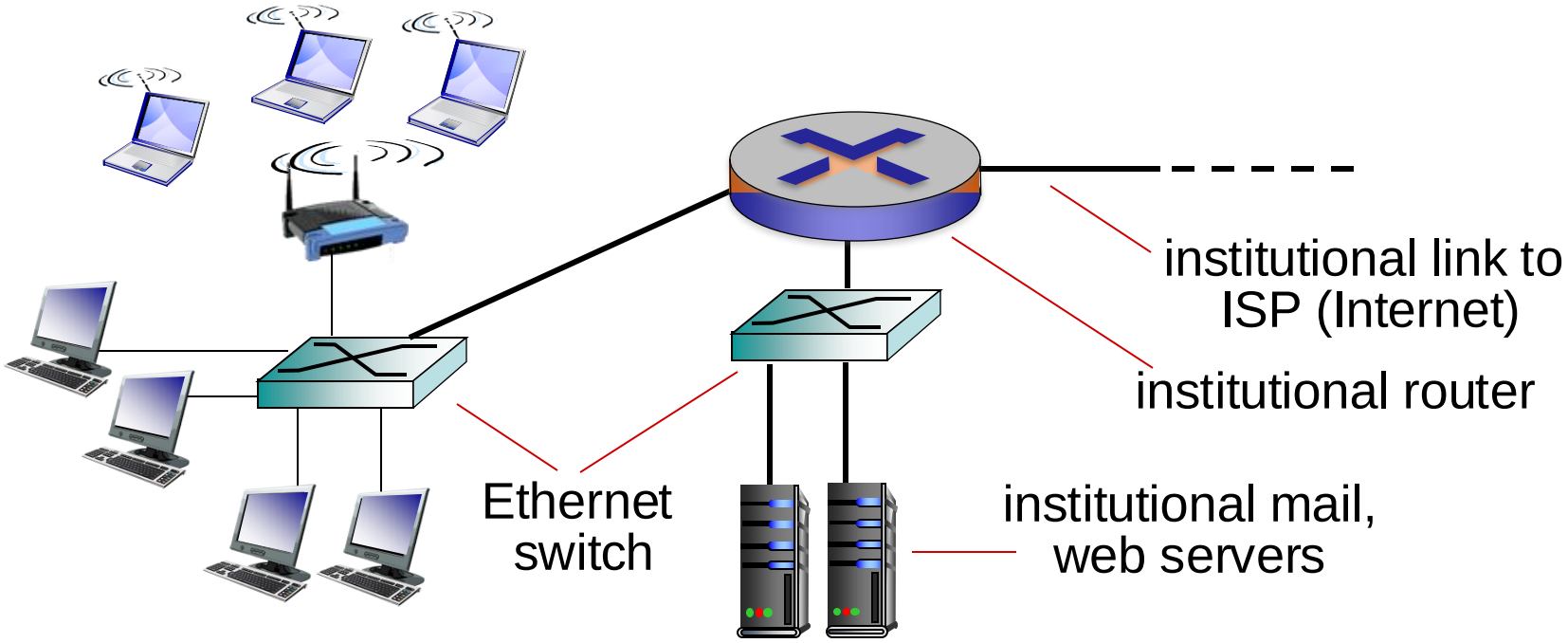
Wireless network

- Wireless networks use wireless data connection between the devices in the network.
- Wireless Local Area Networks (WLAN) use radio waves to connect devices within a building. There usually is at least one cable that connects the router to the internet.
- Wireless Wide Area Networks use more powerful antennas to cover large areas. They are usually provided by telecommunication operators.

Enterprise access networks (Ethernet)



- typically used in companies, universities, etc.
- different transmission rates (e.g. 10 Mbps, 100Mbps, 10Gbps)
- End systems typically connect into Ethernet switch

Physical media

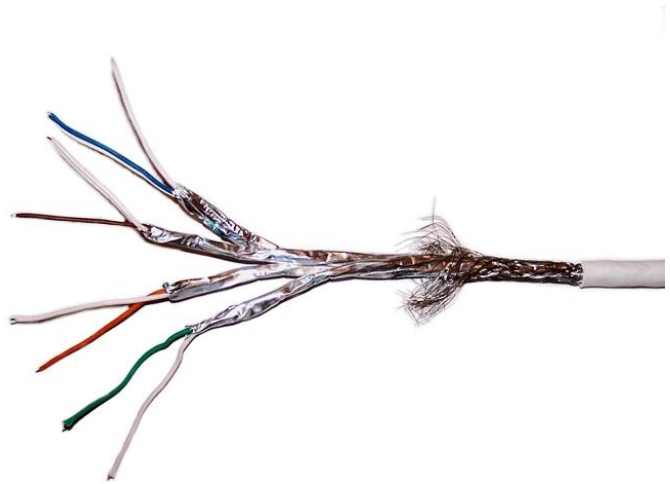
- bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- guided media:
  - signals propagate in solid media: copper, fiber, coax
- unguided media:
  - signals propagate freely, e.g., radio

twisted pair (TP)

- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gbps Ethernet
  - Category 6: 10Gbps

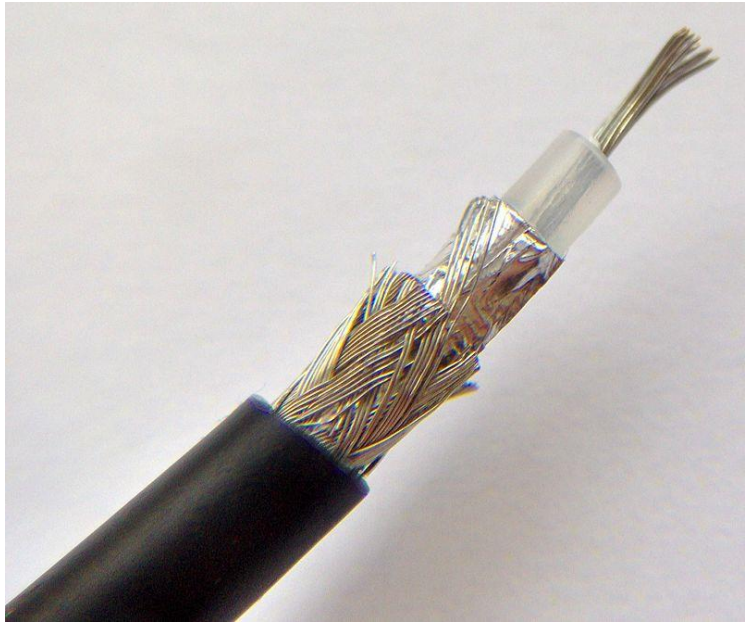
Twisted Pair

- Two insulated copper wires twisted around each other
- Twisting reduces noise
- Often bundled into cables
- Mainly used for telephone signals and low-rate data transmission
- Inexpensive and simple
- Low Bandwidth and sensitive to interference and noise
- Unshielded Twisted Pair (UTP)
- Shielded Twisted Pair (STP)



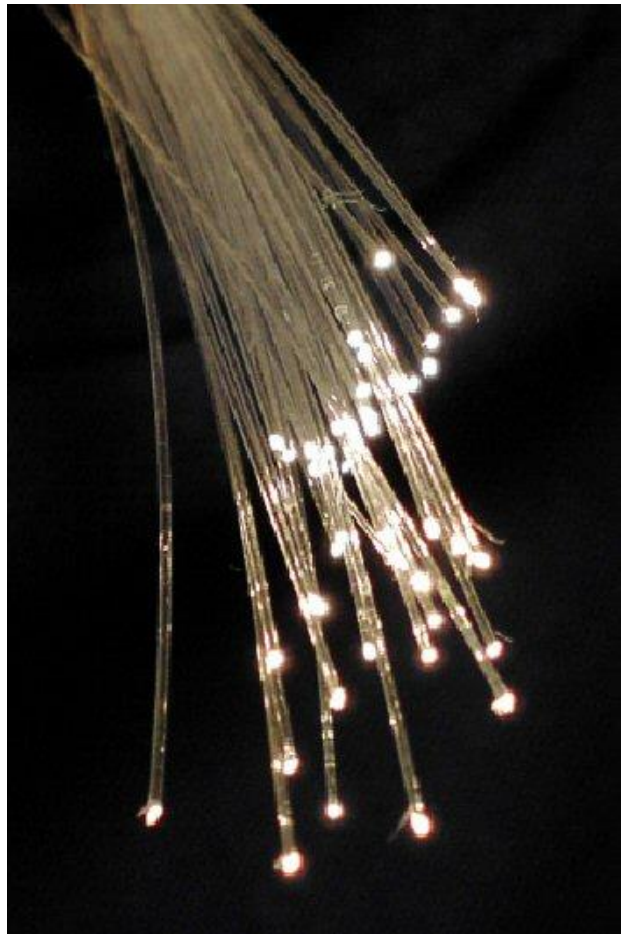
Coaxial Cable

- Outer and inner conductor each separated with insulating material
- Inner conductor is a copper wire, outer conductor is a braided metal shield
- Used for cable television, LAN
- Higher bandwidth
- Less sensitive to interference
- High attenuation
  - Amplifiers/Repeaters needed



Optical Fiber

- Consists of a glass or plastic core that transmits light surrounded by transparent cladding material
- Used for computer networking, especially for long-distance
- Advantages
  - High Bandwidth
  - Less attenuation
  - Immune to interference
- Disadvantages
  - High Cost
  - Fragile
  - Difficult to install



Radio Waves

- Frequencies from 3KHz to 1GHz
- Used for radio and television
- Omnidirectional
- Waves easy to generate
- Can penetrate through buildings and other obstacles
- High attenuation

Microwave

- Frequencies from 1GHz to 300GHz
- Can cut through the ionosphere
- Unidirectional
- Line of sight transmission
- Longer distances
- Used for point-to-point communication, satellite communication, etc.
- High costs for setup and usage

Infrared

- Frequencies from 300GHz to 400THz
- Cannot penetrate through obstacles
- Used for very short-distance communication (TV remote, wireless mouse/keyboard, etc.)
- Low cost
- Use does not need any license

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Today's lecture

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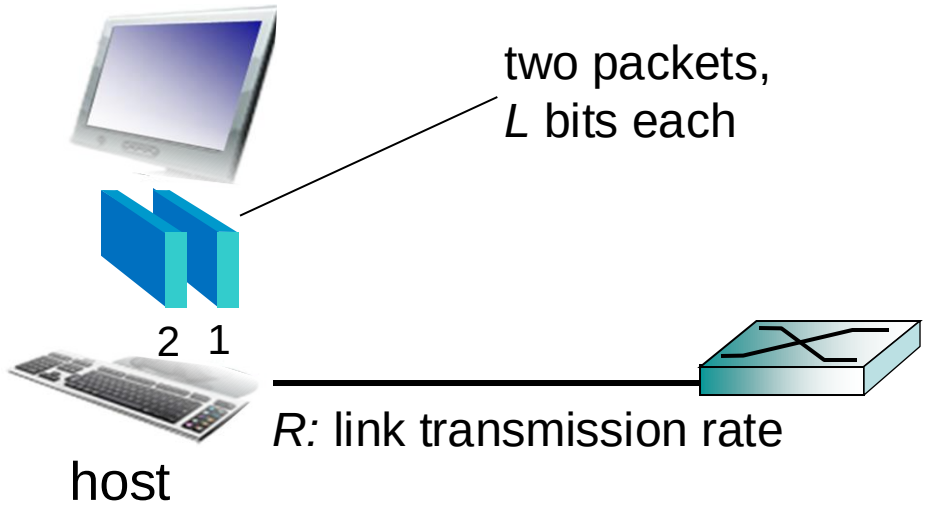
Host: sends *packets* of data

host sending function:

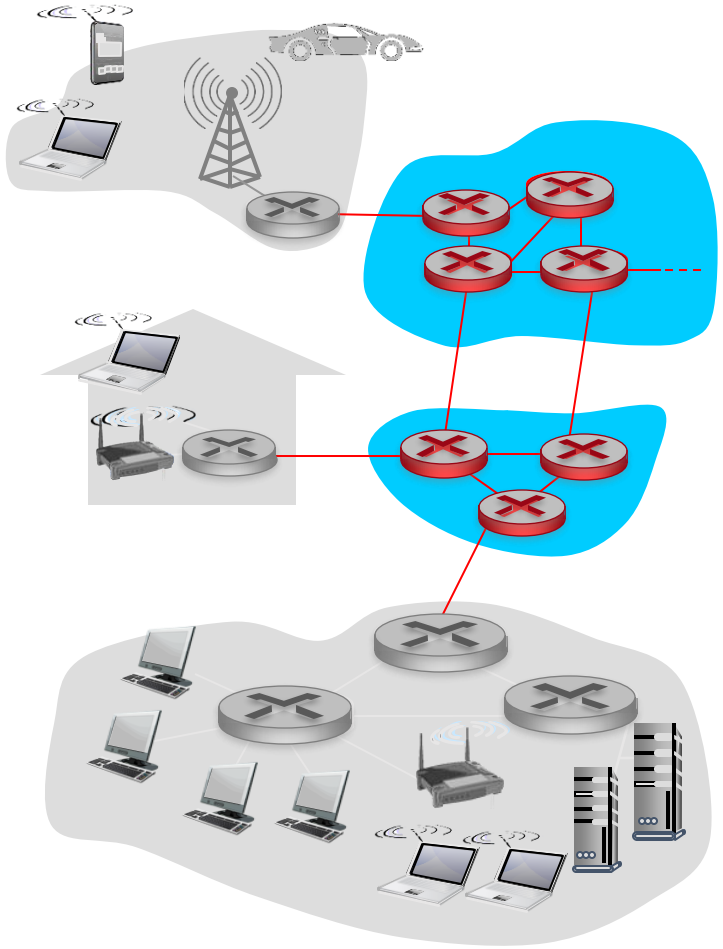
- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate, aka link *capacity, aka link bandwidth*



$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

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

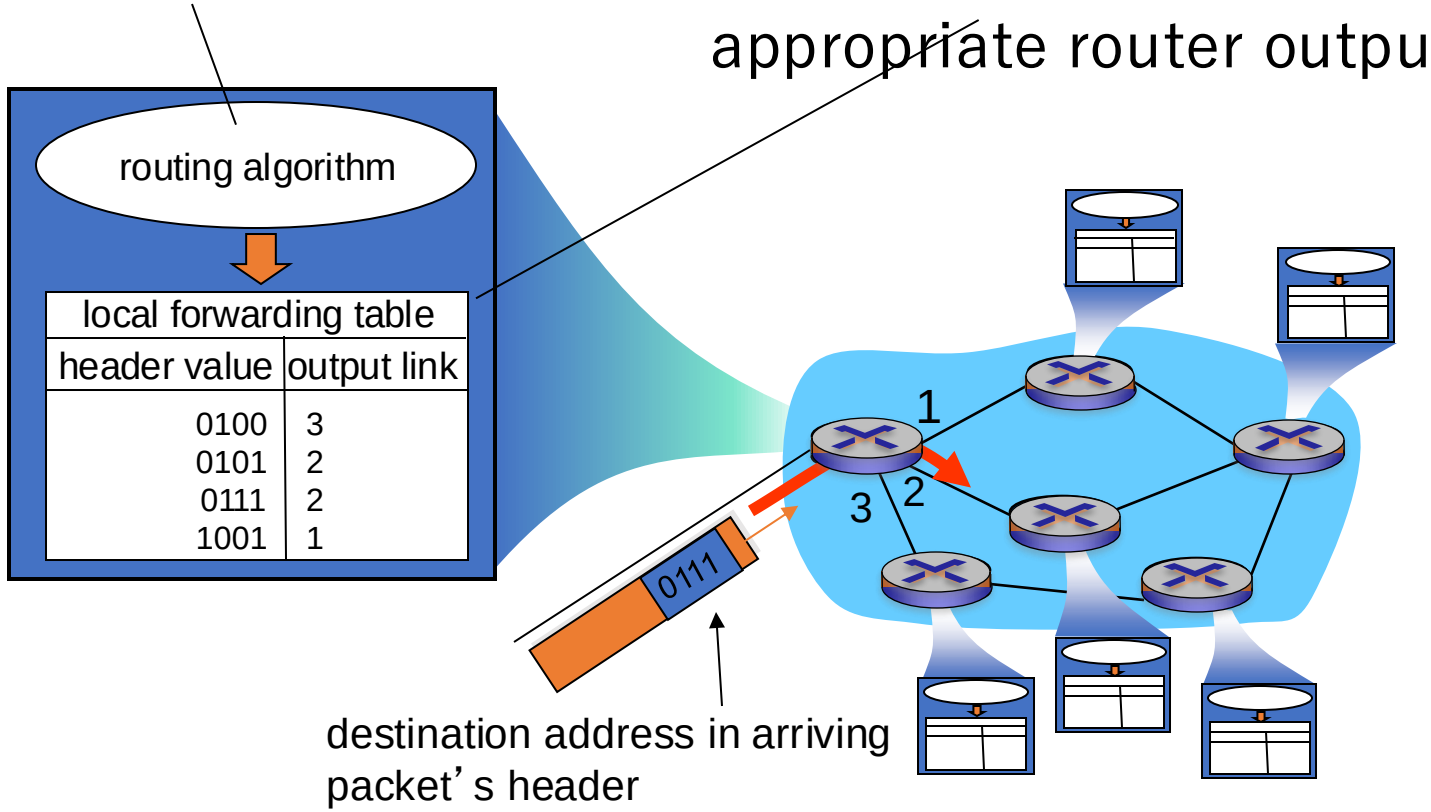


Two key network-core functions

routing: determines source-destination route taken by packets

- *routing algorithms*

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



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routing
45 h
3,053 miles
48 h
3,309 miles
United States
Victoria
Seattle
Portland
San Francisco
San Jose
Sacramento
Las Vegas
Los Angeles
San Diego
Phoenix
Tucson
El Paso
Dallas
Austin
Houston
San Antonio
New Orleans
Kansas City
Minneapolis
Chicago
Detroit
Toronto
Ottawa
Montreal
Quebec City
Northampton
New York
Philadelphia
Indianapolis
Nashville
Charlotte
Atlanta
Jacksonville
Orlando
Tampa
WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
MINNESOTA
IOWA
MISSOURI
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
MARYLAND
DE
NJ
CT
RI
VERMONT
NEW HAMPSHIRE
MAINE
OKLAHOMA
ARKANSAS
TEXAS
LOUISIANA
BAJA CALIFORNIA
SONORA
CHIHUAHUA
COAHUILA

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forwarding
forwarding
45 h
3,053 miles
48 h
3,309 miles
United States
Victoria
Seattle
Portland
WASHINGTON
NORTH DAKOTA
MINNESOTA
SOUTH DAKOTA
Minneapolis
WISCONSIN
MICHIGAN
Toronto
Quebec City
Montreal
Ottawa
MAINE
VERMONT
NEW HAMPSHIRE
Northampton
WYOMING
IOWA
Chicago
Detroit
ILLINOIS
INDIANA
OHIO
Indianapolis
Kansas City
COLORADO
KANSAS
MISSOURI
KENTUCKY
Nashville
TENNESSEE
San Francisco
San Jose
CALIFORNIA
Las Vegas
OKLAHOMA
ARKANSAS
Atlanta
Los Angeles
ARIZONA
NEW MEXICO
Dallas
MISSISSIPPI
ALABAMA
San Diego
Phoenix
Tucson
El Paso
TEXAS
BAJA CALIFORNIA
SONORA
CHIHUAHUA
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LOUISIANA
New Orleans
San Antonio
COAHUILA
Tampa
FLORIDA
Cleveland
DOWNTOWN
CENTRAL
OHIO CITY

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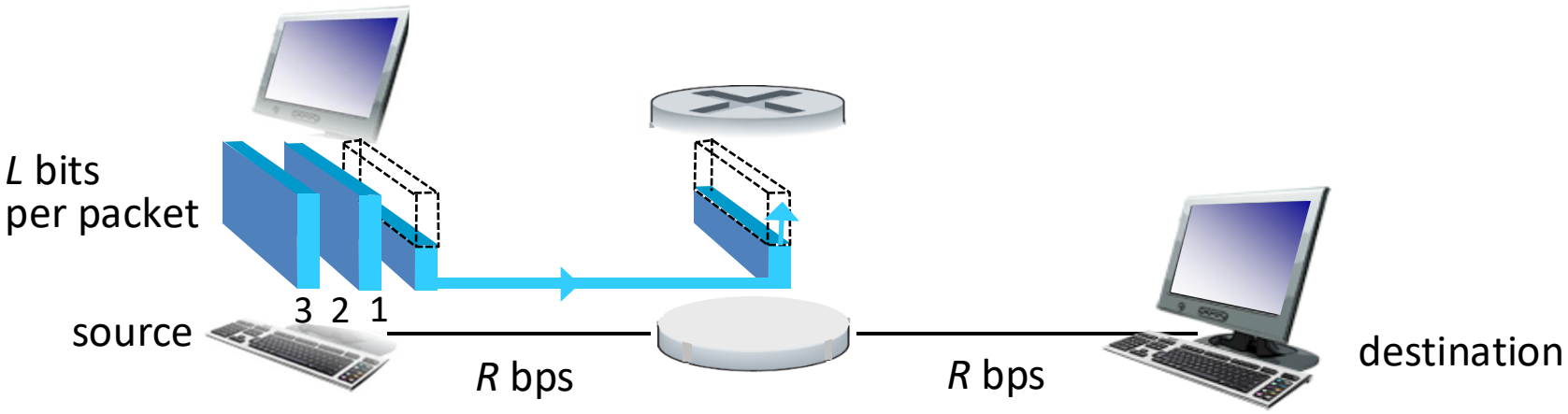
Packet Switching

- End systems exchange messages
- To send a message from source to destination, the source breaks down long messages into packets
- Between source and destination each packet travels through communication links and packet switches
- Packets are transmitted over each communication link at a rate equal to the full transmission rate of the link
- If source end system or packet switch is sending a packet of L bits over a link with transmission rate R bits/s, the time to transmit the packet is L/R seconds.

Packet-switching: store-and-forward



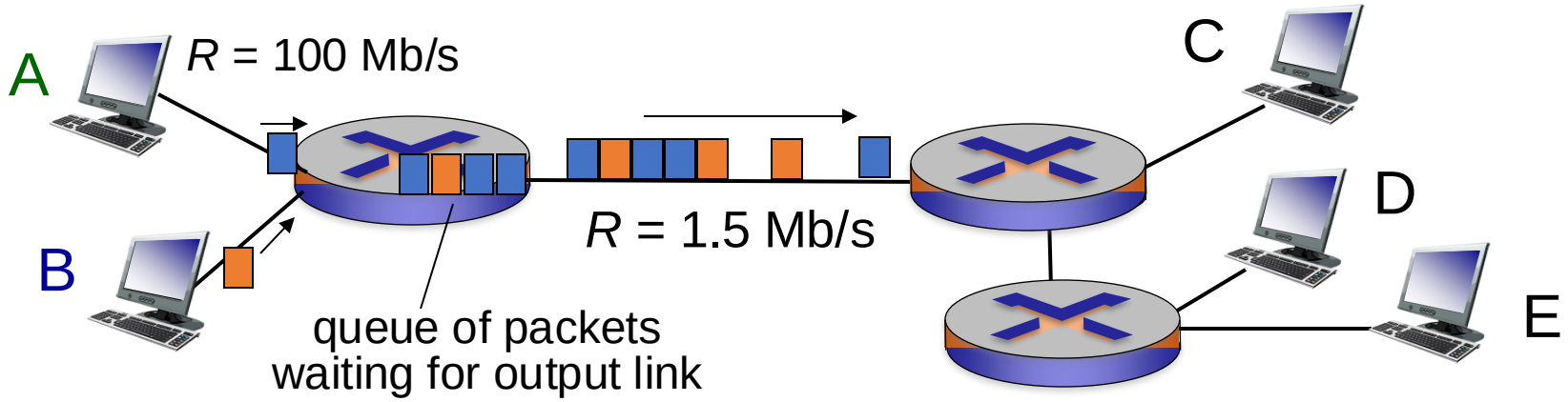
- takes L/R seconds to transmit (push out) L-bit packet into link at R bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link

one-hop numerical example:

- L = 7.5 Mbits
- R = 1.5 Mbps
- one-hop transmission delay = 5 sec

- end-end delay = $2L/R$ (assuming zero propagation delay)

Packet Switching: queueing delay, loss



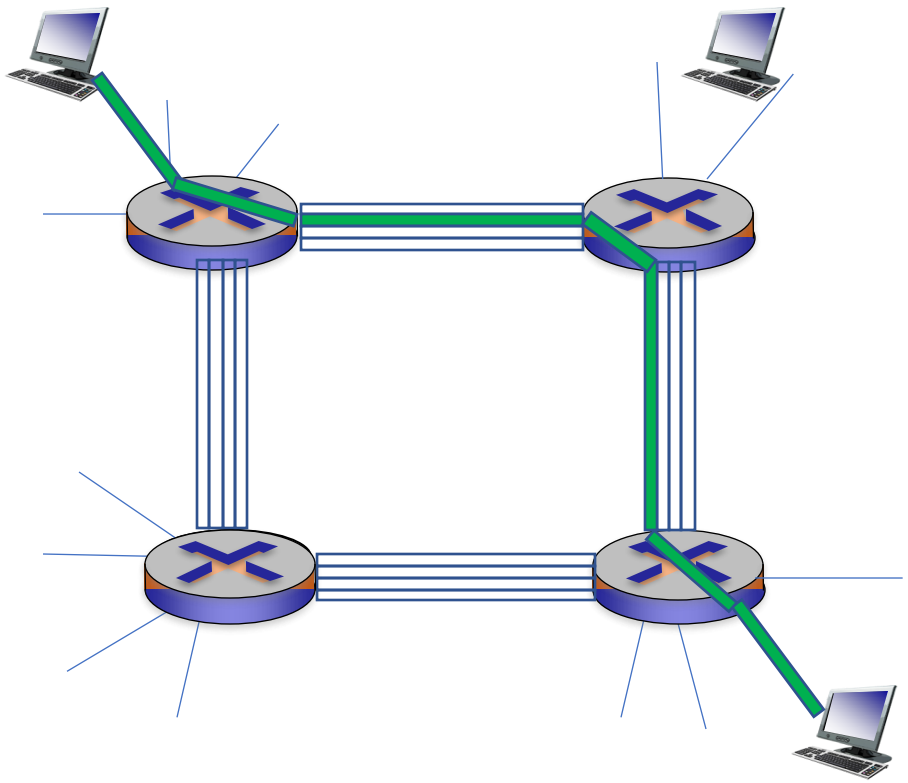
queuing and loss:

- 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

Alternative core: circuit switching

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

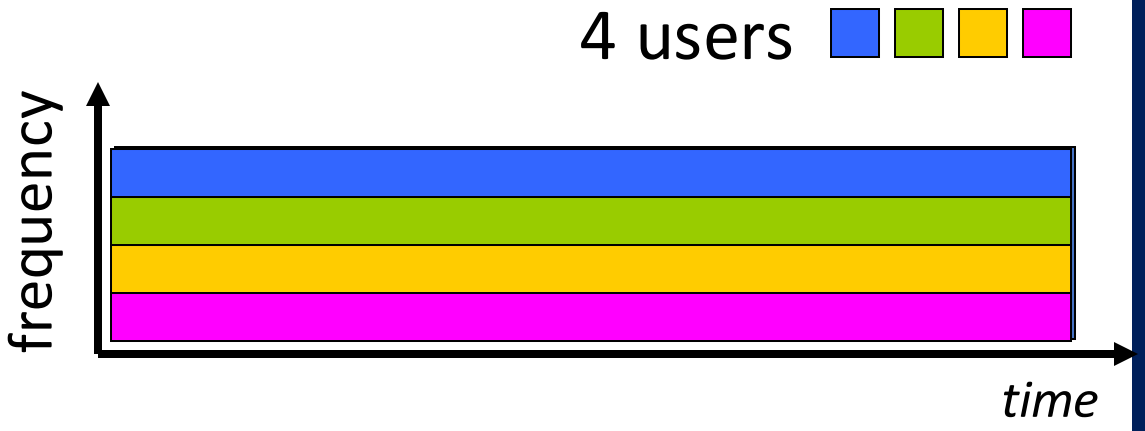
- in diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call *(no sharing)*
- commonly used in traditional telephone networks



Circuit switching: FDM and TDM

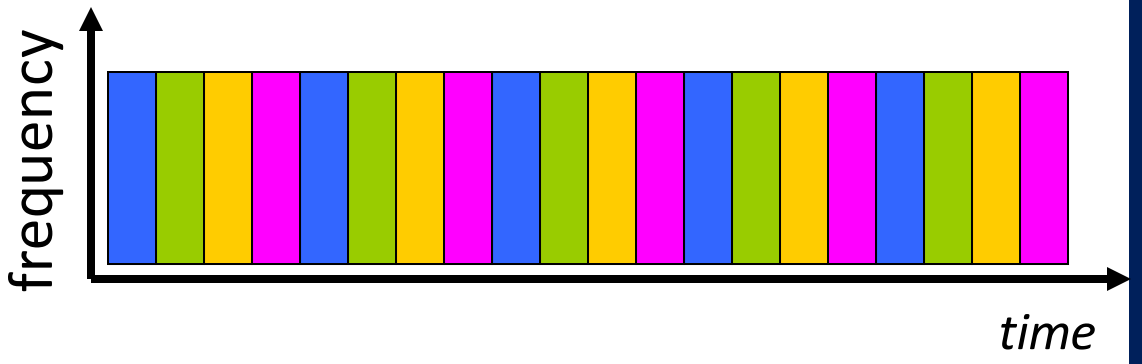
Frequency Division Multiplexing (FDM)

- optical, electromagnetic frequencies divided into (narrow) frequency bands
  - each call allocated its own band, can transmit at max rate of that narrow band



Time Division Multiplexing (TDM)

- time divided into slots
- each call allocated periodic slot(s), can transmit at maximum rate of (wider) frequency band (only) during its time slot(s)



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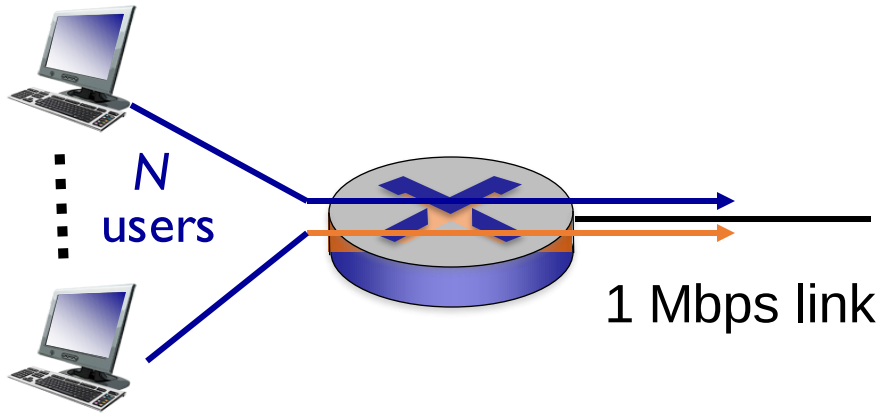
Packet switching versus circuit switching

packet switching allows more users to use network!

example:

- 1 Mb/s link
- each user:
  - 100 kb/s when “active”
  - active 10% of time



- *circuit-switching:*
  - 10 users
- *packet switching:*
  - with 35 users, probability > 10 active at same time is around 0.04%

Packet switching versus circuit switching

Packet switching advantages

- Simple
- Less costly
- Resource sharing

Disadvantages

- protocols needed for reliable data transfer, congestion control
- Packet loss and delay possible

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?

…. or at least our discussion of networks?

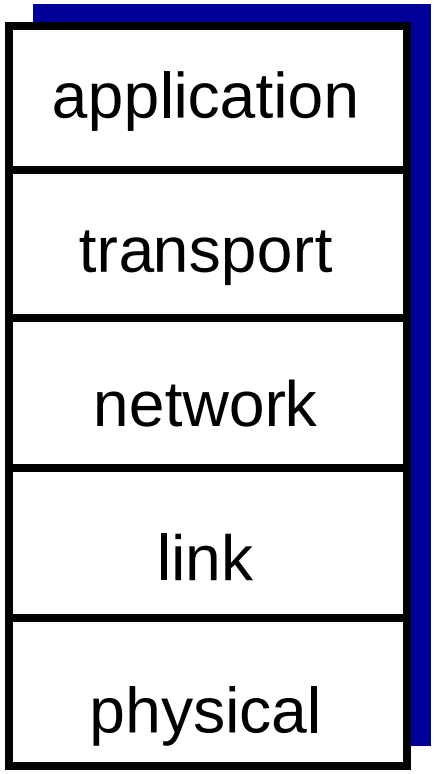
Why layering?

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

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"



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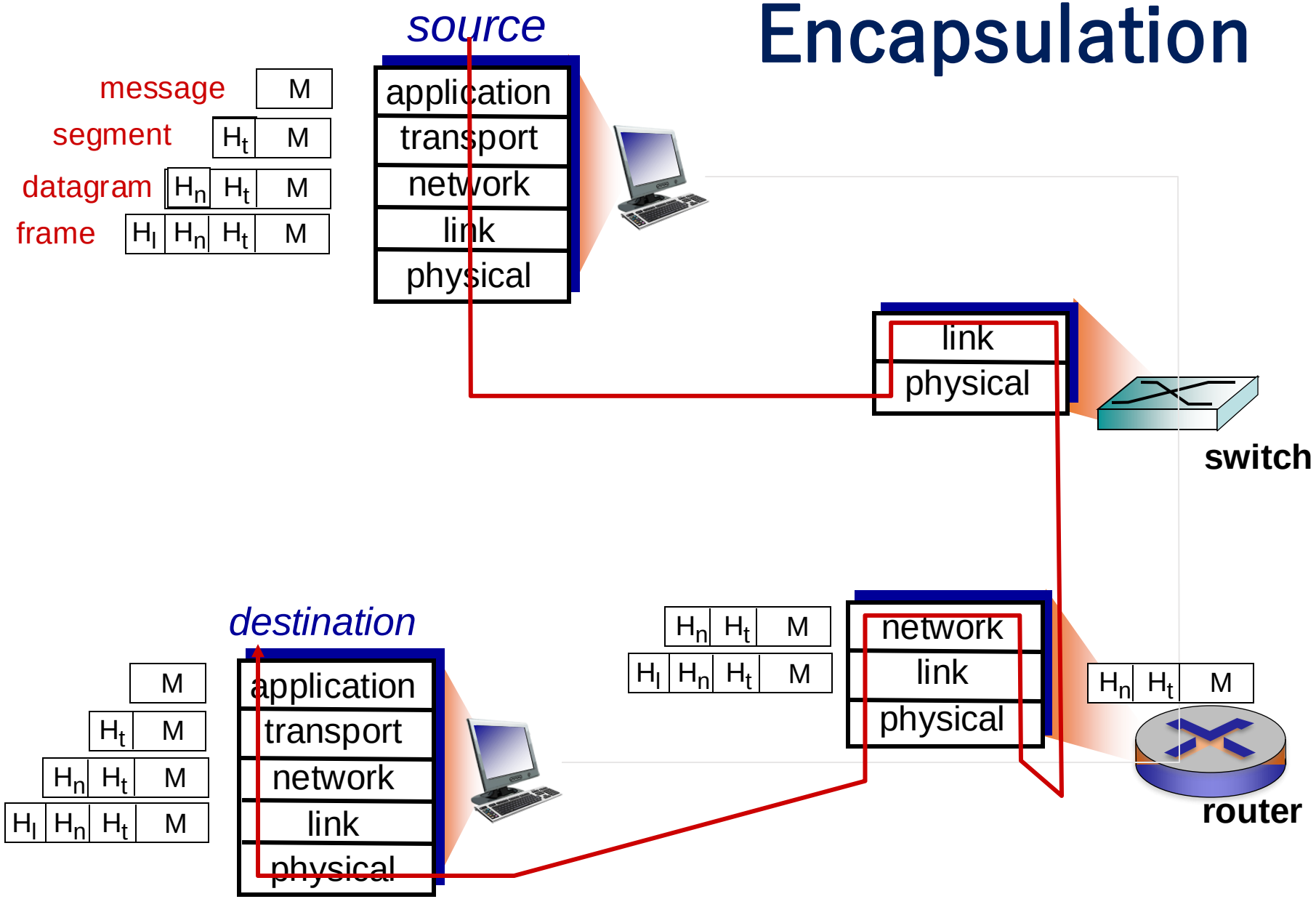
Encapsulation



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