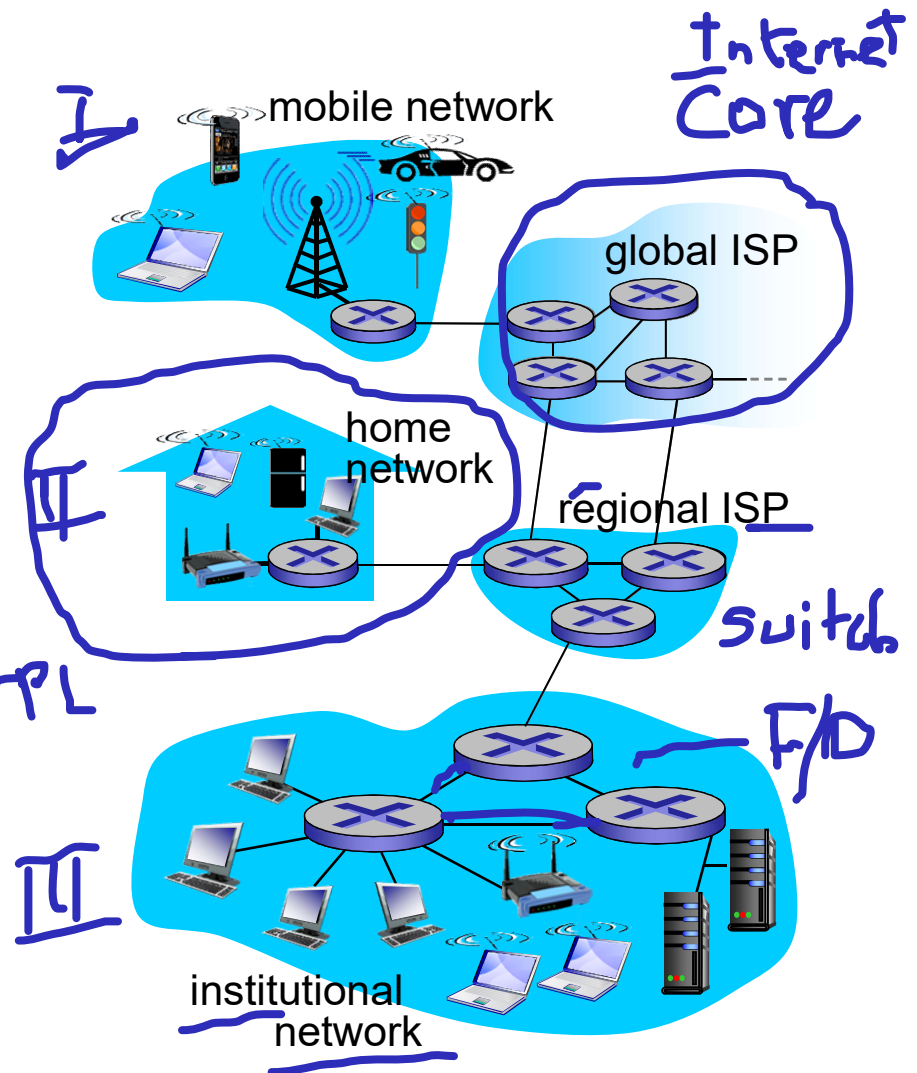


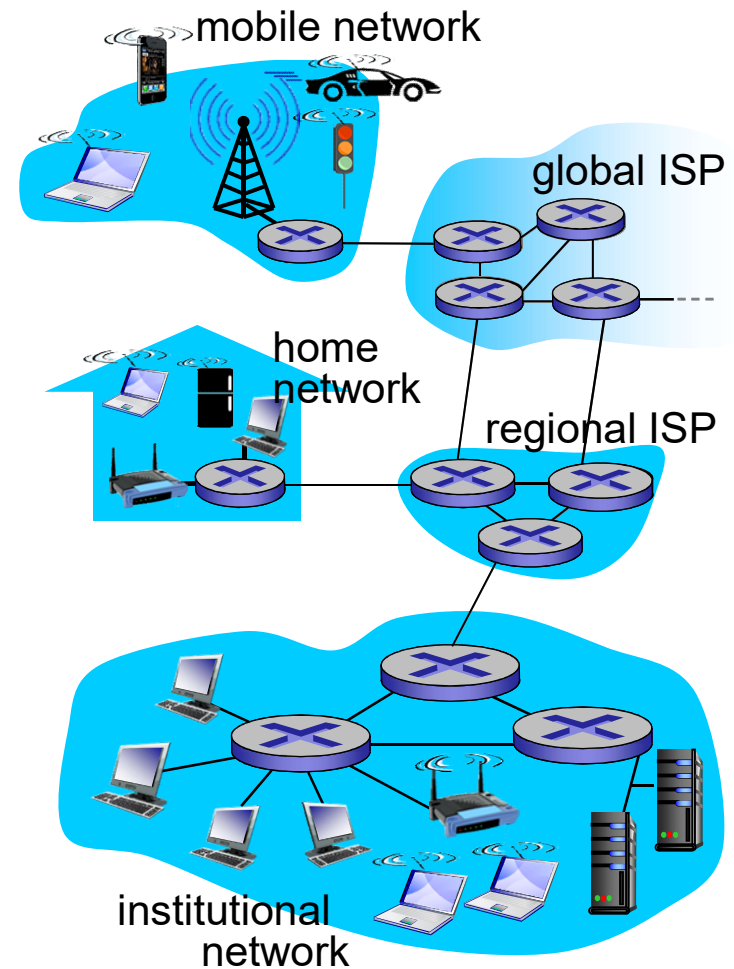
What's the Internet: "nuts and bolts" view

- **Internet: "network of networks"**
 - Interconnected ISPs
- **protocols** control sending, receiving of messages
 - 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 applications:*
 - Web, VoIP, email, games, e-commerce, social nets, ...
- *provides programming interface to apps*
 - hooks that allow sending and receiving app programs to “connect” to Internet
 - provides service options, analogous to postal service



→ SOCKETS Library

What's a protocol?

human protocols: A B

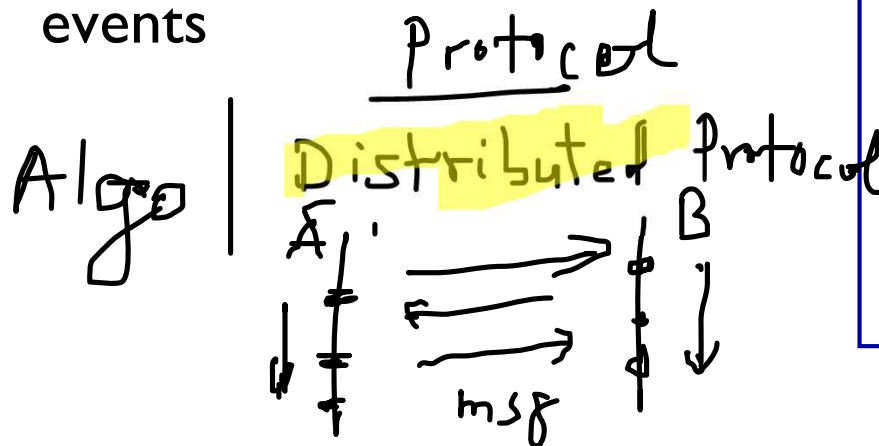
- “what's the time?” →
- “I have a question” {
Time is 8:50
- introductions

network protocols:

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

... specific messages sent

... specific actions taken
when messages
received, or other
events

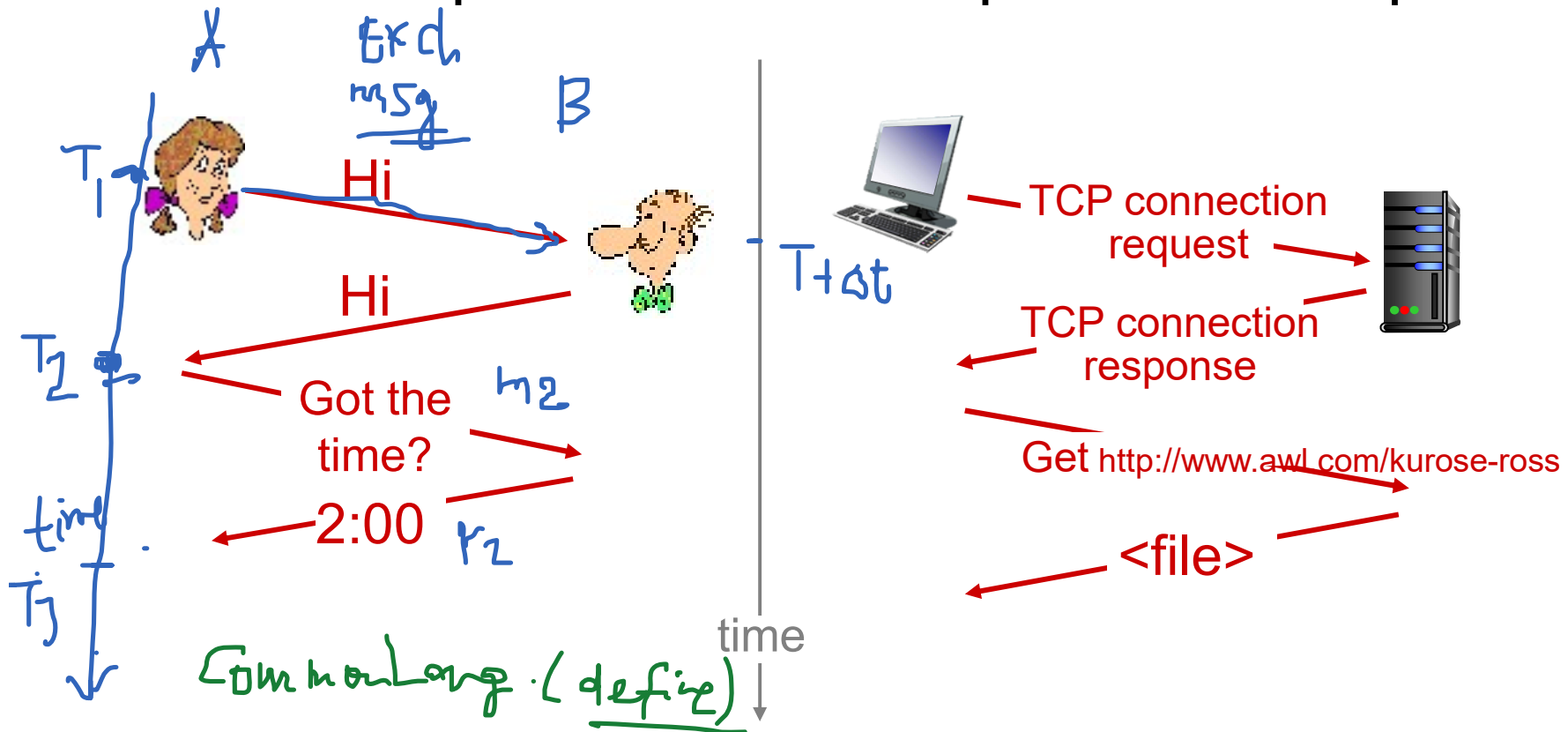


protocols define format, order of messages sent and received among network entities, and actions taken on message transmission, receipt

What's a protocol?

Representation

a human protocol and a computer network protocol:



Q: other human protocols?

Access networks and physical media

Q: How to connect end systems to edge router?

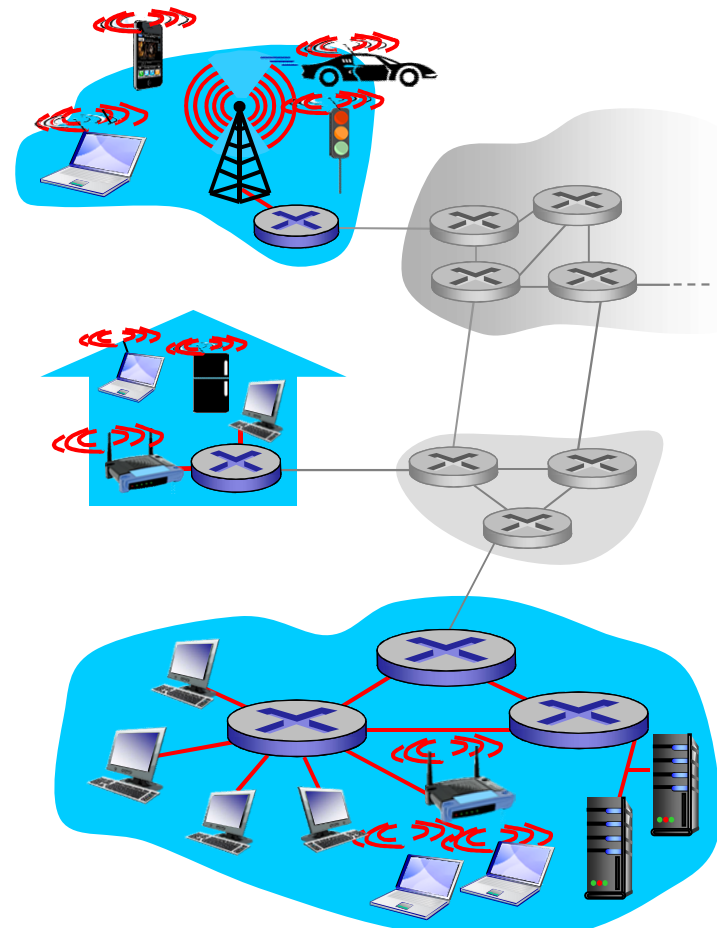
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

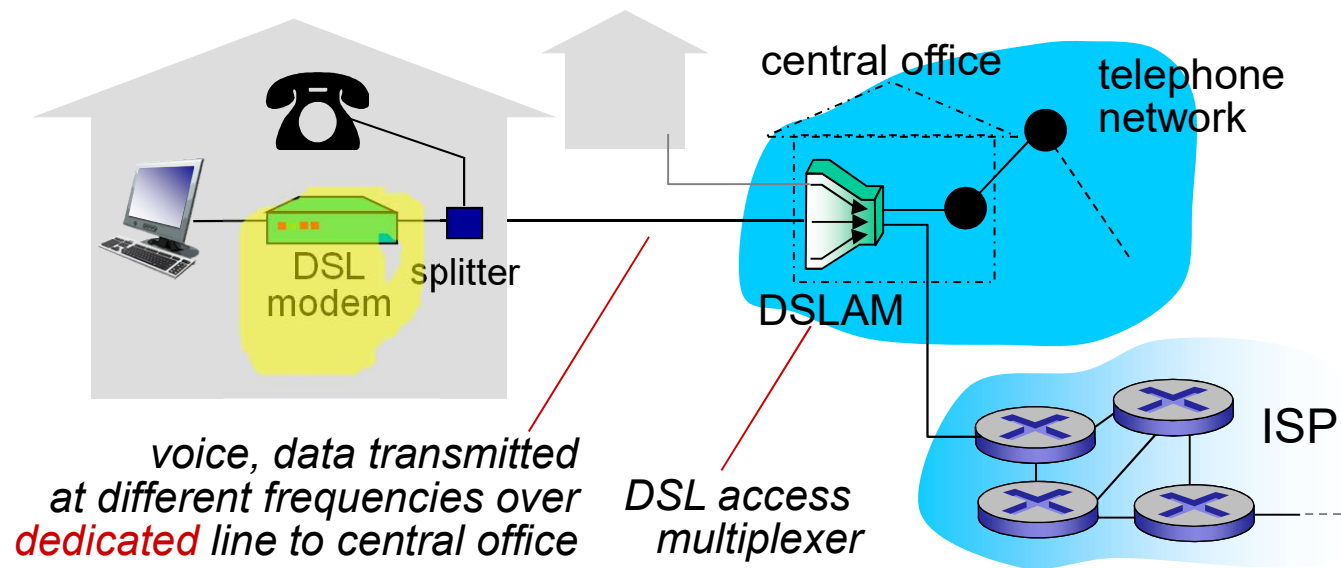
- bandwidth (bits per second) of access network?
- shared or dedicated?

Router, Switch, Hub,

Repeaters - [Copper Cables - CAT5, UTP
Fiber Optic Cable -]

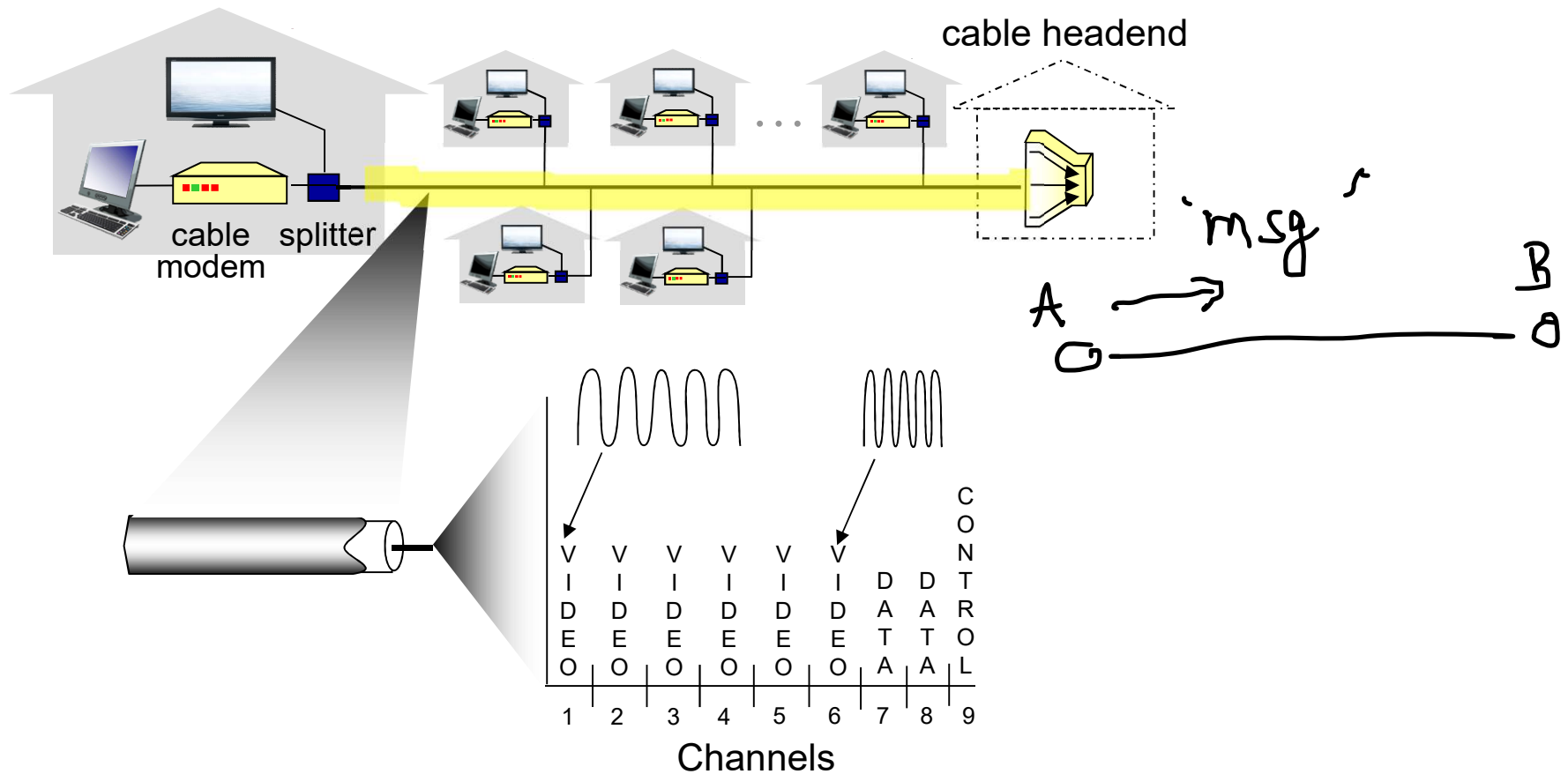


Access network: digital subscriber line (DSL)

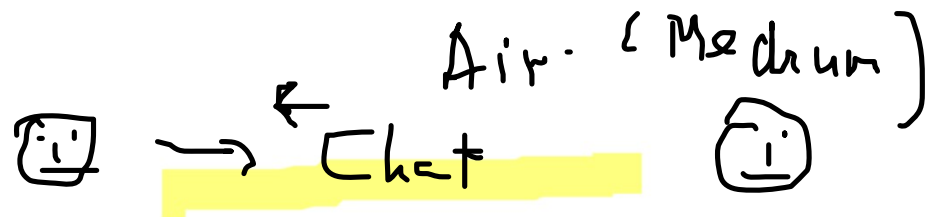


- use *existing* telephone line to central office DSLAM
 - data over DSL phone line goes to Internet
 - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

Access network: cable network



frequency division multiplexing: different channels transmitted in different frequency bands



People Talking

• Vineeta. Sound carrier

open/close mouth

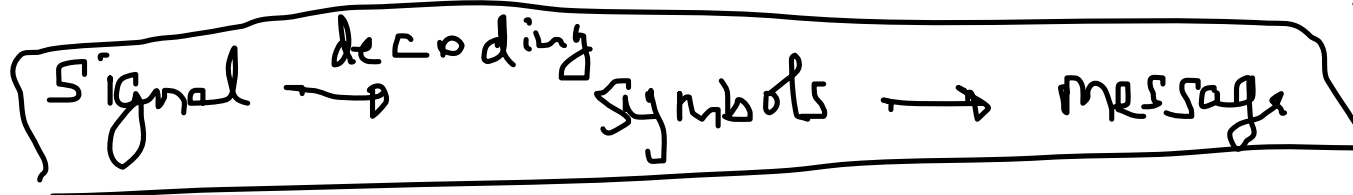
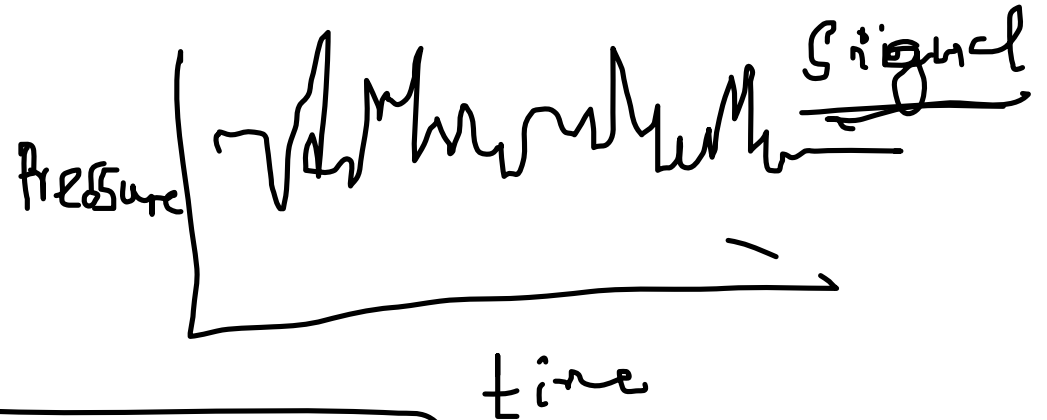
Change the pressure
in the air → pres. wave
disturbance

produce sound [mouth]

→ Sound

recv sound [ear]

proc Signal
[Brain]



Transmitter
o Recv

Medium: Copper

Trans.
Recv

F/o

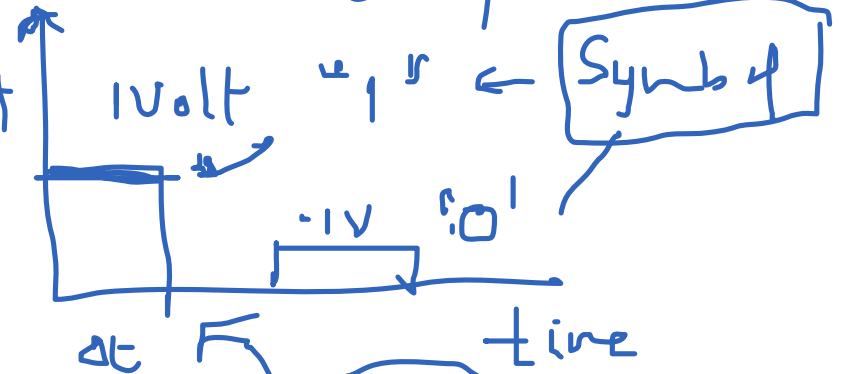
EM w

Wireless (Nothing - Vacuum)

→ Electro Magnetic Waves [light, RFreq....]

→ Signal Modulation Volt

Coding

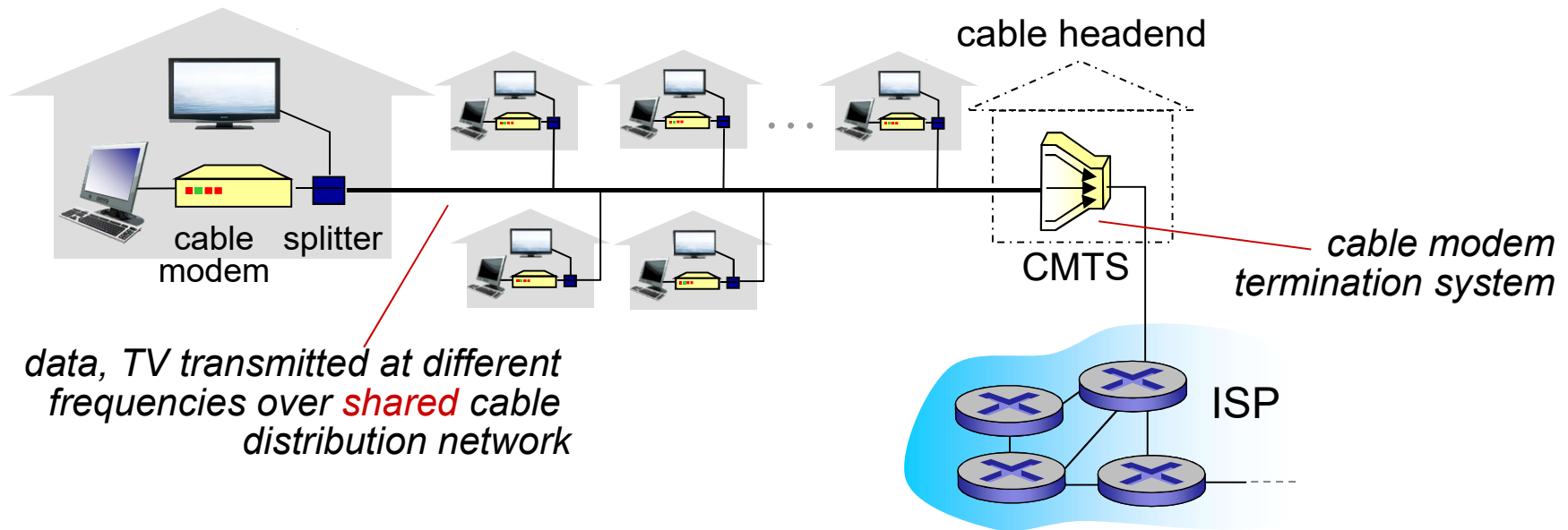


MSG → I am here

I → ASCII code

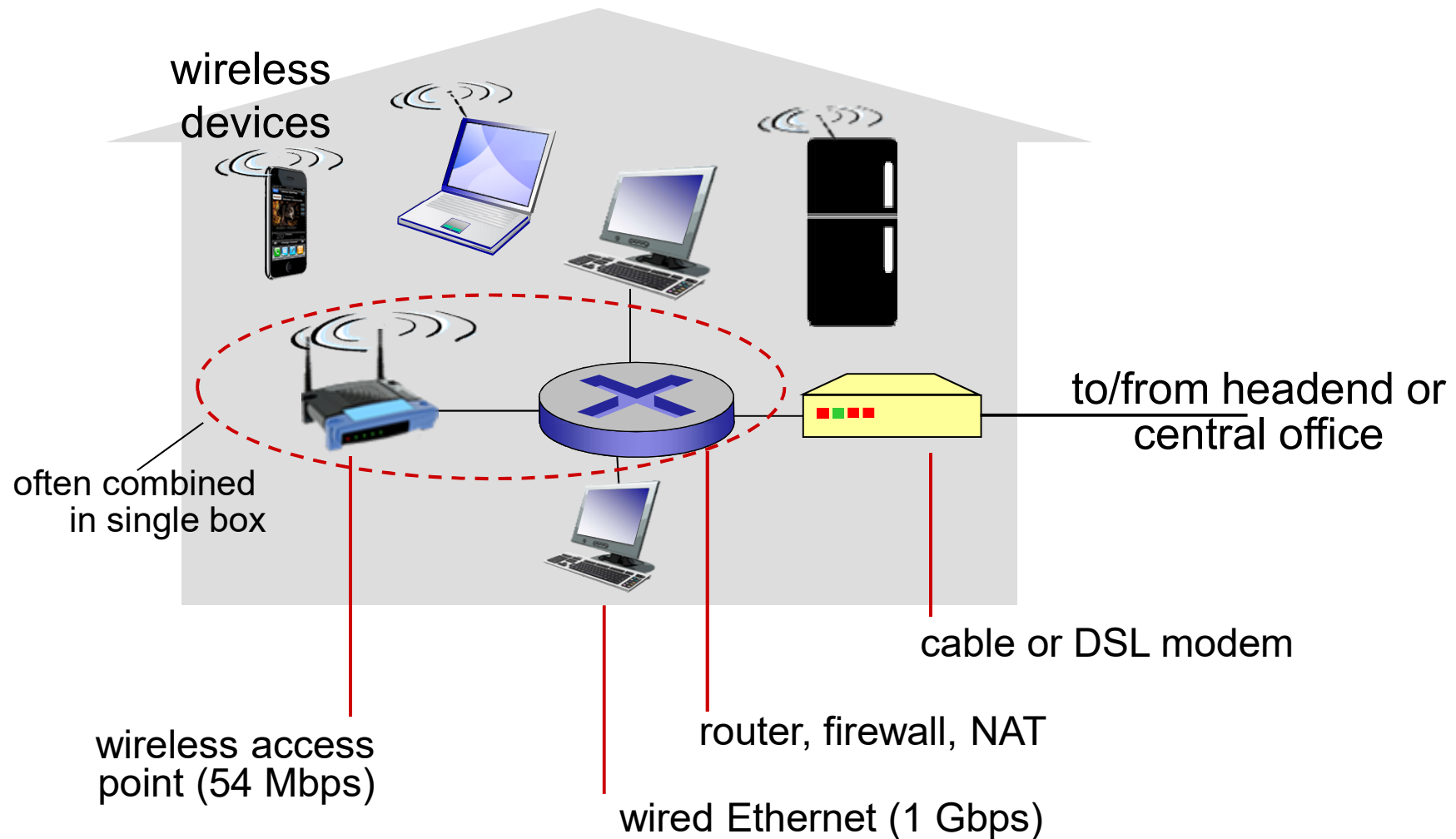
→ 105 → 10111

Access network: cable network

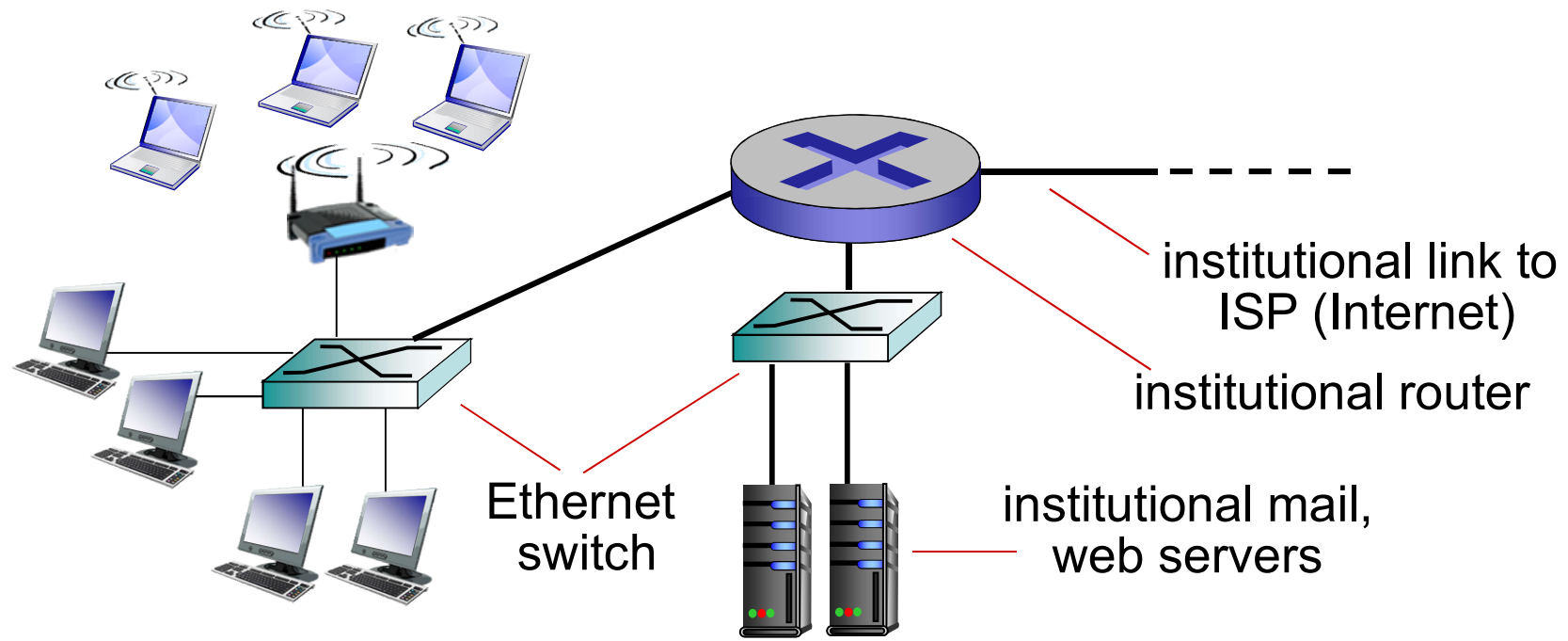


- **HFC: hybrid fiber coax**
 - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- **network** of cable, fiber attaches homes to ISP router
 - homes **share access network** to cable headend
 - unlike DSL, which has dedicated access to central office

Access network: home network



Enterprise access networks (Ethernet)



- typically used in companies, universities, etc.
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

Wireless access networks

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

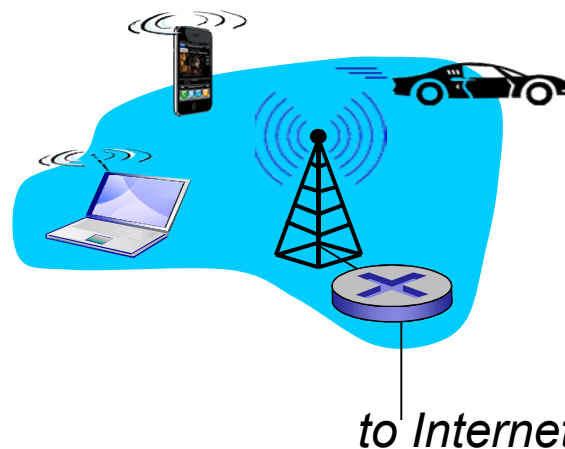
wireless LANs:

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



wide-area wireless access

- provided by telco (cellular) operator, 10's km
- between 1 and 10 Mbps
- 3G, 4G: LTE



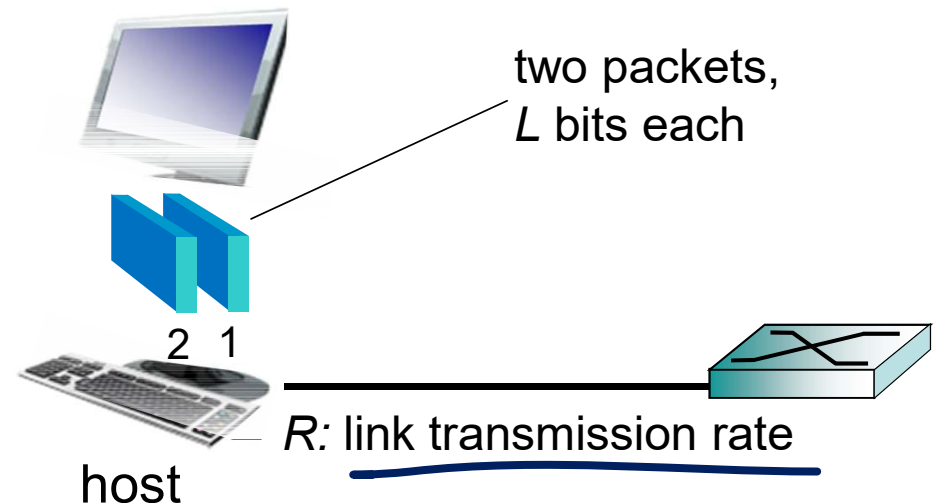
Host: sends packets of data

50 Mbps

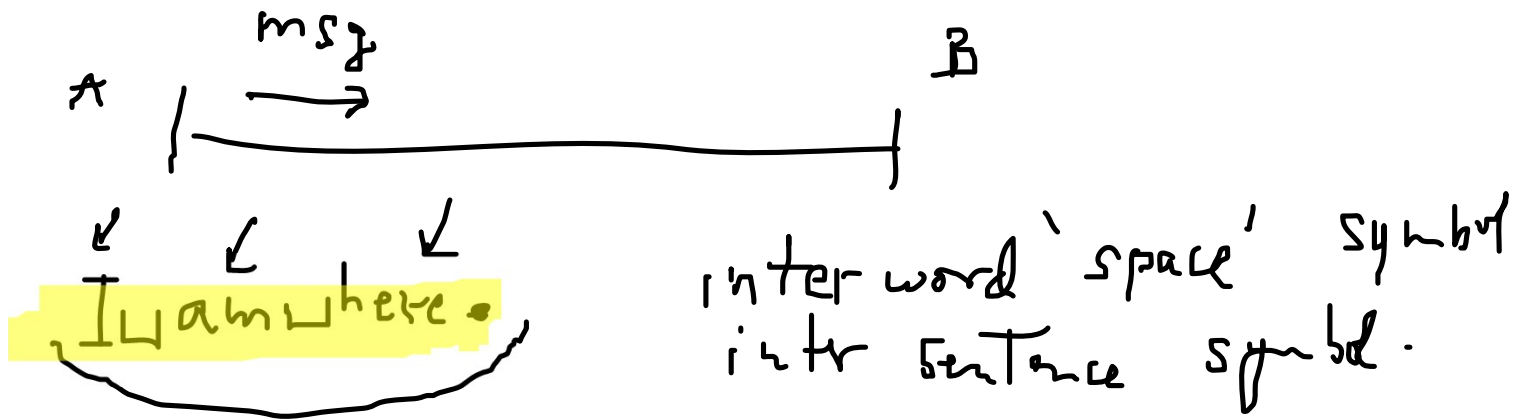
↳ Message

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

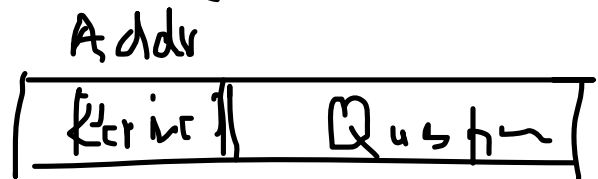
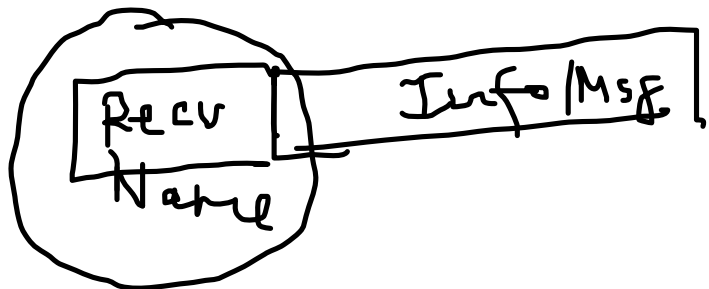


$$\Delta : \frac{L}{R} \quad \text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$



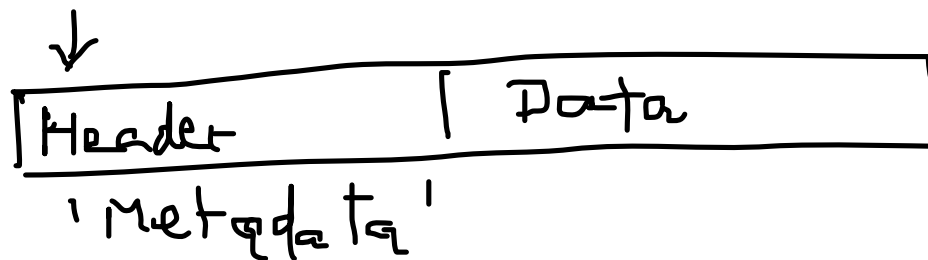
Message → Structure

packet → Structured message.



→ sent to all.

Packet:



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



Physical media: coax, fiber

coaxial cable:

- two concentric copper conductors
- bidirectional
- broadband:
 - multiple channels on cable
 - HFC



fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
 - high-speed point-to-point transmission (e.g., 10's-100's Gbps transmission rate)
- low error rate:
 - repeaters spaced far apart
 - immune to electromagnetic noise



Physical media: radio

- signal carried in electromagnetic spectrum
- no physical “wire”
- bidirectional
- propagation environment effects:
 - reflection
 - obstruction by objects
 - interference

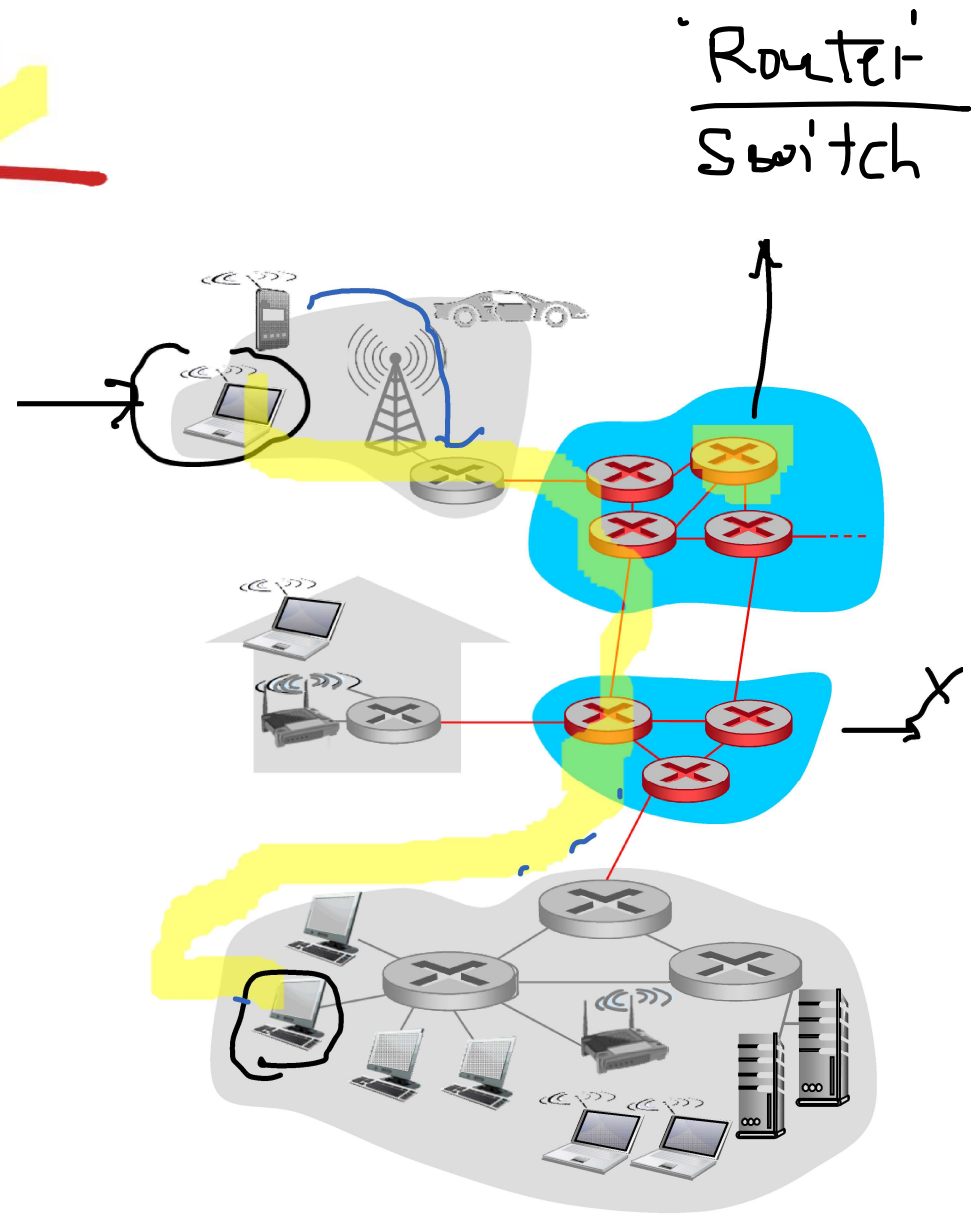
radio link types:

- **terrestrial microwave**
 - e.g. up to 45 Mbps channels
- **LAN** (e.g., WiFi)
 - 54 Mbps
- **wide-area** (e.g., cellular)
 - 4G cellular: ~ 10 Mbps
- **satellite**
 - Kbps to 45Mbps channel (or multiple smaller channels)
 - 270 msec end-end delay
 - geosynchronous versus low altitude

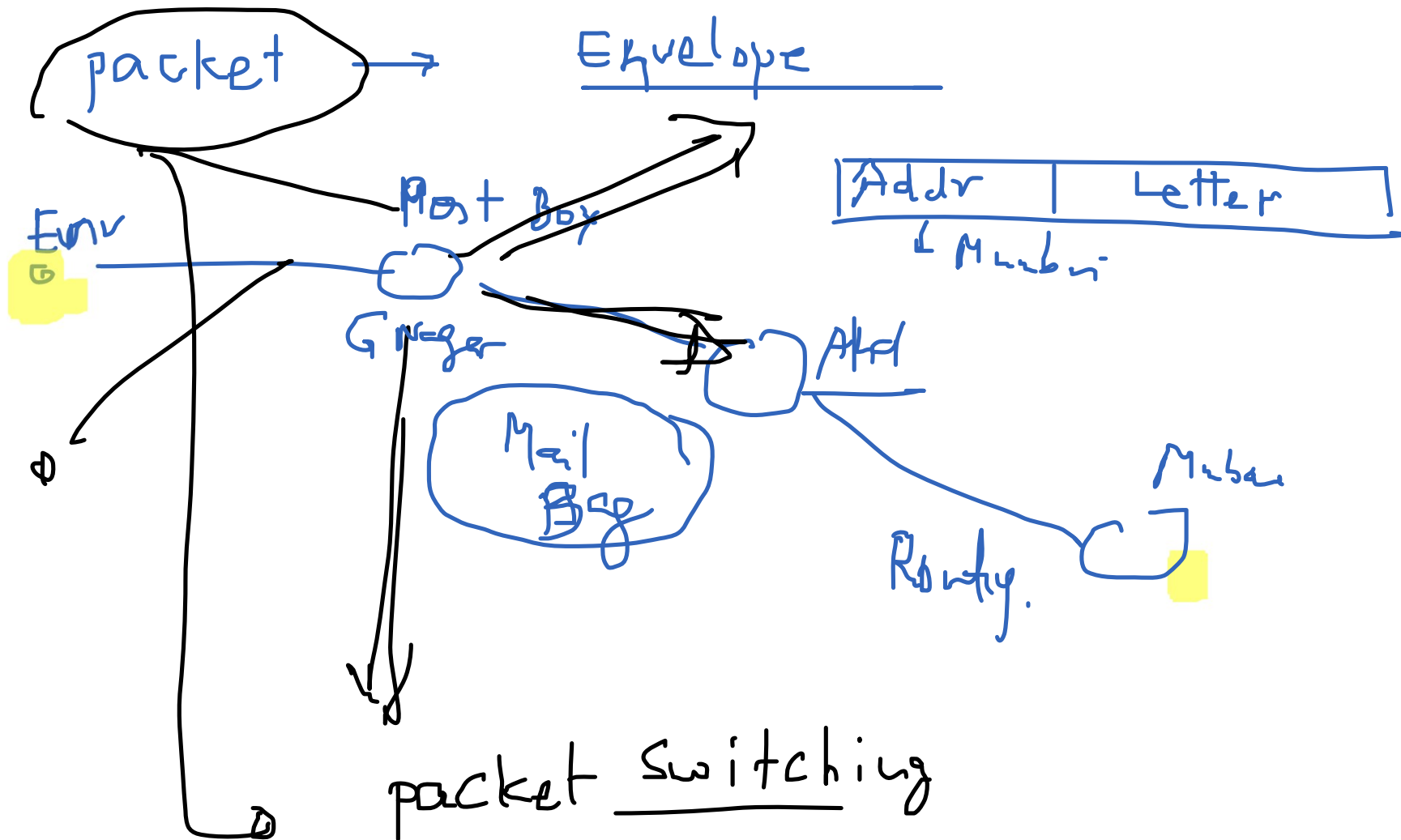
The network core

- 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

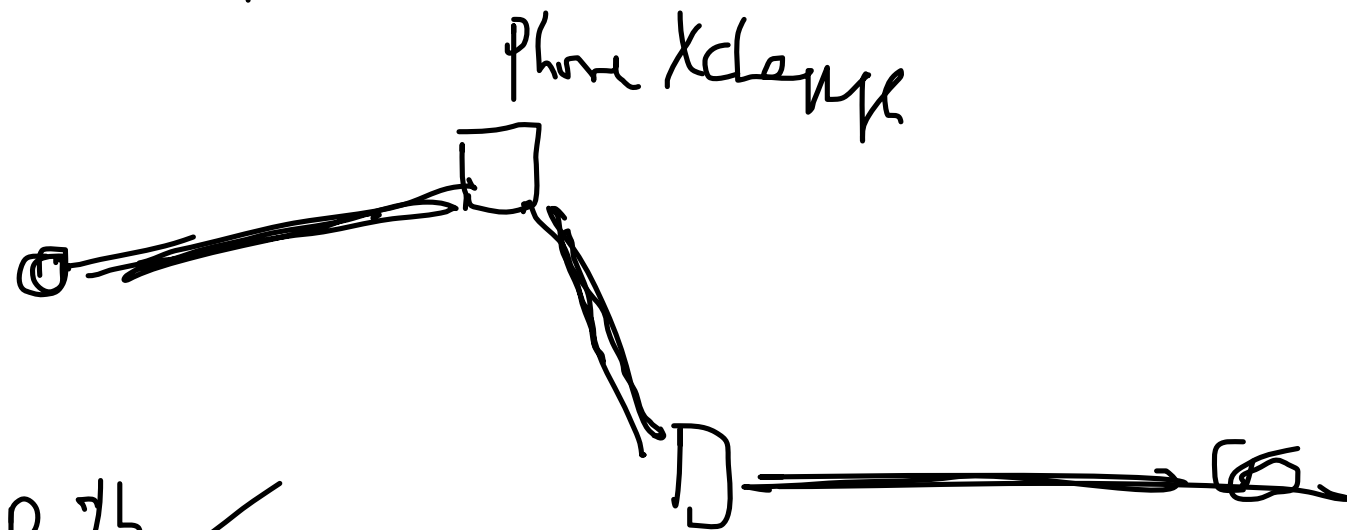
Exchange 'Packets'



Postal N/w



Telephone conn.



path

Circuit is created → For the
duration of call

Circuit Switching