National University of Computer & Emerging Sciences

CS 3001 – COMPUTER NETWORKS

Lecture 02
Chapter 1

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Office Hours: 01:00 pm till 06:00 pm (Every Tuesday & Thursday)

Course Administration

Course Information

Program: BS

Credit Hours: 3+1 (Theory + LAB (Separate Instructor))

Type: Core

Class Meeting Time: Sec 5J & 5K , Tuesday & Thursday 10:00 am till 01:00 pm

Course Website: Google Classroom

Class Venue: CS-8

Prerequisites: CS 218 , CL 218

Instructor Email: nauman.moazzam@lhr.nu.edu.pk

TA Name: TBD

TA Email: TBD

Course Information (Subject to Change)

Assignments: 6 - 7   **(10%)**

Quizzes: 6 - 7   **(15%)**

Midterm / Sessional: 2   **(15% + 15% = 30%)**

Final Exam: 1   **(45%)**

Total: **(100%)**

Grading Policy

Absolute Grading as per Department policy for Core Courses

What is The Internet? (Wikipedia)

The Internet is the global system of interconnected computer networks that uses the Internet protocol suite (TCP/IP) to link devices worldwide. It is a network of networks that consists of private, public, academic, business, and government networks of local to global scope, linked by a broad array of electronic, wireless, and optical networking technologies. The Internet carries a vast range of information resources and services, such as the inter-linked hypertext documents and applications of the World Wide Web (WWW), electronic mail, telephony, and file sharing.
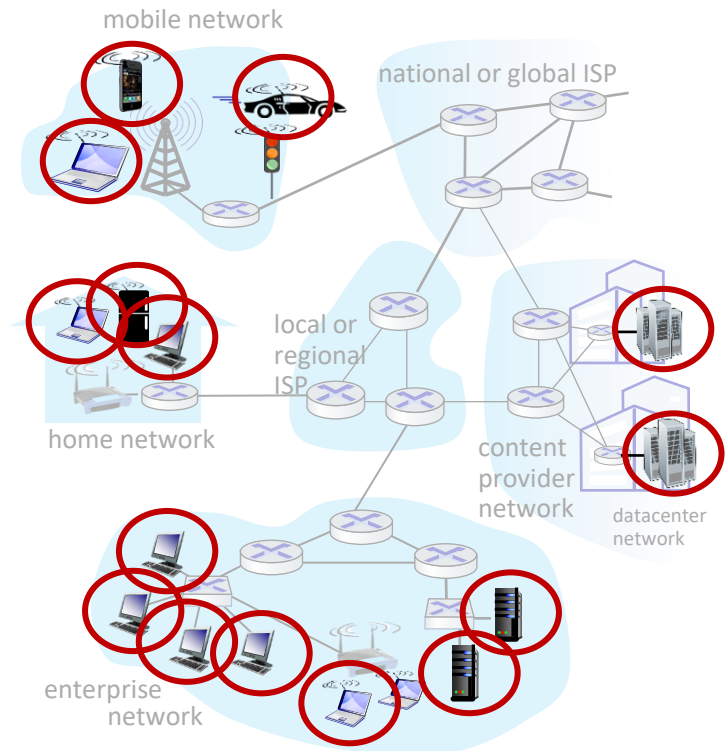
Chapter 1: roadmap

- What *is* the Internet?
- What *is* a protocol?
- **Network edge:** hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History

A closer look at Internet structure

Network edge:

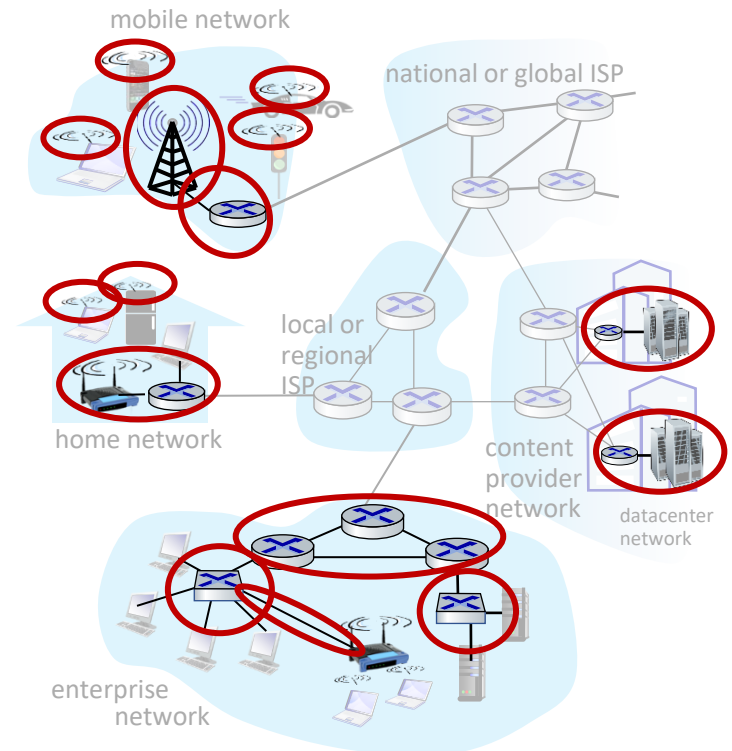- hosts: clients and servers
- servers often in data centers

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

mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

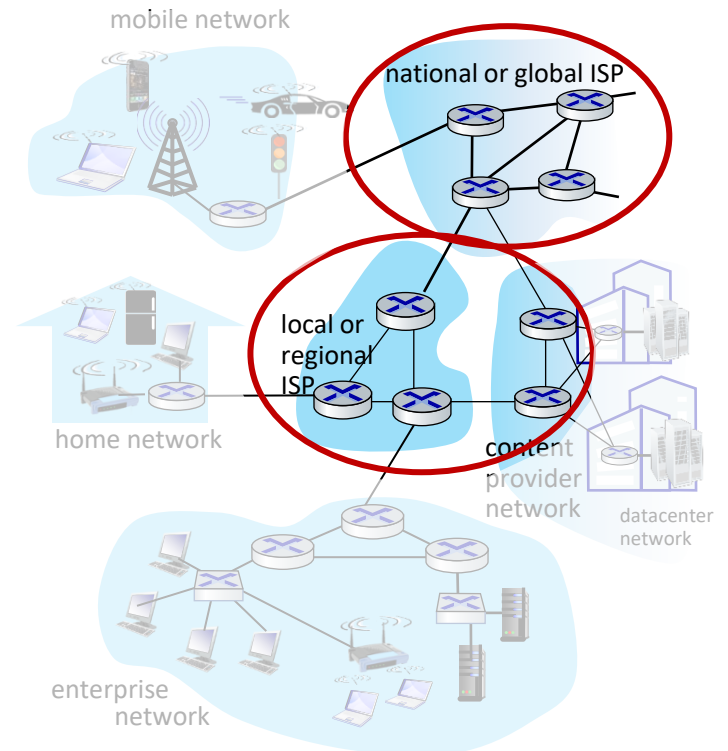# A closer look at Internet structure

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

Access networks, physical media:
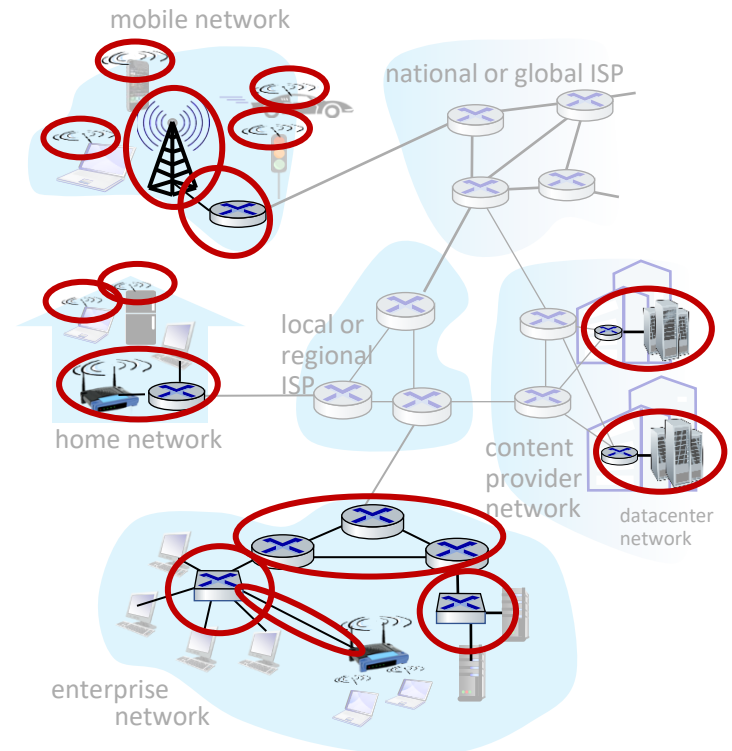- wired, wireless communication links

Network core:
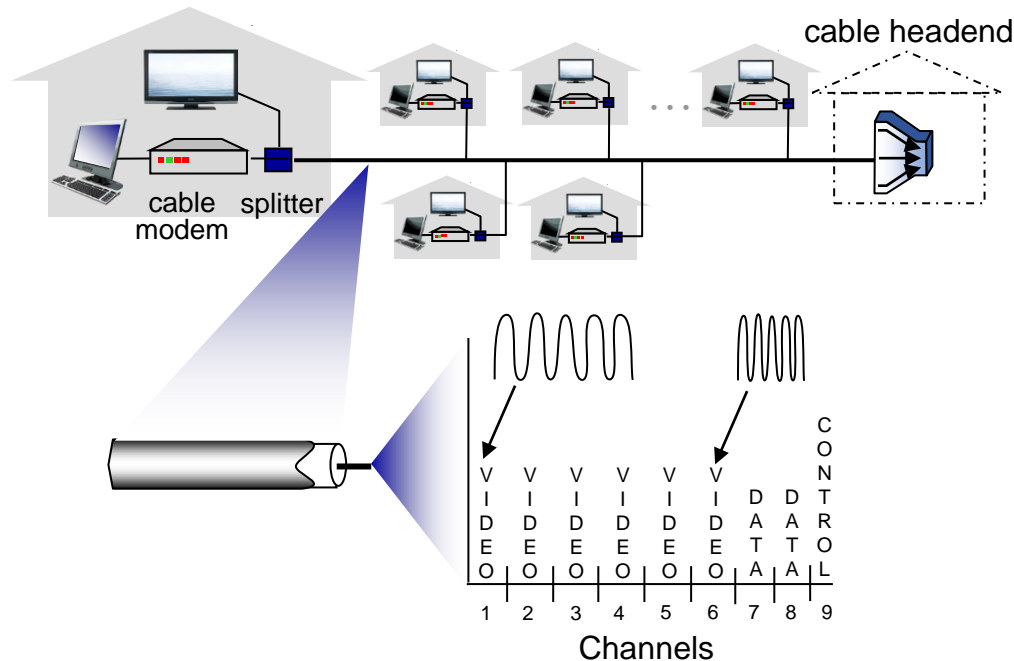- interconnected routers
- network of networks

mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

Access networks and physical media

Q: How to connect end systems to edge router?

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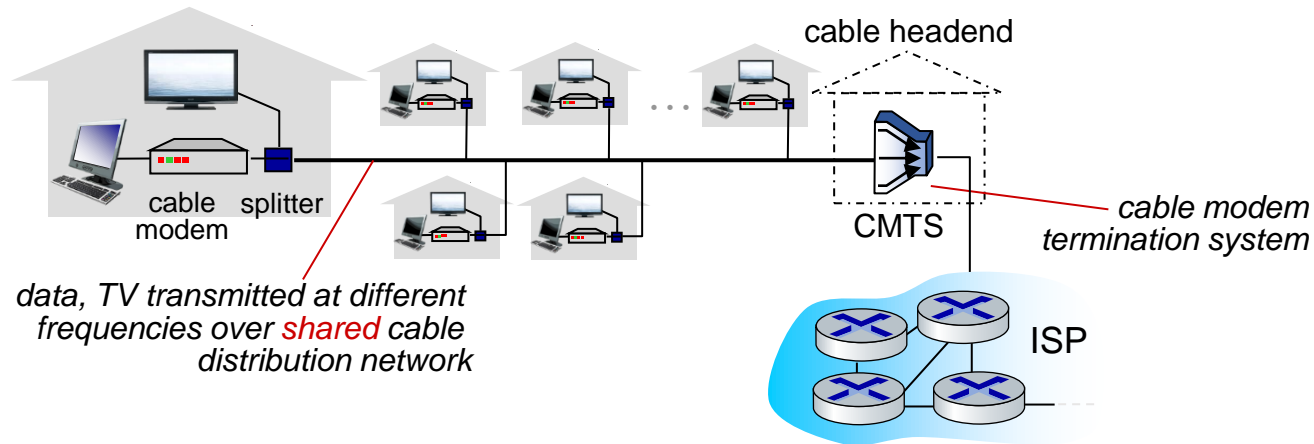- mobile access networks (WiFi, 4G/5G)

mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

Access networks: cable-based access

frequency division multiplexing (FDM): different channels transmitted in different frequency bands

Access networks: cable-based access

cable headend

cable modem
splitter

cable
modem

data, TV transmitted at different frequencies over shared cable distribution network

CMTS

cable modem termination system

ISP

- HFC: hybrid fiber coax
  - asymmetric: up to 40 Mbps – 1.2 Gbps downstream transmission rate, 30-100 Mbps upstream transmission rate
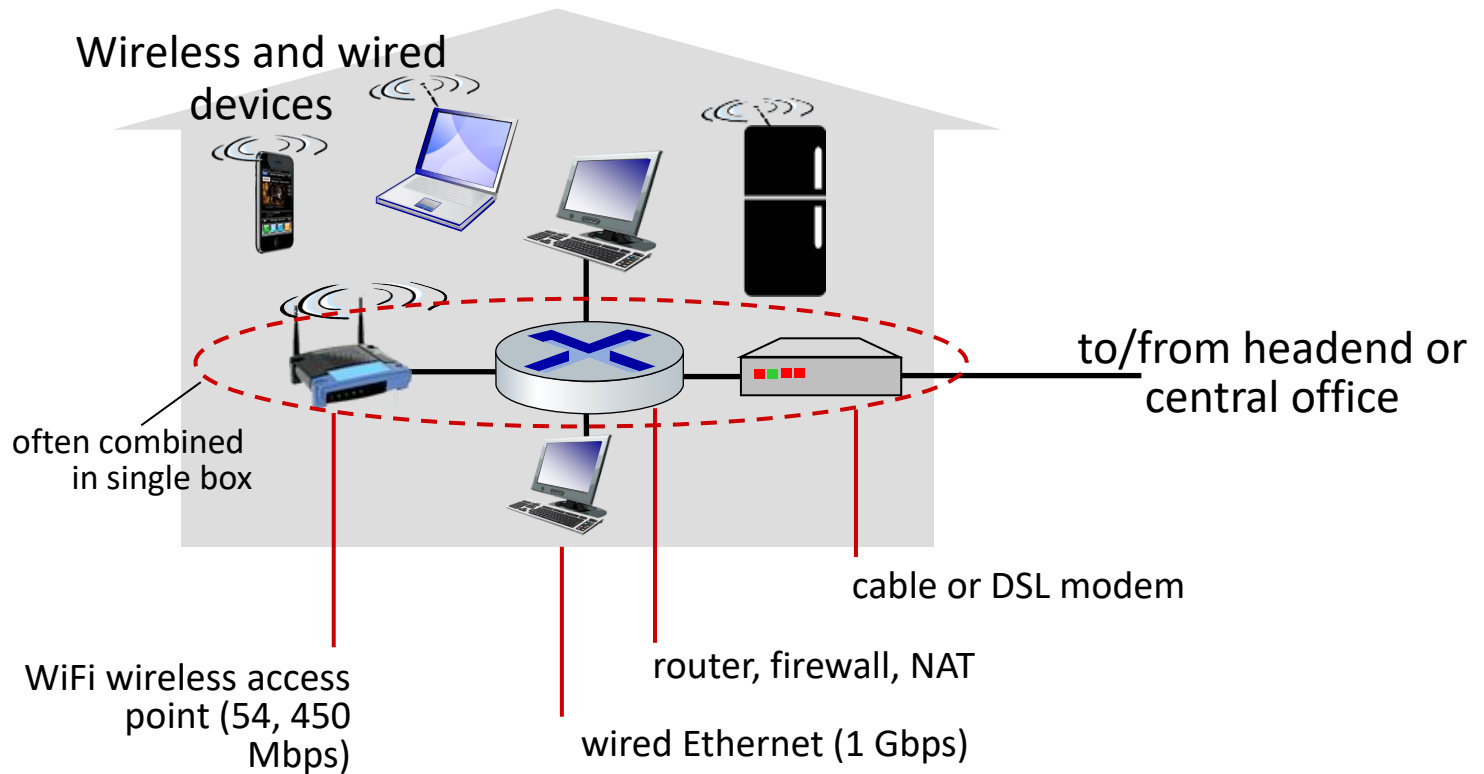- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend

Access networks: digital subscriber line (DSL)

voice, data transmitted at different frequencies over *dedicated* line to central office

DSL access multiplexer
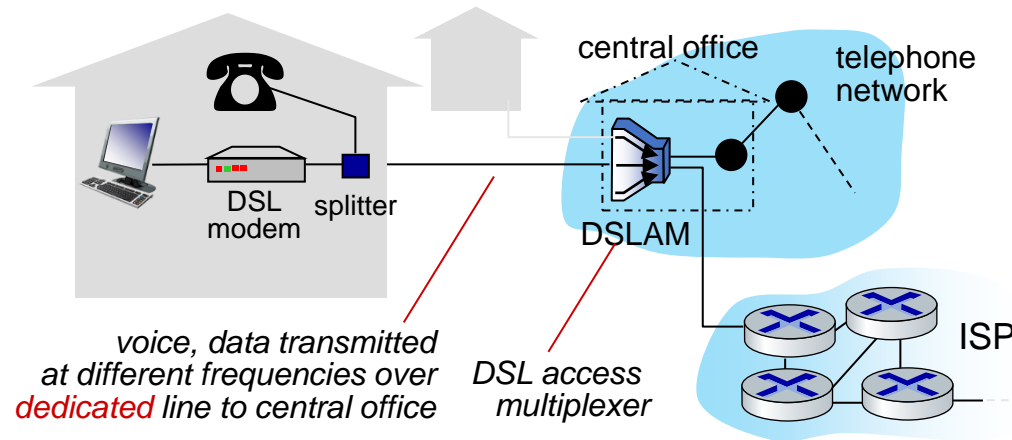
- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- 24-52 Mbps dedicated downstream transmission rate
- 3.5-16 Mbps dedicated upstream transmission rate
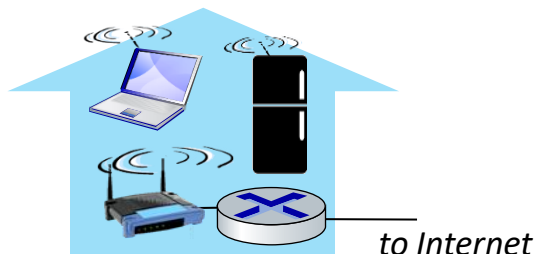
Access networks: home networks

Wireless and wired devices

often combined in single box

WiFi wireless access point (54, 450 Mbps)

wired Ethernet (1 Gbps)

router, firewall, NAT

cable or DSL modem

to/from headend or central office

Wireless access networks

Shared *wireless* access network connects end system to router
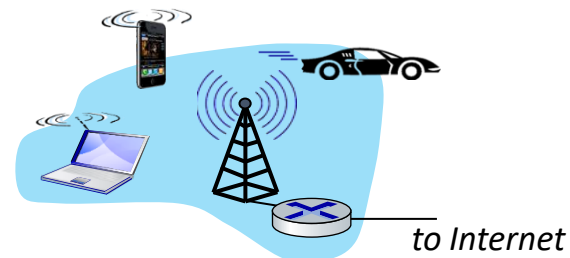
- via base station aka "access point"

Wireless local area networks
(WLANs)

- typically within or around building (~100 ft)
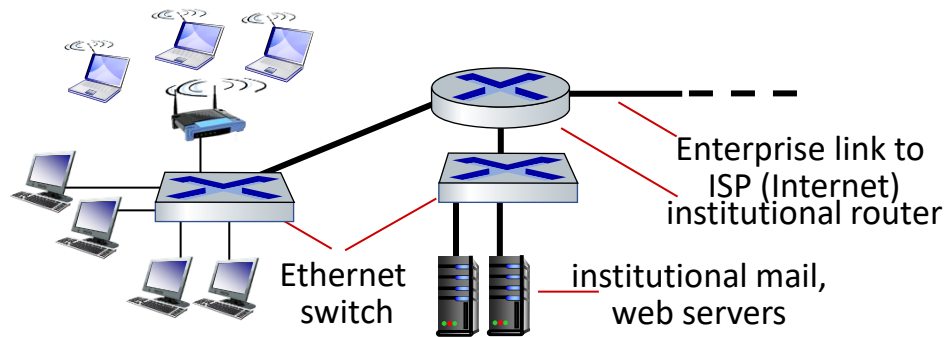- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate

to Internet

Wide-area cellular access networks

- provided by mobile, cellular network operator (10's km)
- 10's Mbps
- 4G/5G cellular networks

to Internet

Access networks: enterprise networks
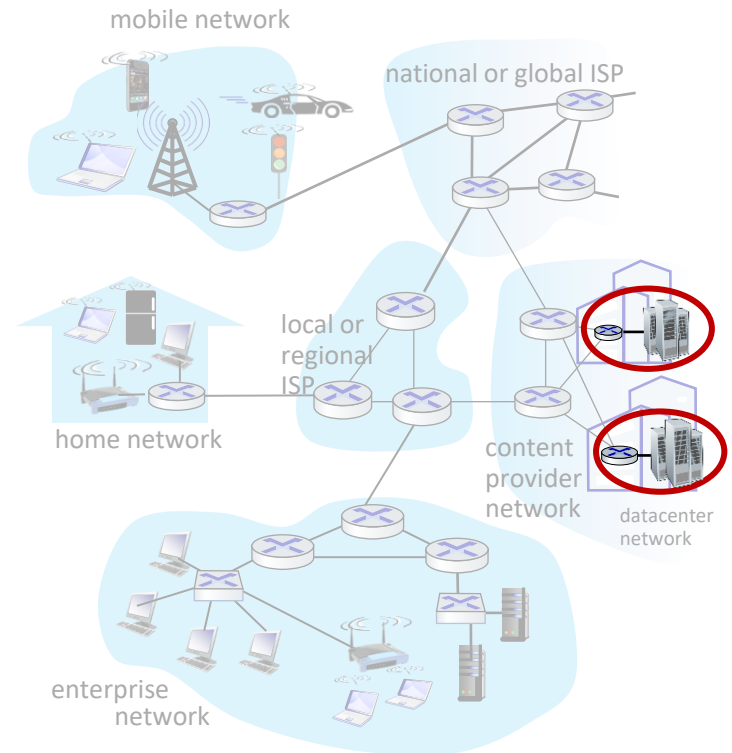

companies, universities, etc.

- 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

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)

mobile network

national or global ISP

local or regional ISP

home network

content provider network

datacenter network

enterprise network

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*

two packets, *L* bits each

host

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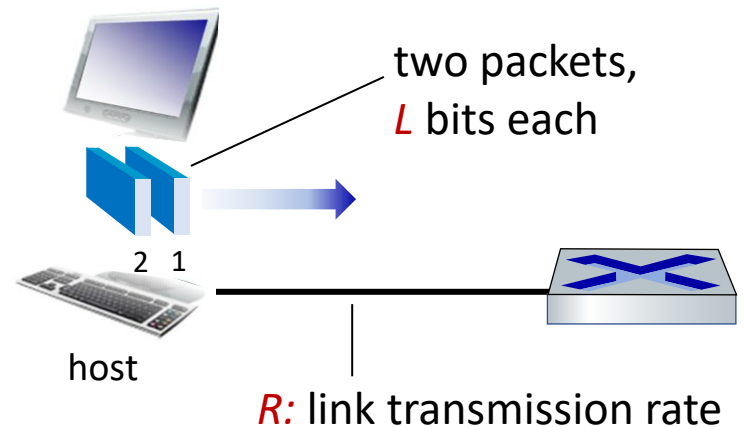
$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

Links: 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 Ethernet
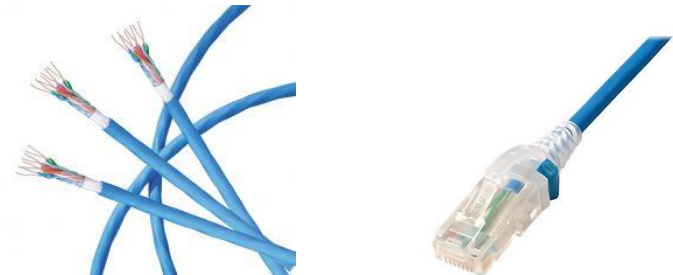
Links: physical media

Coaxial cable:

- two concentric copper conductors

- bidirectional

- broadband:
  - multiple frequency channels on cable
  - 100's Mbps per channel

Fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit

- high-speed operation:
  - high-speed point-to-point transmission (10's-100's Gbps)

- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise

Links: physical media

Wireless radio

- signal carried in various "bands" in electromagnetic spectrum
- no physical "wire"
- broadcast, "half-duplex" (sender to receiver)
- propagation environment effects:
  - reflection
  - obstruction by objects
  - Interference/noise

Radio link types:

- Wireless LAN (WiFi)
  - 10-100's Mbps; 10's of meters
- wide-area (e.g., 4G/5G cellular)
  - 10's Mbps (4G) over ~10 Km
- Bluetooth: cable replacement
  - short distances, limited rates
- terrestrial microwave
  - point-to-point; 45 Mbps channels
- satellite
  - up to < 100 Mbps (Starlink) downlink
  - 270 msec end-end delay (geostationary)