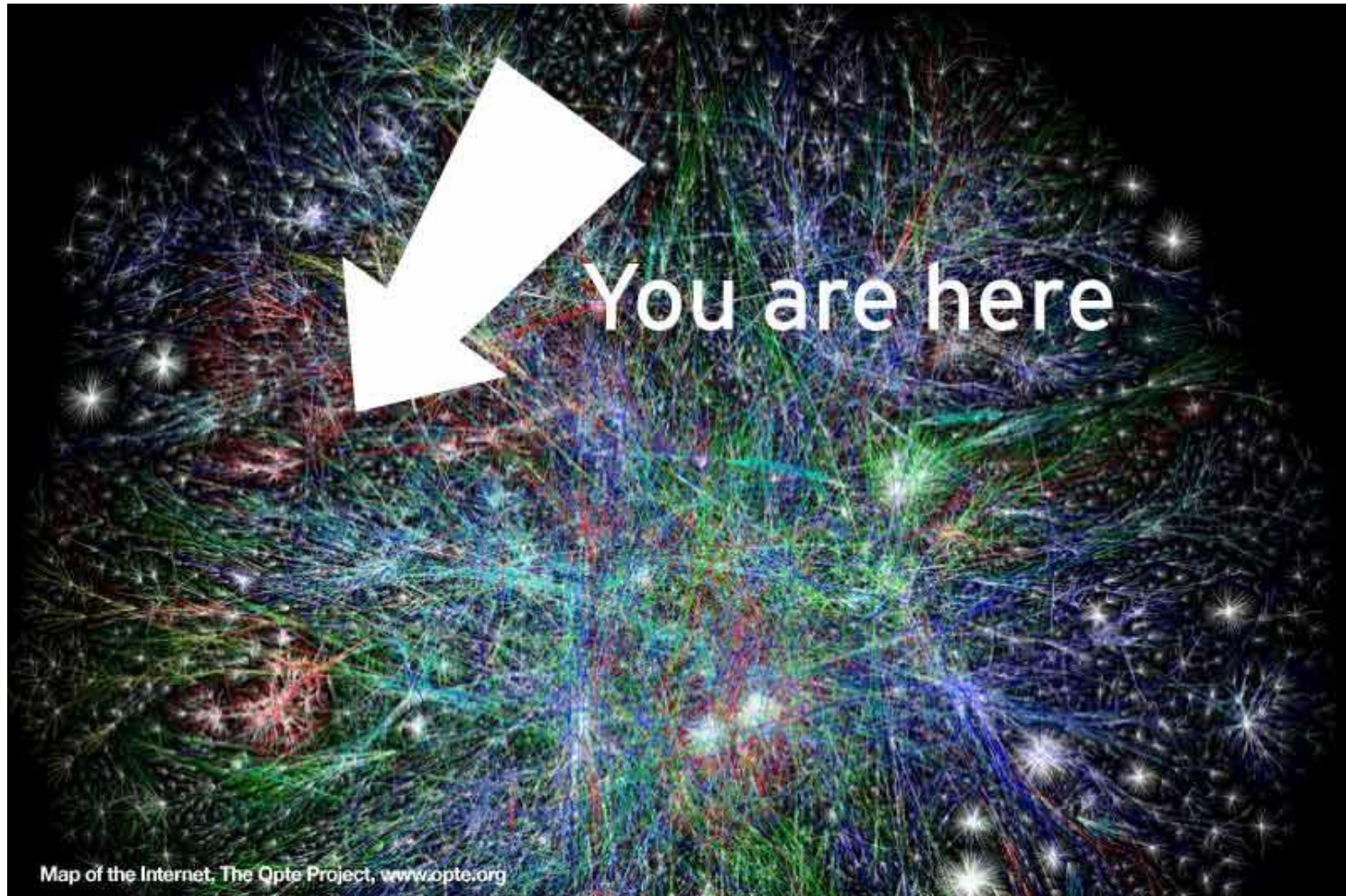


The Internet and network edge



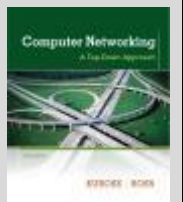
Computer Networking: A Top Down Approach

6th edition

Jim Kurose, Keith Ross

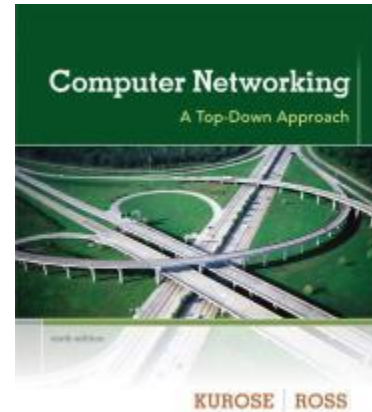
Addison-Wesley

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Overview

- Chapter 1: Introduction
 - Quick overview of field
 - Learn some terminology
- What is the Internet?
 - Different ways to describe:
 - As services
 - By components
- Network edge
 - How you and I connect
 - Physical transmission mediums



What is the Internet?

- For most people, the Internet = applications
 - Web surfing
 - Email
 - Social networking (**Facebook**)
 - Broadcast audio and video (**YouTube, Netflix**)
 - Two-way audio and video (**Skype**)
 - File sharing (**BitTorrent**)
 - Instant messaging (**Twitter**)



More applications

- Virtual workplace ([Amazon Mechanical Turk](#))
- Mega-mega mall ([Amazon.com](#))
- Global supercomputer ([SETI@home](#))
- Virtual reality ([Second Life](#))
- Online gaming ([World of Warcraft](#))
- Online voting
- Online whistleblowing
- ???

"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

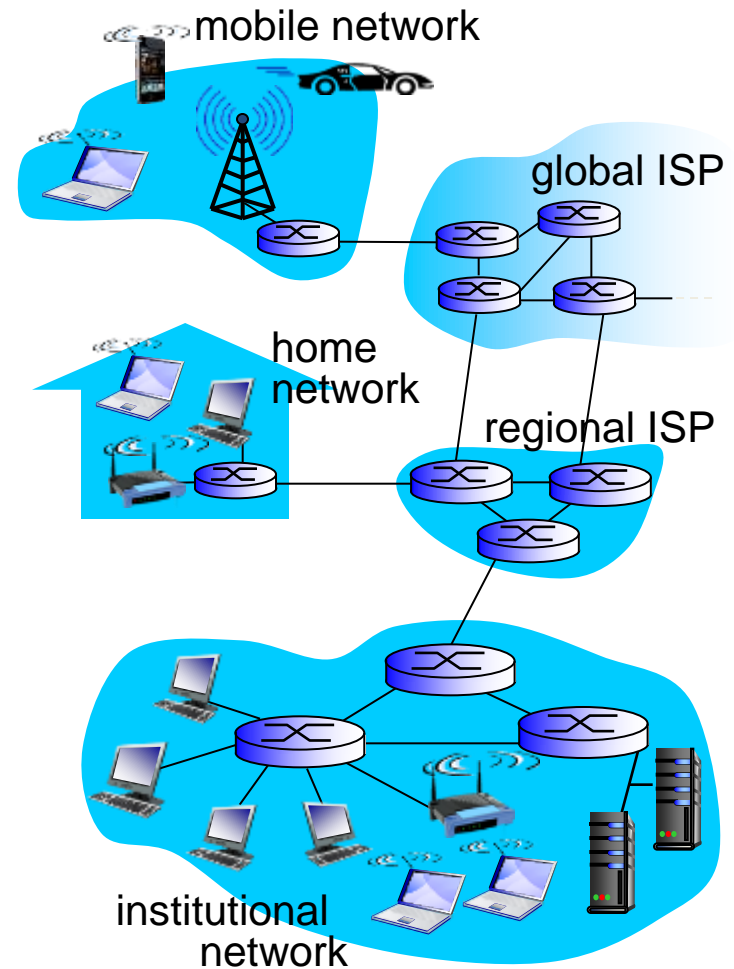


Internet phones

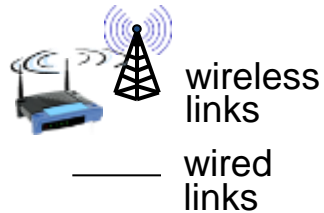
http://www.theregister.co.uk/2001/06/04/bread_as_a_display_device/

"services" view of Internet

- *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



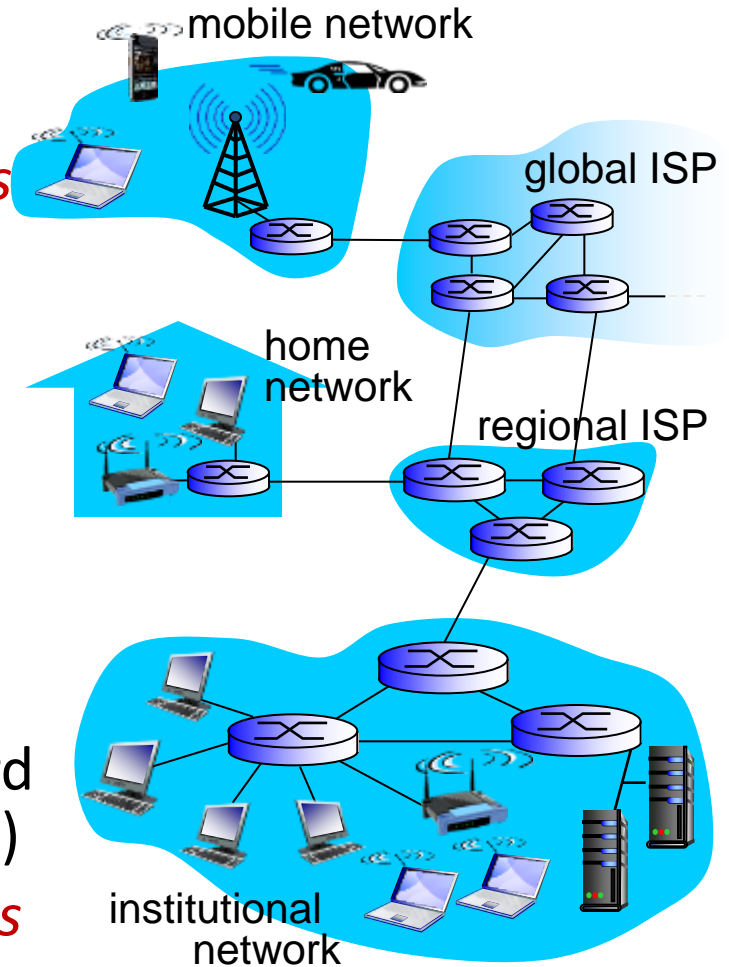
"nuts and bolts" view of Internet



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

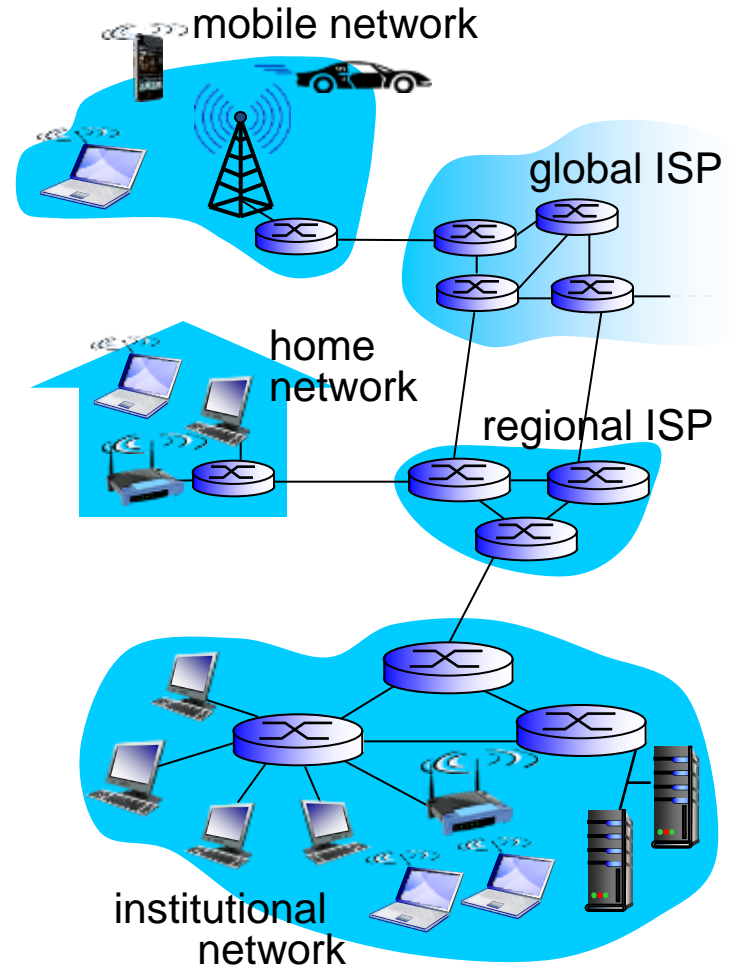
- ❖ *Communication links*
 - fiber, copper, radio, satellite
 - transmission rate: *bandwidth*

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

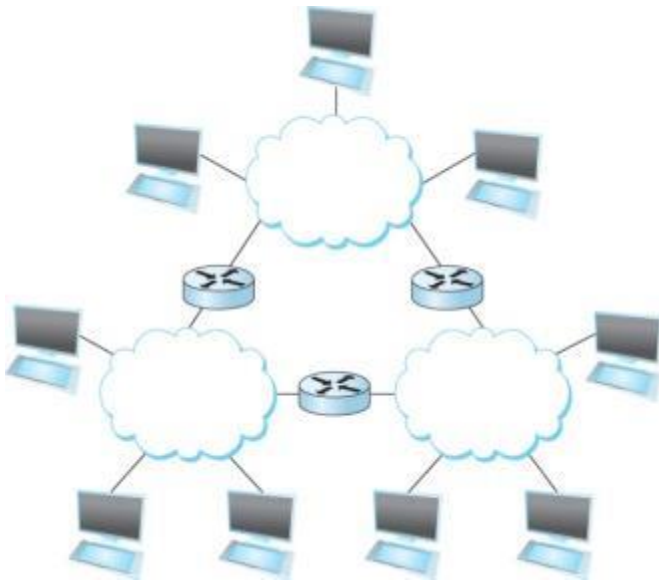


"nuts and bolts" view of Internet

- ❖ *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



Terminology: internet vs. Internet



internetwork / internet:

A set of independent networks interconnected, could be completely walled off from world.



Internet

Global public network consisting of interconnected networks running TCP/IP.

Terminology: ?ANs

PANs	Personal area networks A few meters
LANs	Local area networks < 1 km
MANs	Metropolitan area networks Spans a city or large campus
WANs	Wide area networks Worldwide
SANs	Storage area networks Specialized high-performance network for providing storage

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

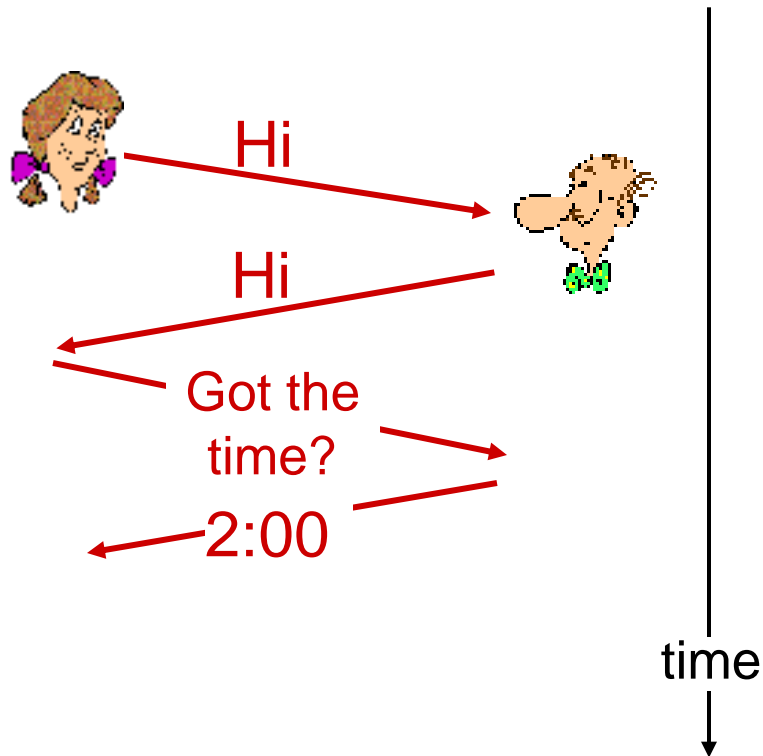
Network protocols:

- Machines instead of humans
- All Internet communication governed by protocols

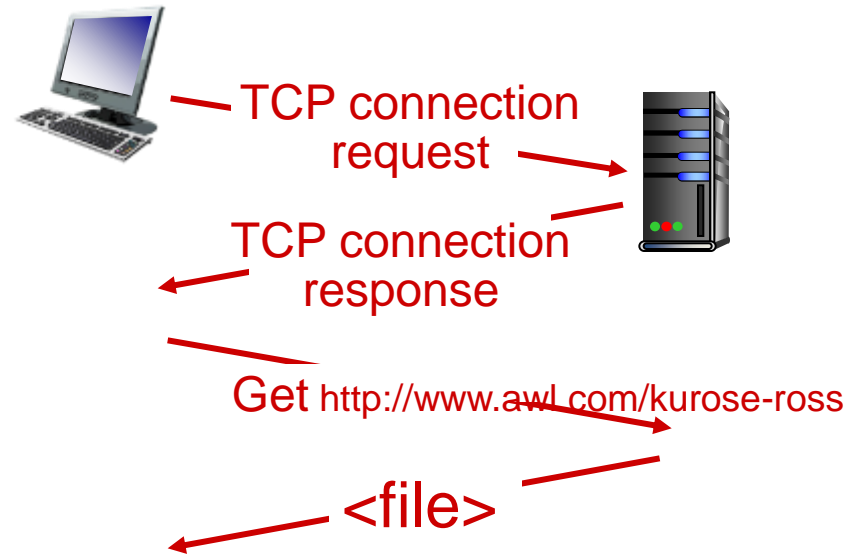
Protocols define format, order of msgs sent and received among network entities, and actions taken on msg transmission, receipt

What's a protocol?

Human protocol:



Network protocol:



Q: Other human protocols?

A closer look at network structure

- *Network edge:*

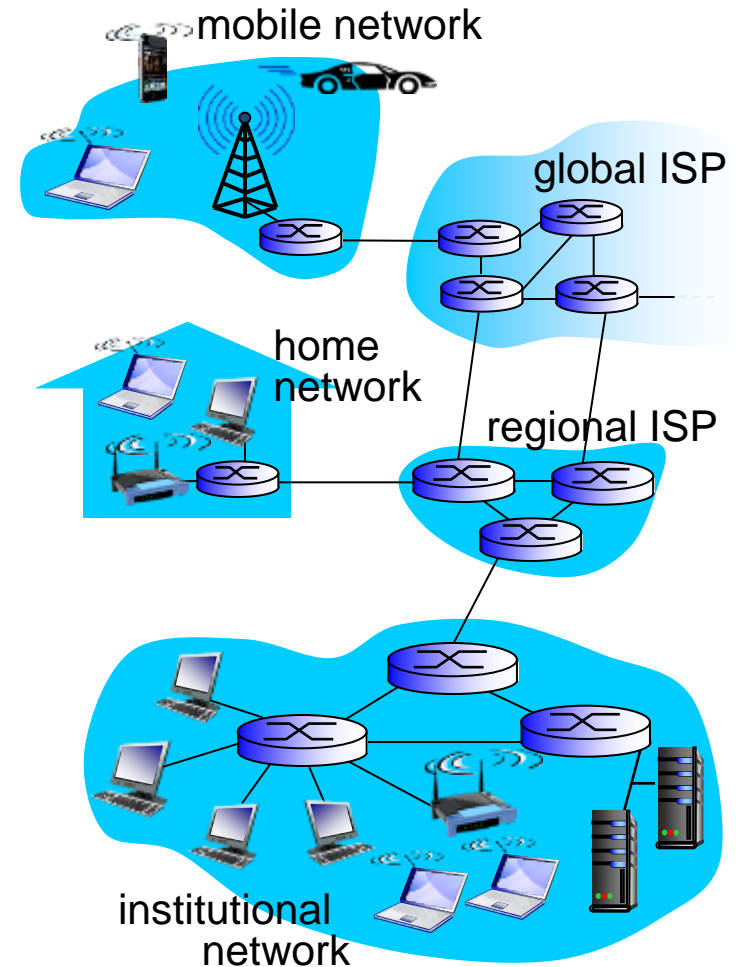
- Hosts: clients and servers
- Servers often in data centers

- *Access networks, physical media:*

- Wired, wireless communication links

- *Network core:*

- Interconnected routers
- Network of networks



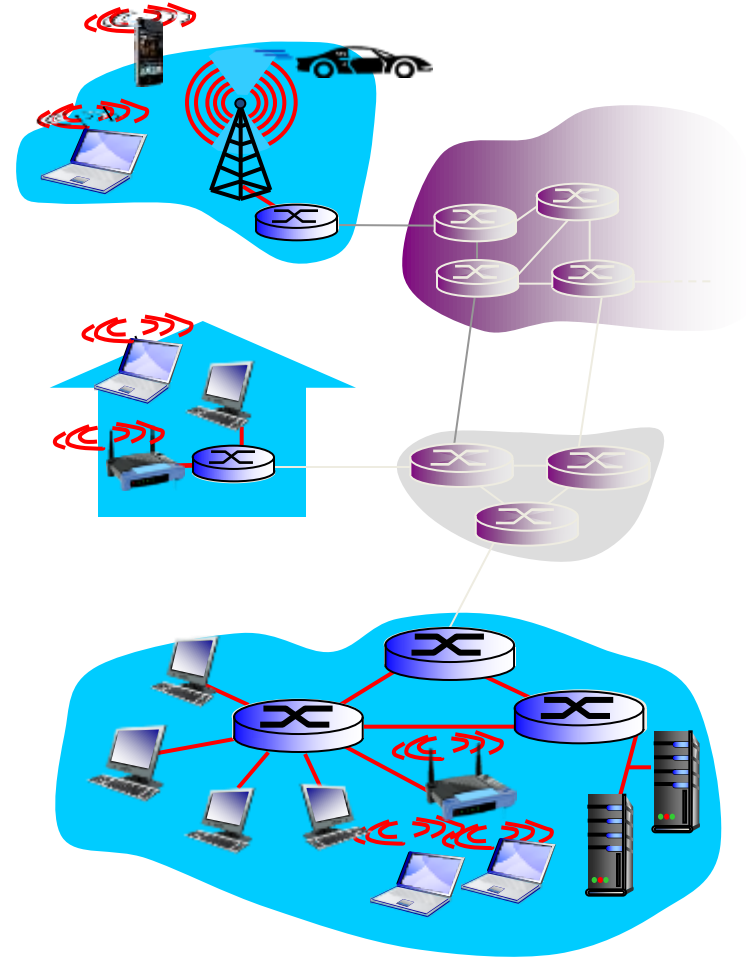
Access networks and physical media

Q: How to connect end systems to edge router?

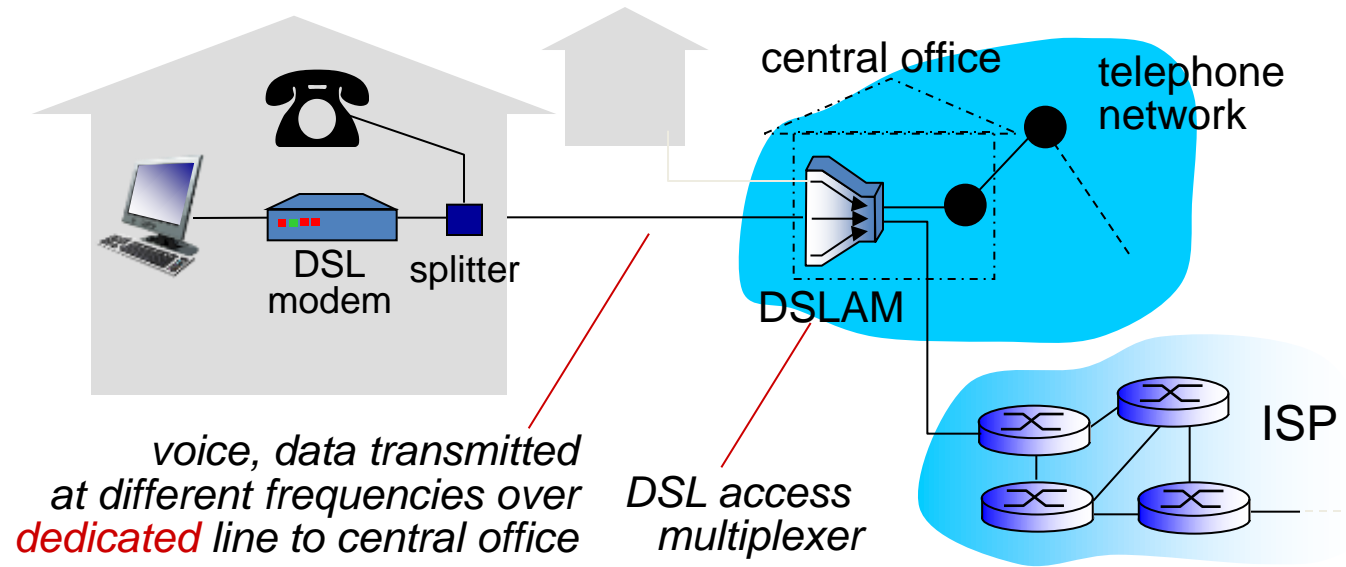
- Residential access nets
- Institutional access networks (school, company)
- Mobile access networks

Keep in mind:

- Bandwidth (bits per second) of access network?
- Shared or dedicated?

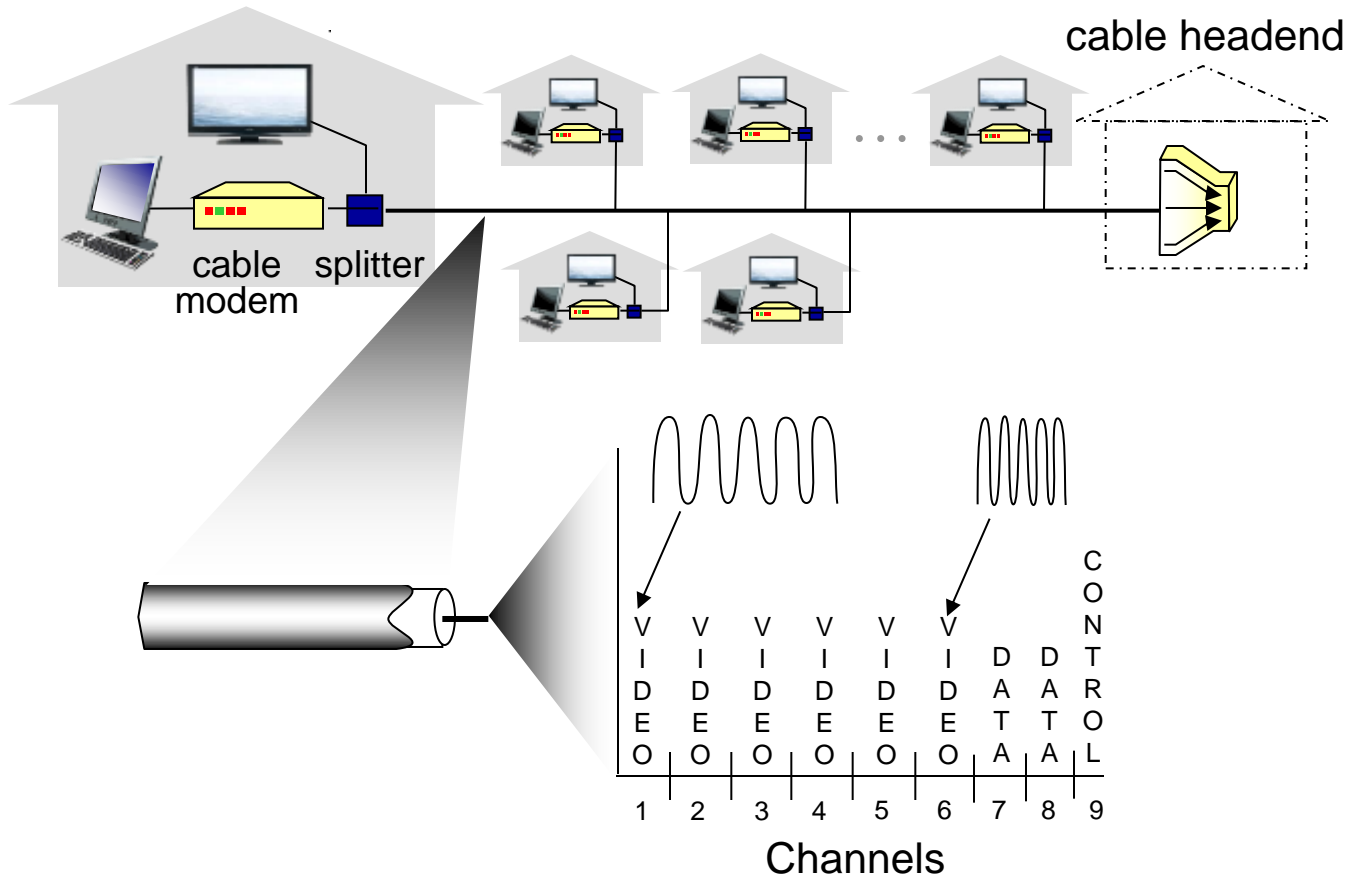


Access net: digital subscriber line (DSL)



- ❖ 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)

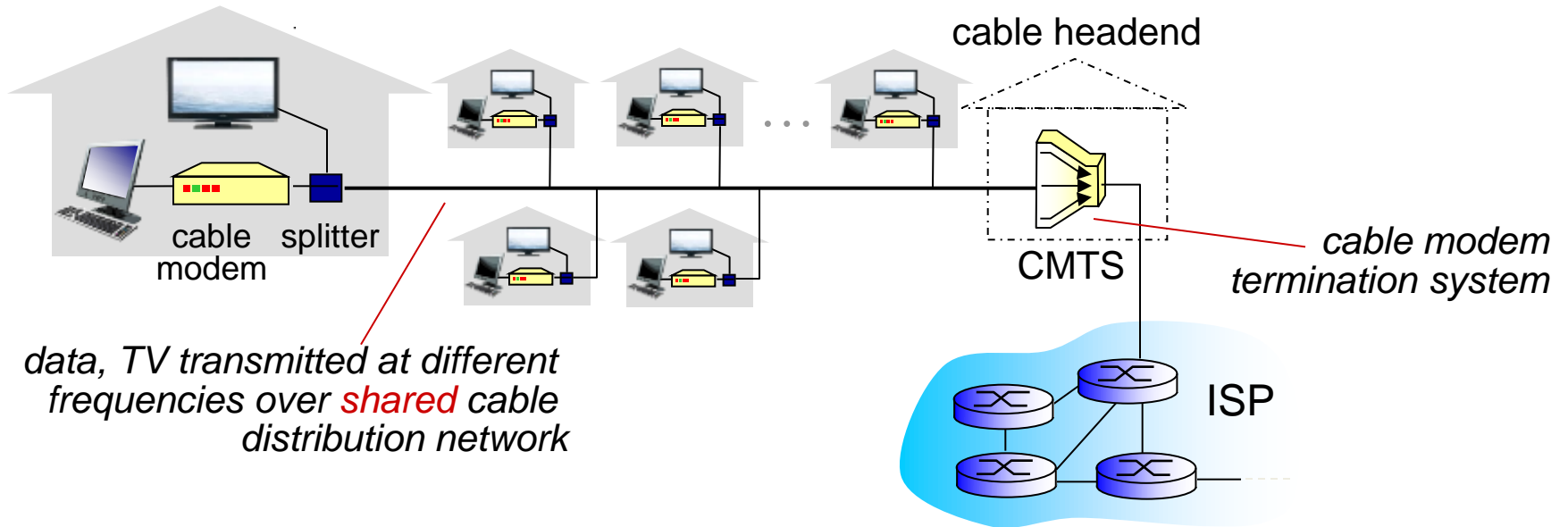
Access net: cable



Frequency division multiplexing:

Different channels transmitted in different frequency bands

Access net: cable



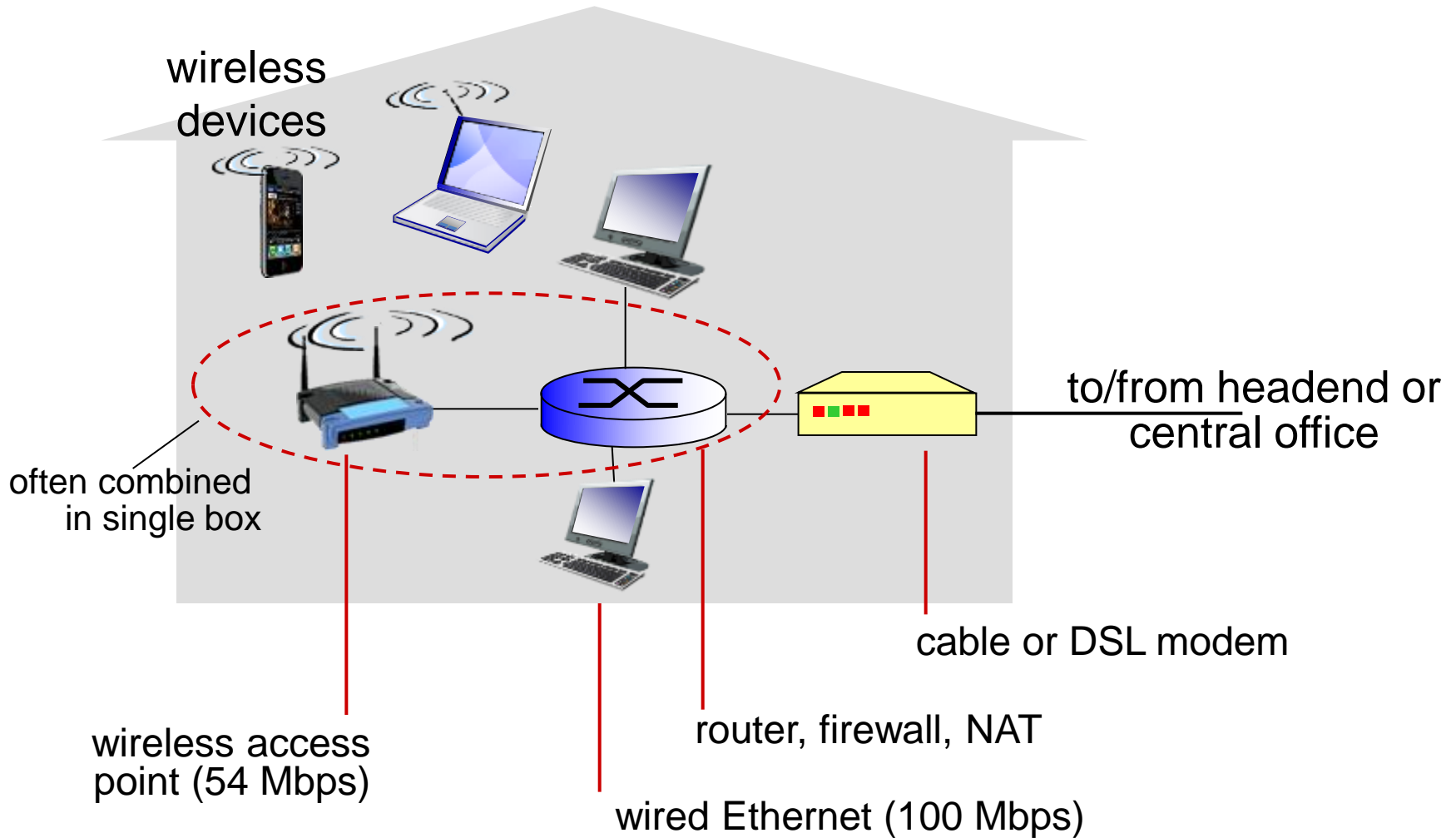
❖ HFC: hybrid fiber coax

- Asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate

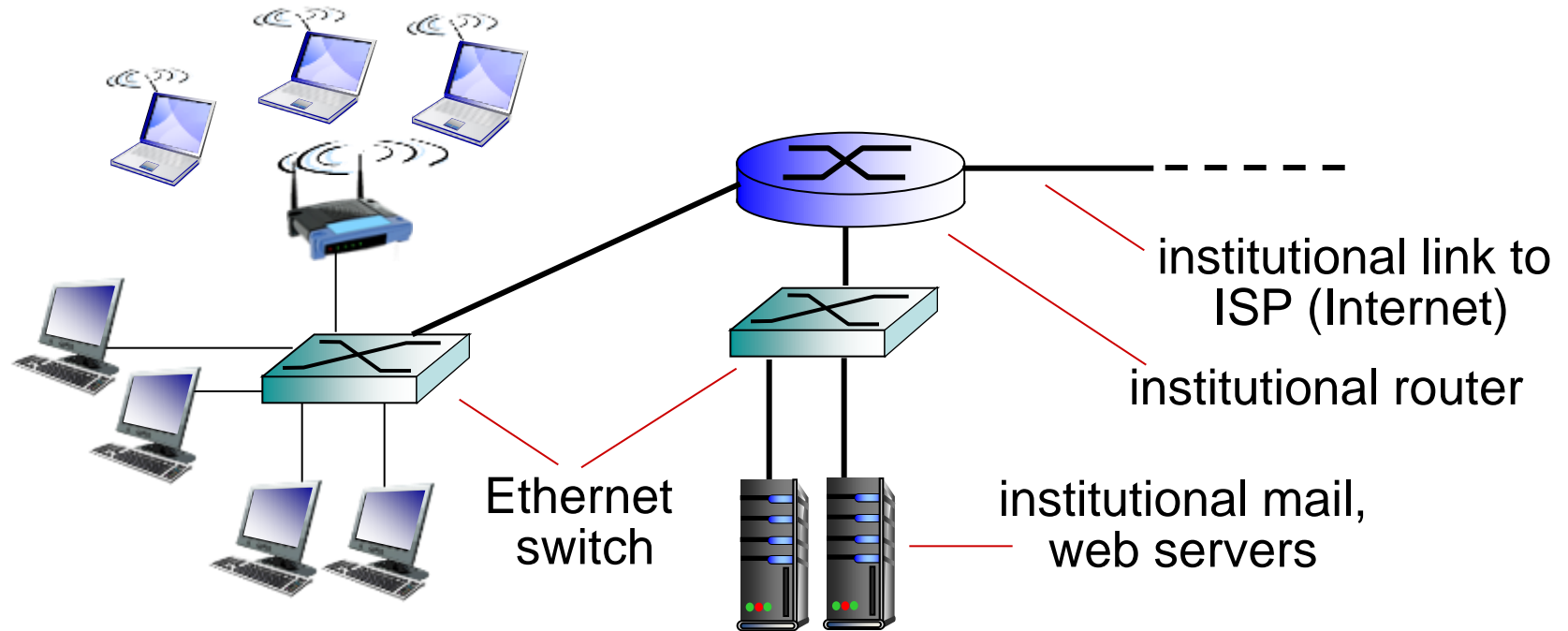
❖ Network of cable, fiber attaches homes to ISP router

- Homes *share access network* to cable headend
- Unlike DSL, which has dedicated access to central office

Access net: home network



Enterprise access networks (Ethernet)



- Typically used in companies, universities, etc.
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps, 100 Gbps 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:

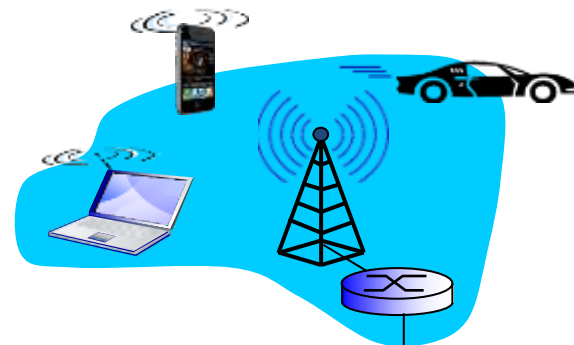
- Within building (100 ft)
- 802.11b/g/n/ac (WiFi)
 - 11, 54, 600, 1000 Mbps (theoretical)



to Internet

Wide-area wireless access:

- Provided by telco (cellular) operator, 10's km
- Between 1-10 Mbps
- 3G, 4G: LTE, WiMax, HSPA+

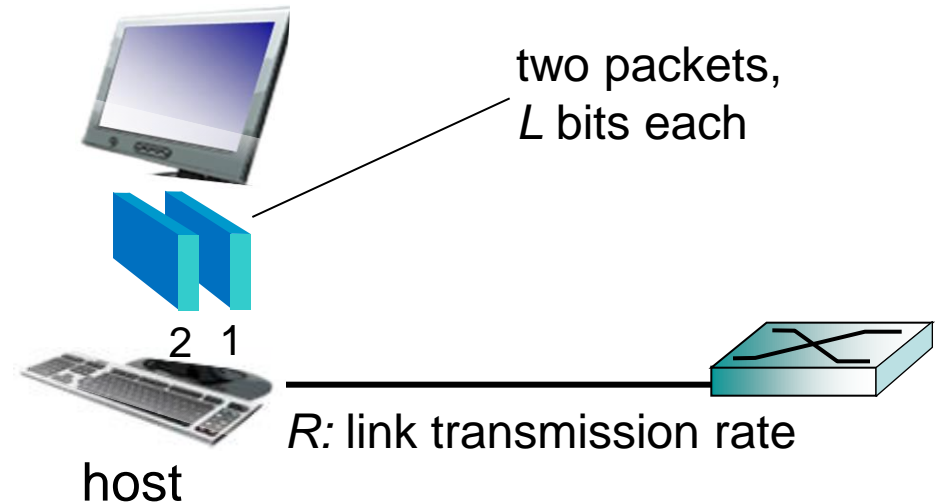


to Internet

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*



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

Physical media

- **Bit:**
 - Propagates between transmitter/receiver pairs
- **Physical link:**
 - What lies between transmitter & receiver
- **Guided media:**
 - Signals propagate in solid media
 - e.g. copper, fiber, coax
- **Unguided media:**
 - Signals propagate freely
 - e.g. radio, satellite

Put data on something

- Magnetic tape, removable media (DVDs)

- "sneakernet"
- Netflix



- Very high bandwidth for very low cost

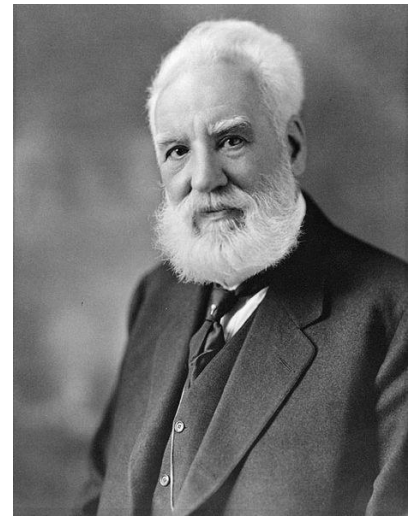
- 60 x 60 x 60 cm box holds 1000 - 800GB tapes
- FedEx overnight, bandwidth: 70 Gbps
- Cost: about 0.5 cents / GB



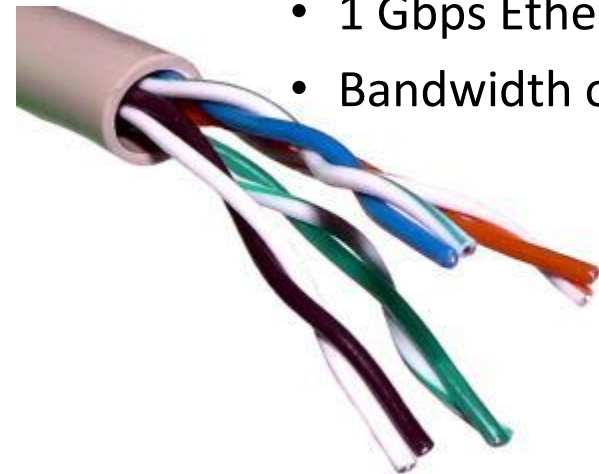
“Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway”

Twisted pair

- Pairs of wires twisted together
 - Normally **unshielded**, just wires and insulation
 - Twists **avoid wires becoming an antenna**
 - Signal carried as **difference in voltage between wires**
 - Noise affects both wires similarly
 - Category 5 "**cat 5**" uses four pairs
 - 100 Mbps Ethernet uses two, one for each direction
 - 1 Gbps Ethernet, all four in both directions simultaneously (cat 5e)
 - Bandwidth of 350 Mhz for cat 5e

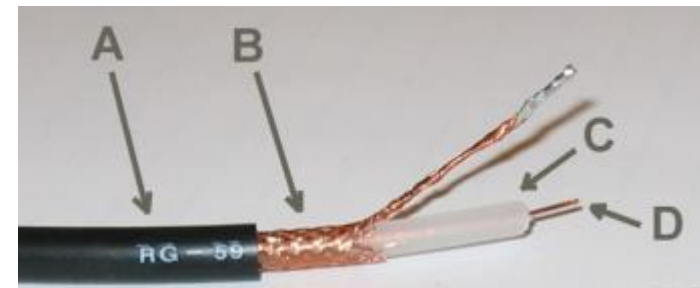
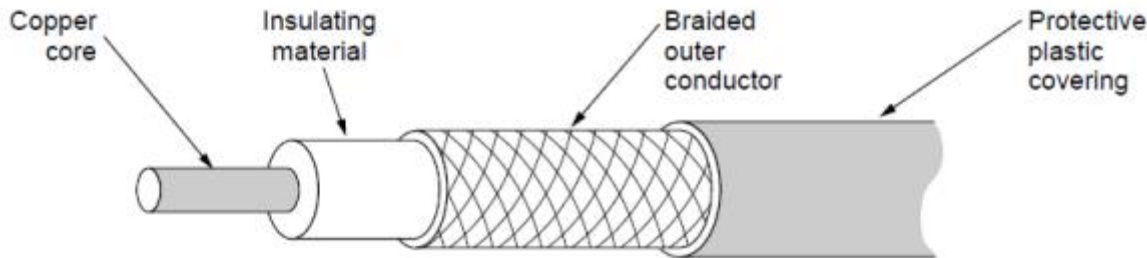


Alexander Graham Bell



Coaxial cable

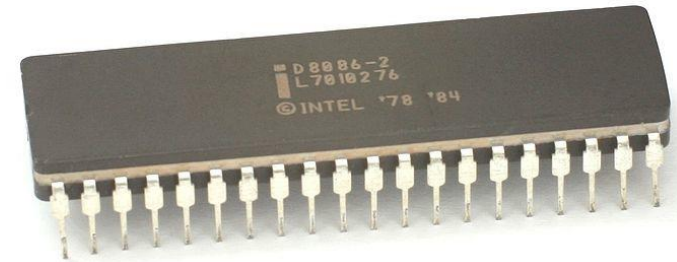
- Coaxial cable "coax"
 - Better shielding than unshielded twisted pair (UTP)
 - Longer distances
 - Greater bandwidth, up to a few GHz
 - Today, primarily last-mile
 - Yesterday: long-distance telephone trunks



Computer industry improvements

- Processing power:

- 1981 IBM PC = 4.77 Mhz
- Today, 6-core CPU = 4 Ghz
- Factor **2500 increase**



- Networking power:

- 1981, T3 telephone line= 45 Mbps
- Today, long haul line = 100 Gbps
- Factor **2000 increase**



Fiber optics

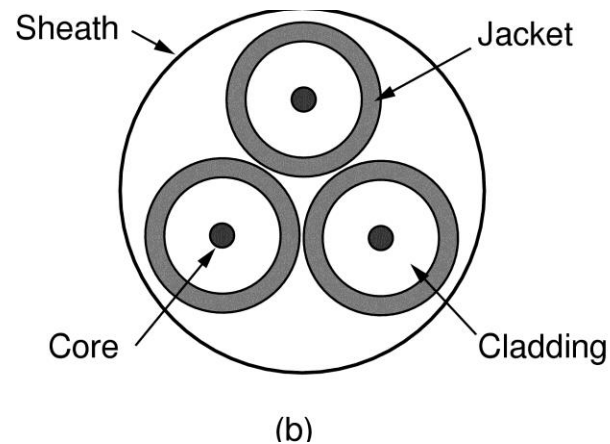
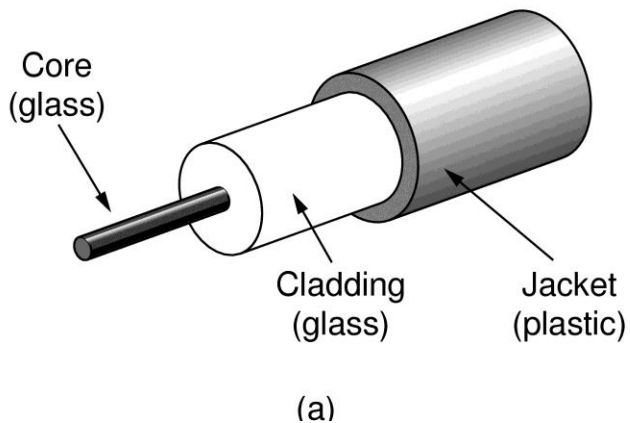
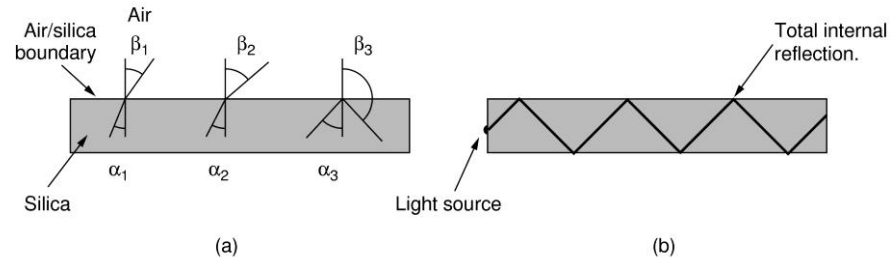
- **Communication via light**

- Optical fibers conduct light

- **Via total internal reflection**

- Parts:

- Light source (LED or semiconductor laser)
- Transmission media (the glass fiber)
- Detector (photodiode)



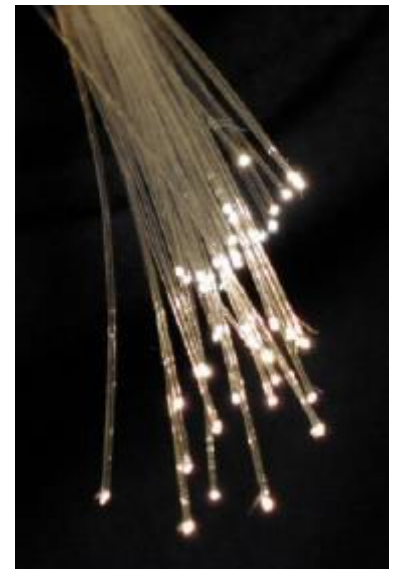
Fiber versus copper

- **Fiber advantages**

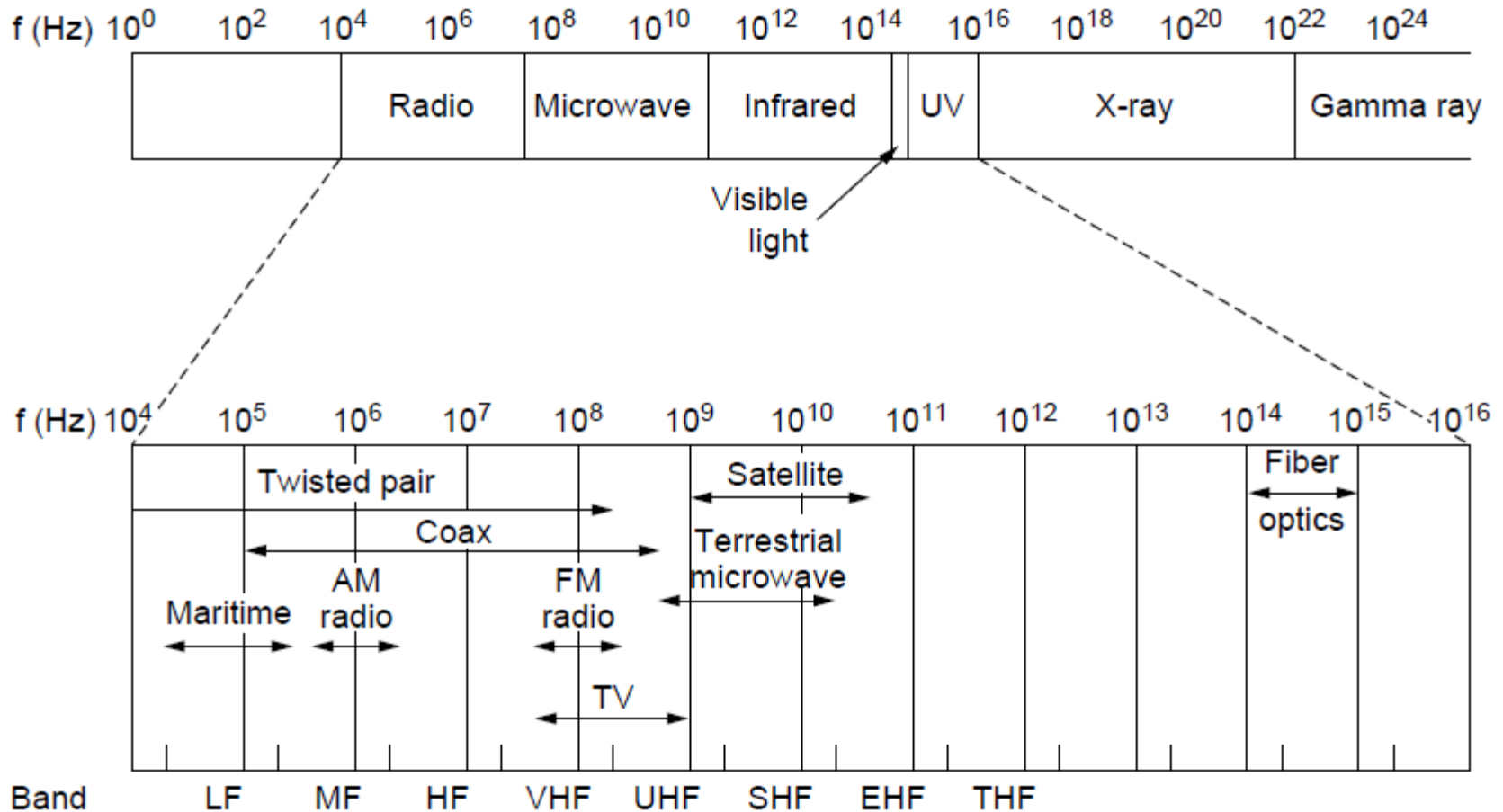
- Higher bandwidth than copper
- Lower attenuation
 - Requires fewer repeaters to cover long distances
- Not affected by electromagnetic interference
 - You can put lots of fiber next to each other
- Thinner and lighter
- Difficult to tap

- **Fiber disadvantages**

- Less familiar technology
- Damaged if bent too much
- Fiber interfaces more expensive than electrical



Electromagnetic spectrum



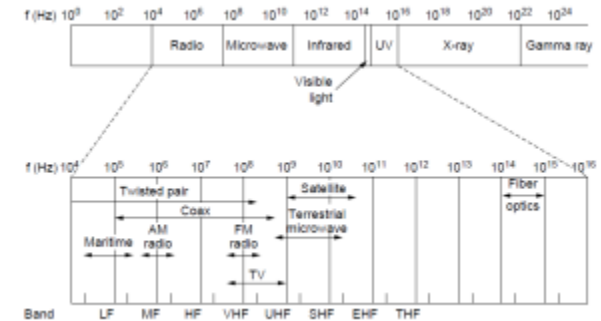
Radio transmission

- Advantages:

- Easy to generate
- Penetrates buildings
- Omnidirectional, no alignment of transmitter and receiver
- Travels long distances
 - Signal drops same fraction as distance doubles
 - VLF, LF, MF bands follow curvature of earth
 - HF band bound off ionosphere

- Disadvantages:

- Interference with other users
- Strictly controlled by governments
- Low bandwidth



Microwave



- **Microwave transmission**
 - Above 100 Mhz waves go in **straight line**
 - **Focus into a beam** with parabolic antenna
 - Use to be heart of long-distance telephone system
 - MCI = Microwave Communications, Inc.
 - Advantages:
 - **No right of way** needed to lay cable
 - **Relatively inexpensive** compared to laying cable
 - Disadvantages:
 - **Earth gets in the way**, 100 m tower → tower every 80 km
 - Refraction off low-lying atmosphere, **multipath fading**
 - Above 4 Ghz, **absorbed by water**

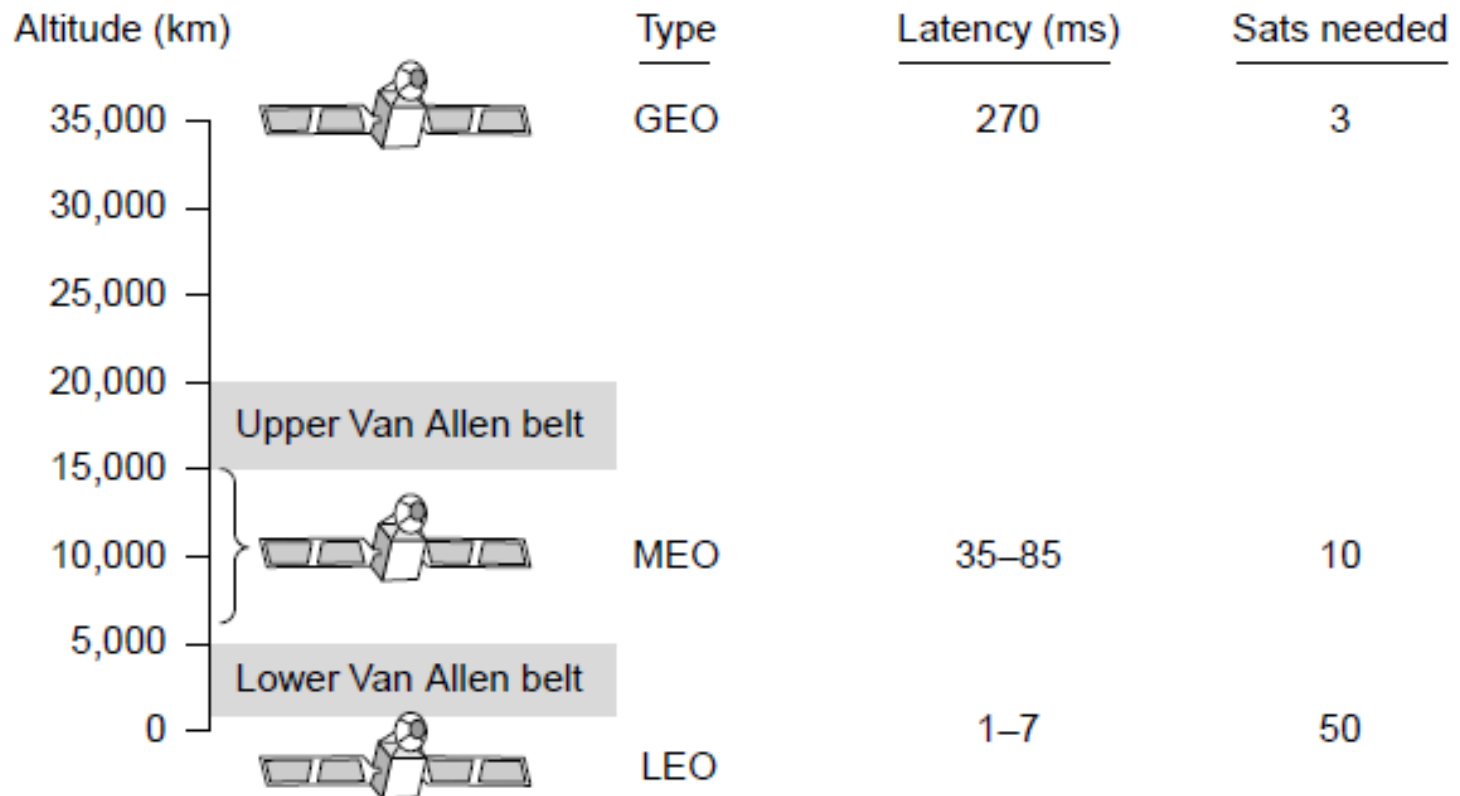
Satellite

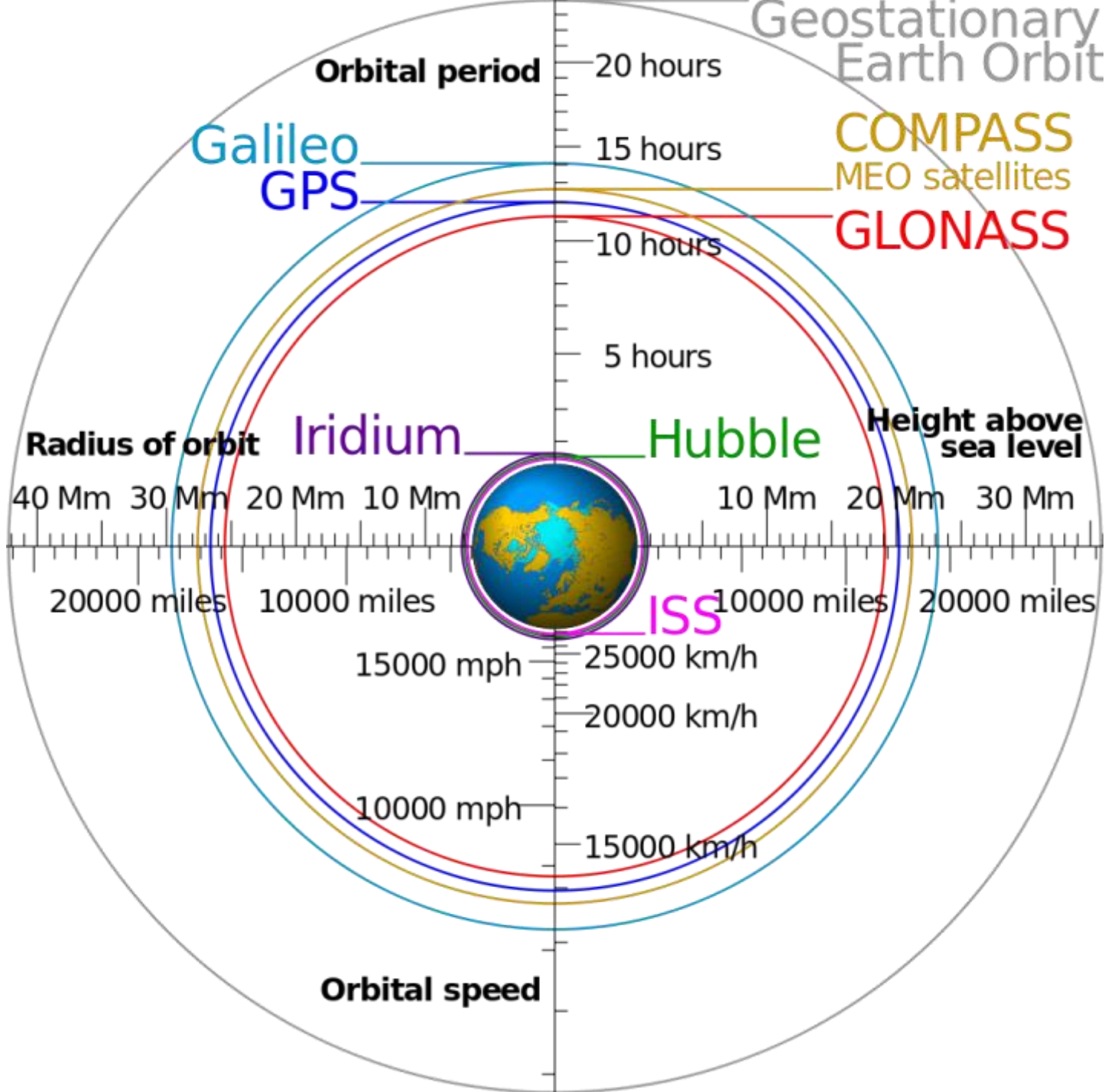
- Communication satellites
 - Big **microwave repeater in the sky**
 - Transponders **listen to portion of spectrum**
 - **Beams signal back** to earth on different frequency
 - Wide beam, cover large portion of Earth
 - Spot beams, area a few hundred km in diameter



Satellite placement

- Geostationary satellites (GEO)
- Medium-Earth orbit (MEO)
- Low-Earth orbit (LEO)





Geostationary orbit

- Geostationary satellites

- At altitude of 35,800km

- Satellite appears to remain motionless

- Examples: DirecTV, Dish Network, HughesNet, WildBlue

- Advantages:

- No need to track, always in view
- Inherently broadcast media

- Disadvantage:

- Long latency due to great distance
- Only 180 or so in sky at once
- Inherently broadcast media



Medium-Earth orbit

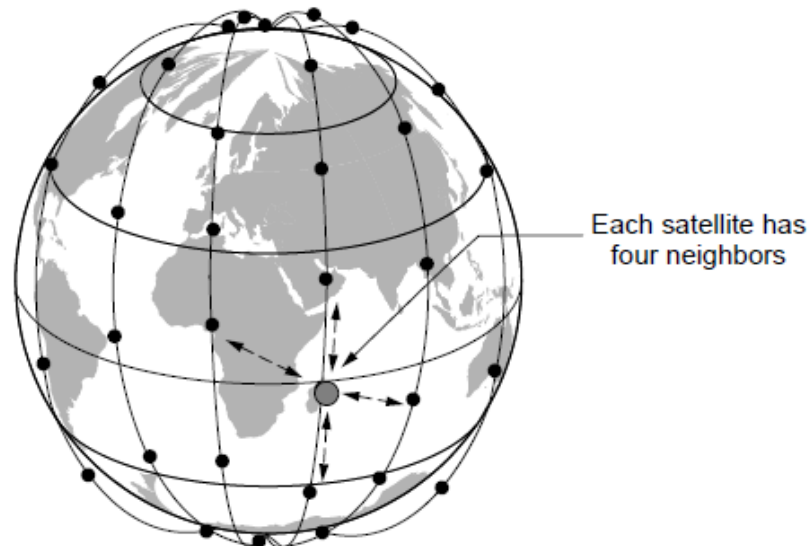
- **Medium-Earth orbit satellites**
 - Around 6 hours to circle Earth
 - Must be tracked as they move through sky
 - Lower so less powerful transmitter needed
 - Examples:
 - GPS global positioning system (USA)
 - Galileo (EU)
 - GLONASS (Russia)



Low-Earth orbit

- Low-Earth orbit satellites

- Rapid motion across sky
- Large number needed for complete system
- Close to ground, low latency and low power
- Cheaper launch cost
- Examples: Globalstar, Iridium, weather satellites



Satellite versus fiber

- Satellite advantages

- Rapid deployment

- Disaster response
 - Military communication

- Poorly developed terrestrial infrastructure

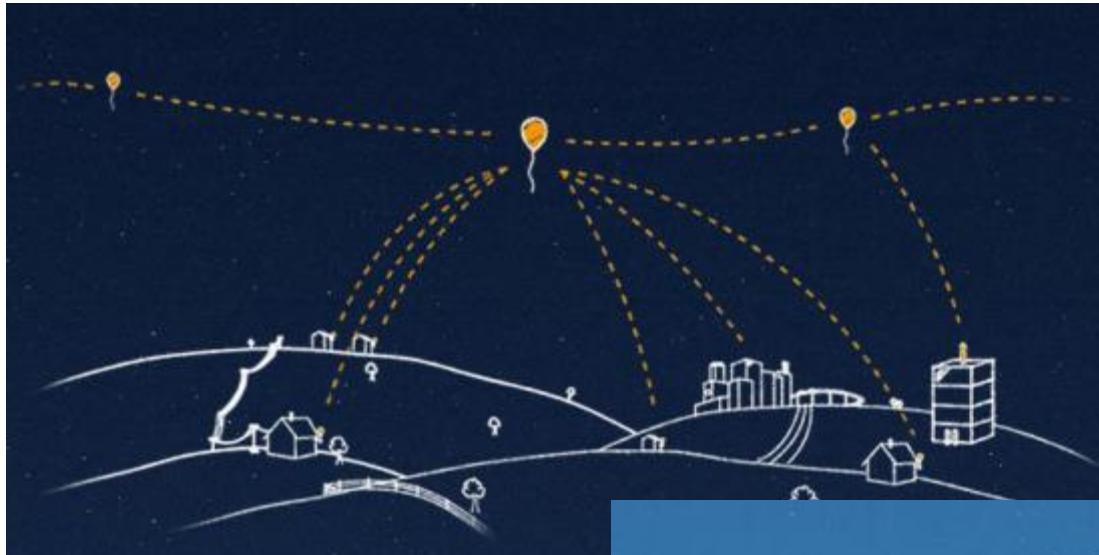
- House in the mountains

- Broadcasting desired

- TV or radio broadcast



Balloon access network?



Summary

- The Internet
 - Services view
 - Nuts-and-bolts view
- Terminology
 - Hosts, end systems, bandwidth, protocol, packets
- Network edge
 - Access network
 - How you and I connect
 - Done via cable, radio, satellite
 - Variety of physical transmission mediums

