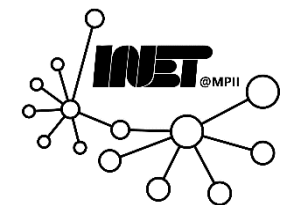




Data Networks

Introduction



Introduction

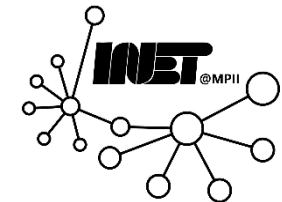


Goals:

- Get “feel” & terminology
- More depth, detail *later* in course
- Approach:
 - Use Internet as example

Overview:

- What’s the Internet?
- What’s a protocol?
- Network edge:
 - *End-systems, access net, physical media*
- Network core:
 - *Packet/circuit switching, Network structure*
- Performance: *Delay, loss, throughput*
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- Networks under attack: Security
- History



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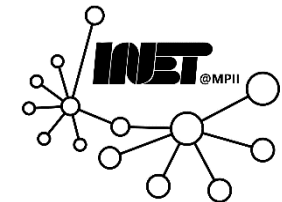
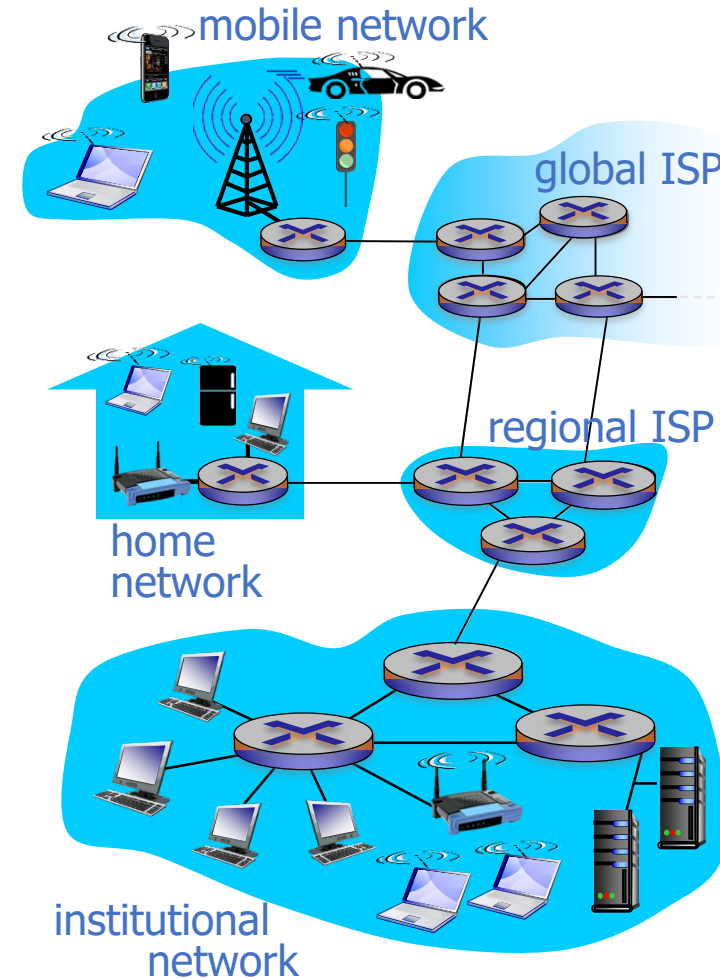
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A closer look at network structure:



- **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

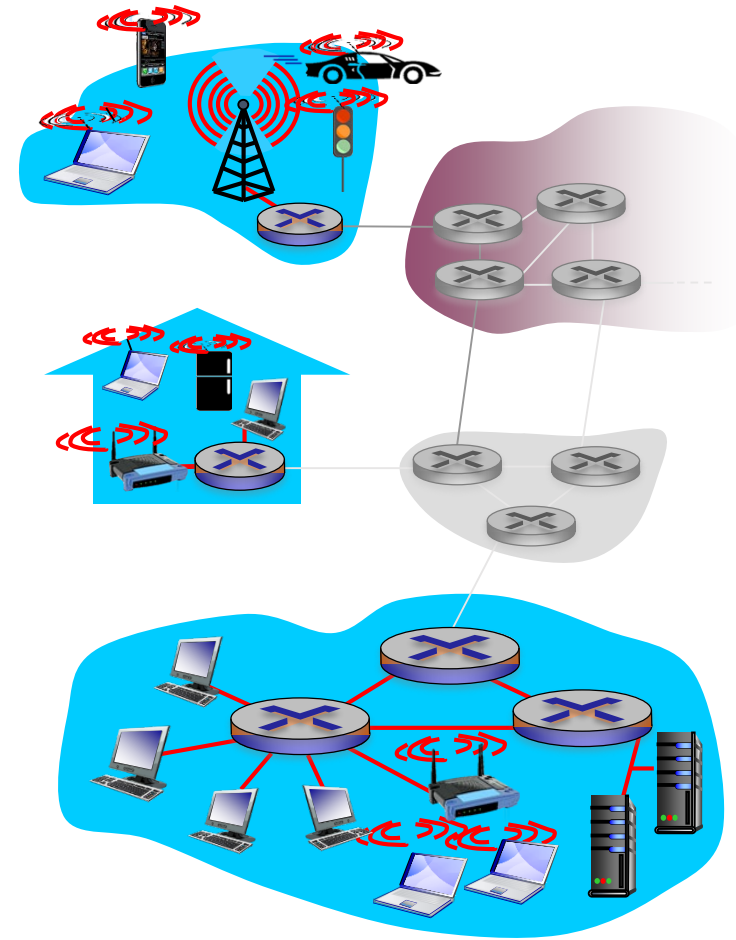


Q: How to connect end systems to edge router?

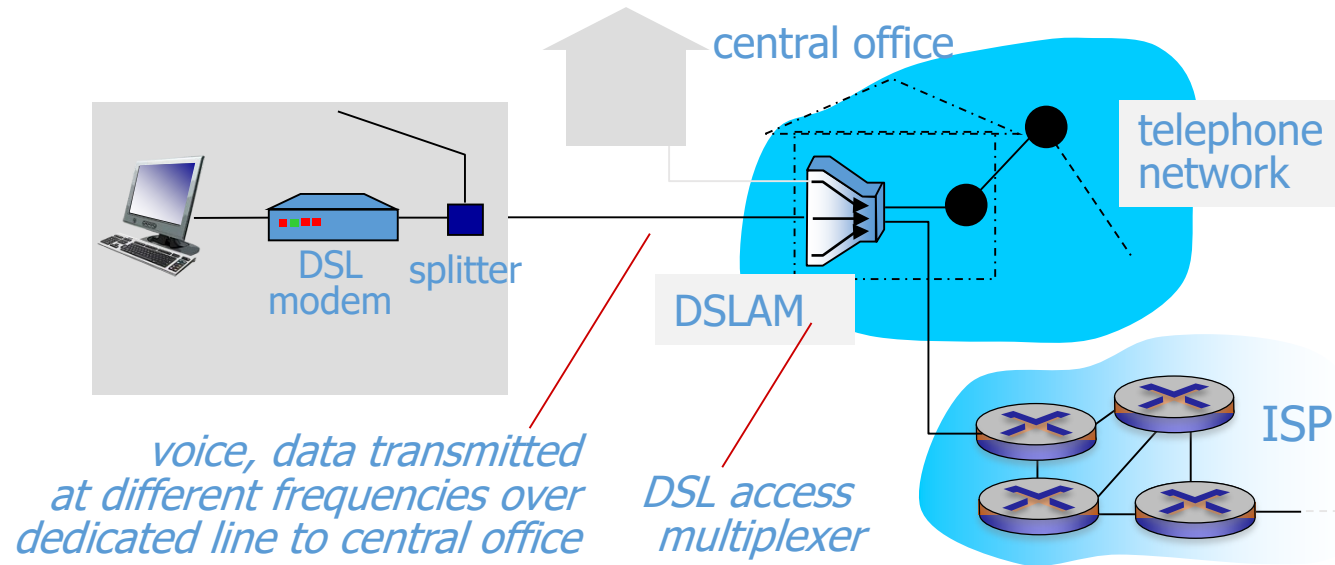
- Residential access networks
- Institutional access networks (school, company)
- Mobile access networks

Keep in mind:

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



Access network: Digital subscriber line (DSL)

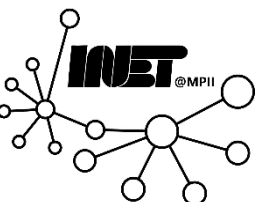


Use **existing** telephone line to central office DSLAM

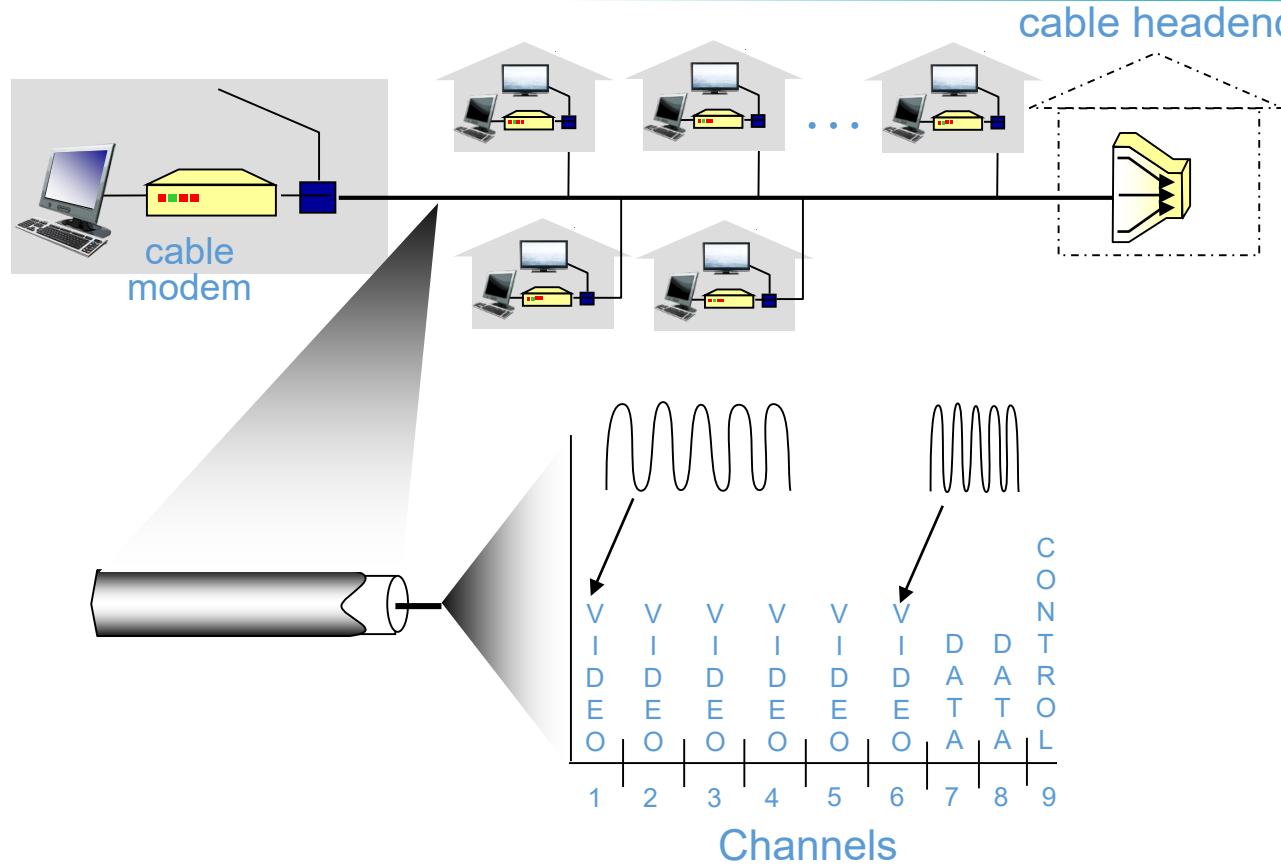
- Data over (v)DSL phone line goes to Internet
- Voice over (v)DSL phone line goes to telephone net via Internet

< 10 Mbps upstream transmission rate (typically < 5 Mbps)

< 100 Mbps downstream transmission rate (typically < 24 Mbps)



Access network: Cable network

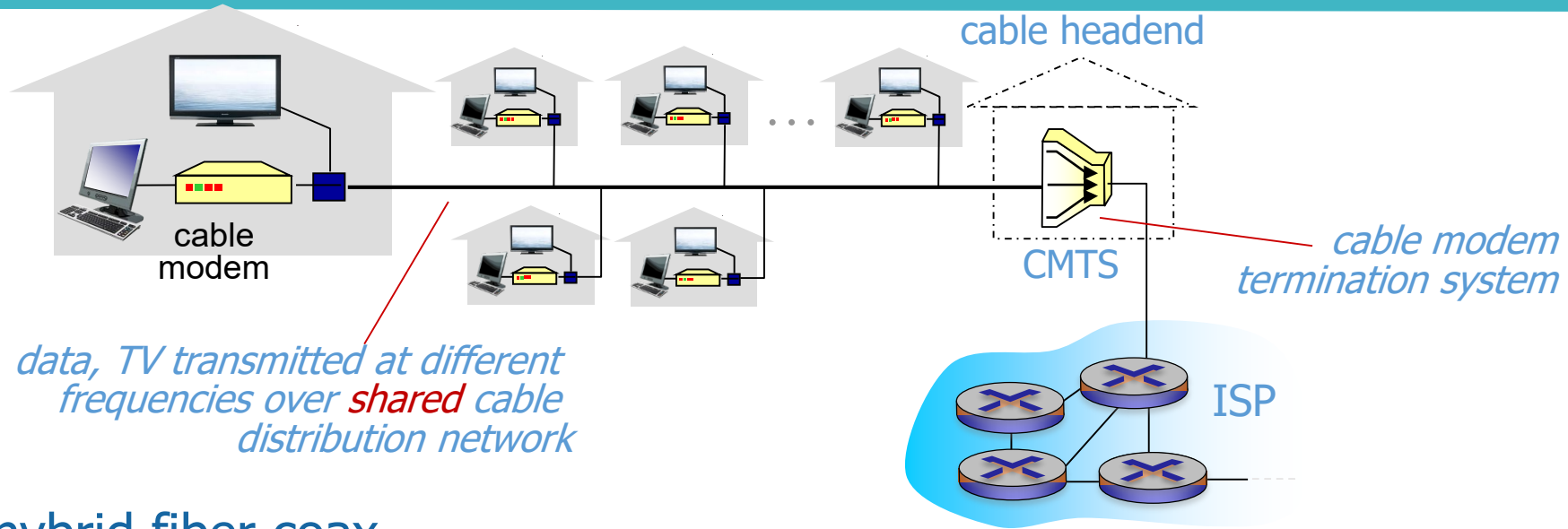


Frequency division multiplexing:

Different channels transmitted in different frequency bands



Access network: Cable network

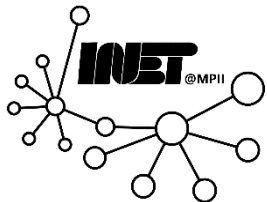


- HFC: hybrid fiber coax

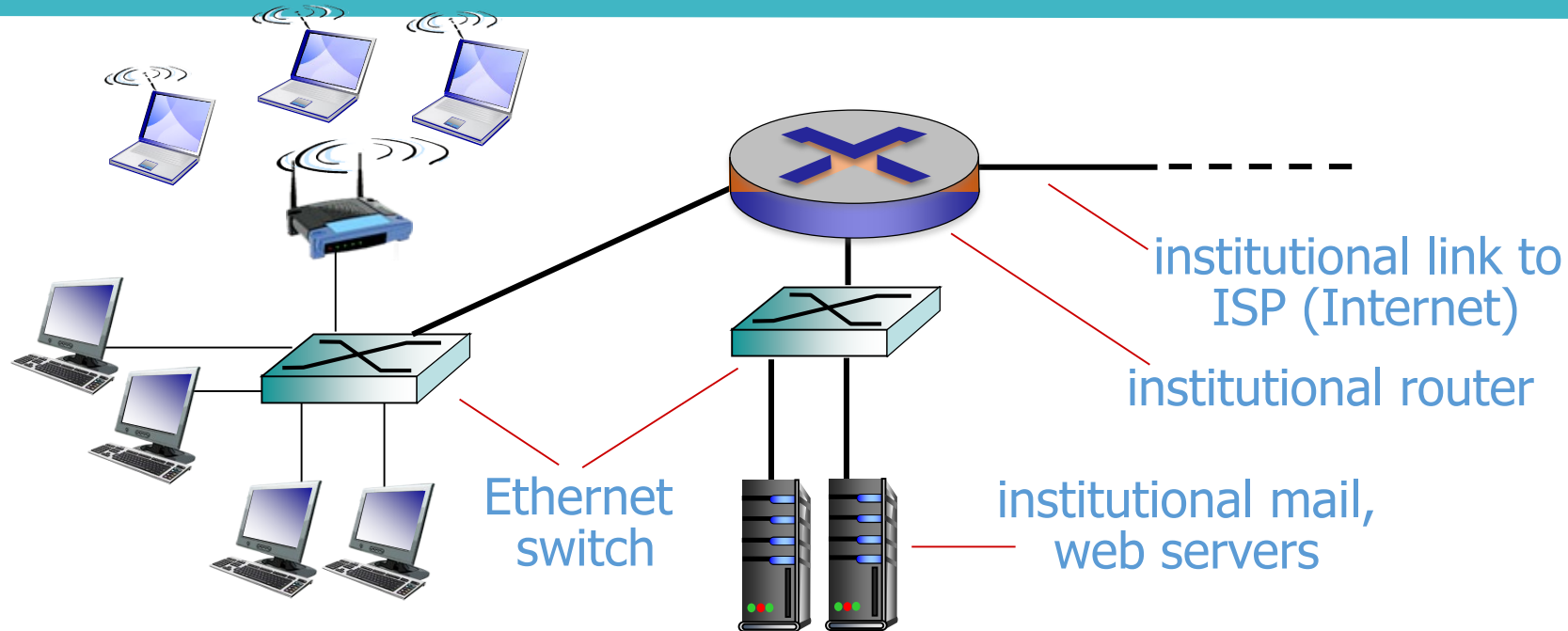
- *Asymmetric:* Up to *30 Mbps downstream* transmission rate, *2 Mbps upstream* transmission rate

- Network of cable, fiber attaches homes to ISP router

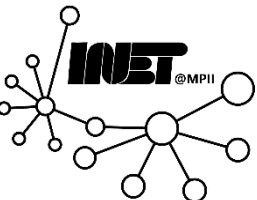
- Homes **share access network** to cable headend
- Unlike DSL, which has dedicated access to central office



Enterprise access networks (Ethernet)



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



Wireless access networks



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

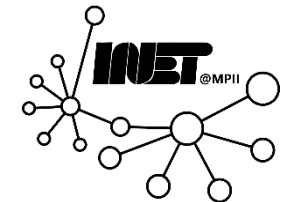
Wireless LANs:

- 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

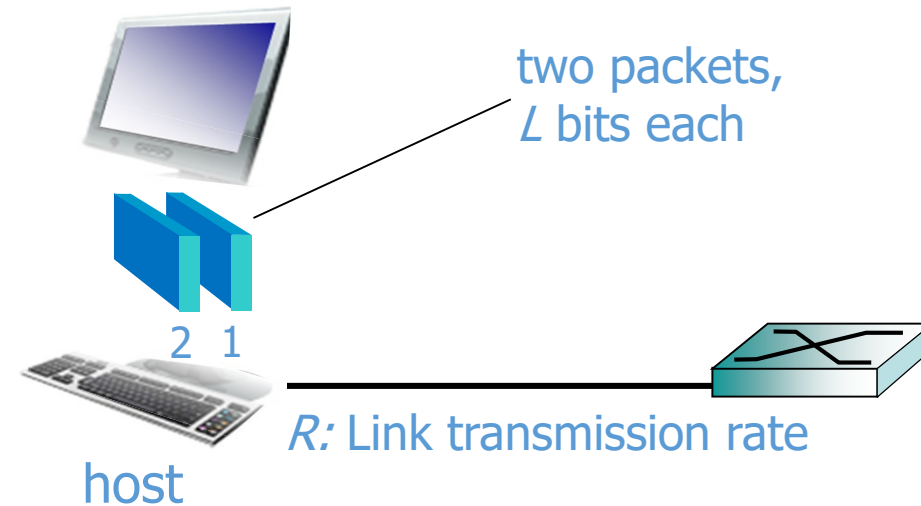


Host: Sends packets of data

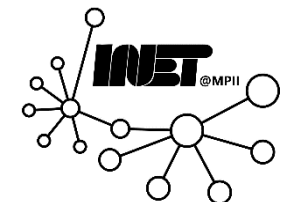


Host sending function:

- 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**



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



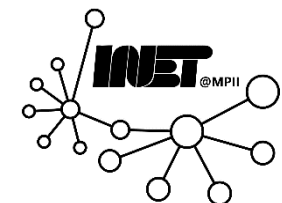
Physical media



- **Bit:**
 - Propagates between transmitter/receiver pairs
- **Physical link:**
 - What lies between transmitter & receiver
- **Guided media:**
 - Signals propagate in solid media: 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: 10 Gbps

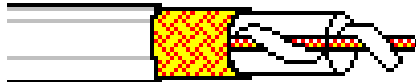


Physical media: Coax, fiber



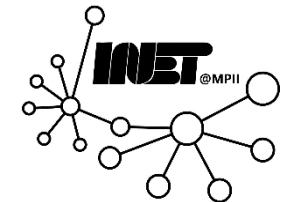
Coaxial cable:

- 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



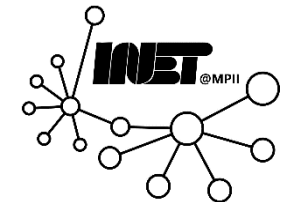
Physical media: Radio



- 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 ms end-to-end delay
 - geosynchronous versus low altitude



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