

# Introduction

COMPSCI 453 **Computer Networks**

Professor Jim Kurose

College of Information and Computer Sciences

University of Massachusetts



- Overview. What *is* the Internet? What *is* a protocol?
- **Network edge**
- Network core
- Performance: loss, delay, throughput
- Protocol layers, service models
- Security
- History

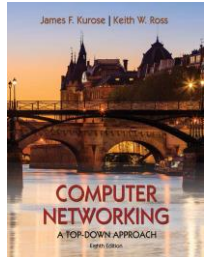
Class textbook:

*Computer Networking: A Top-Down Approach (8<sup>th</sup> ed.)*

J.F. Kurose, K.W. Ross

Pearson, 2020

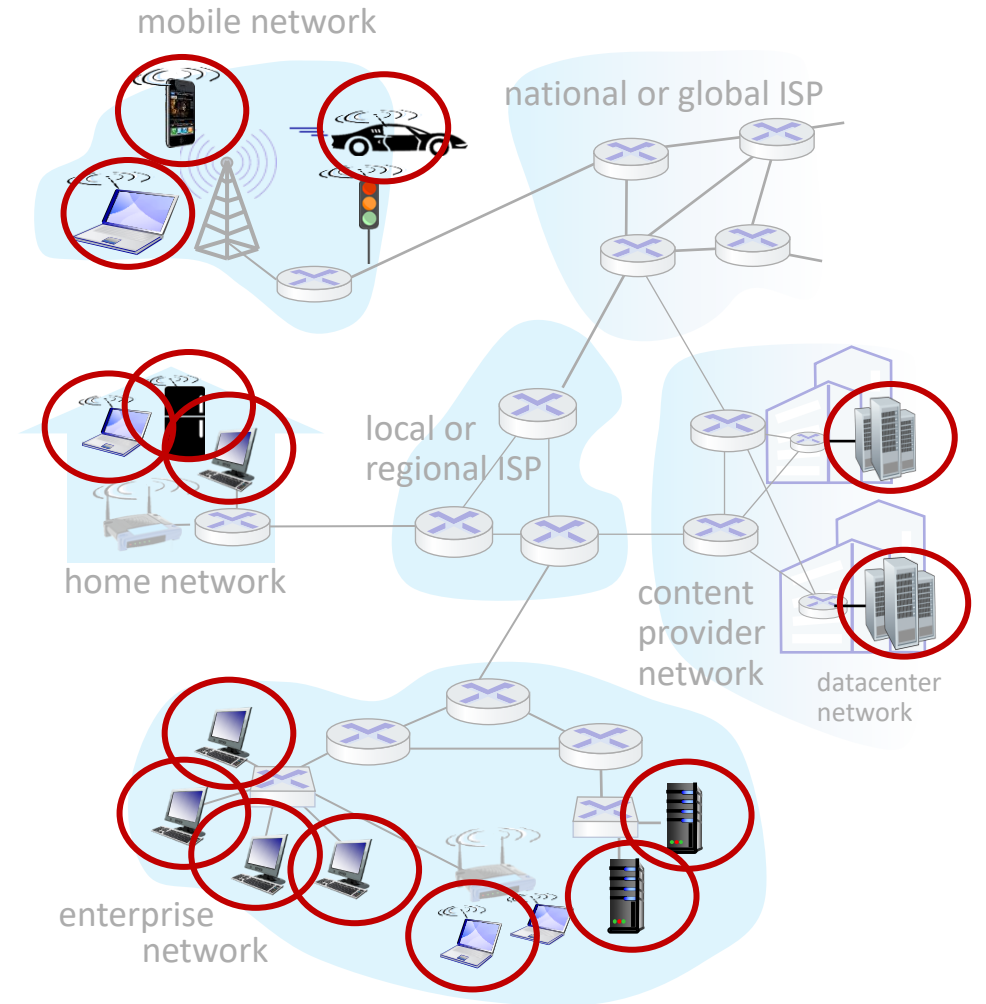
[http://gaia.cs.umass.edu/kurose\\_ross](http://gaia.cs.umass.edu/kurose_ross)



# A closer look at Internet structure

## Network edge:

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



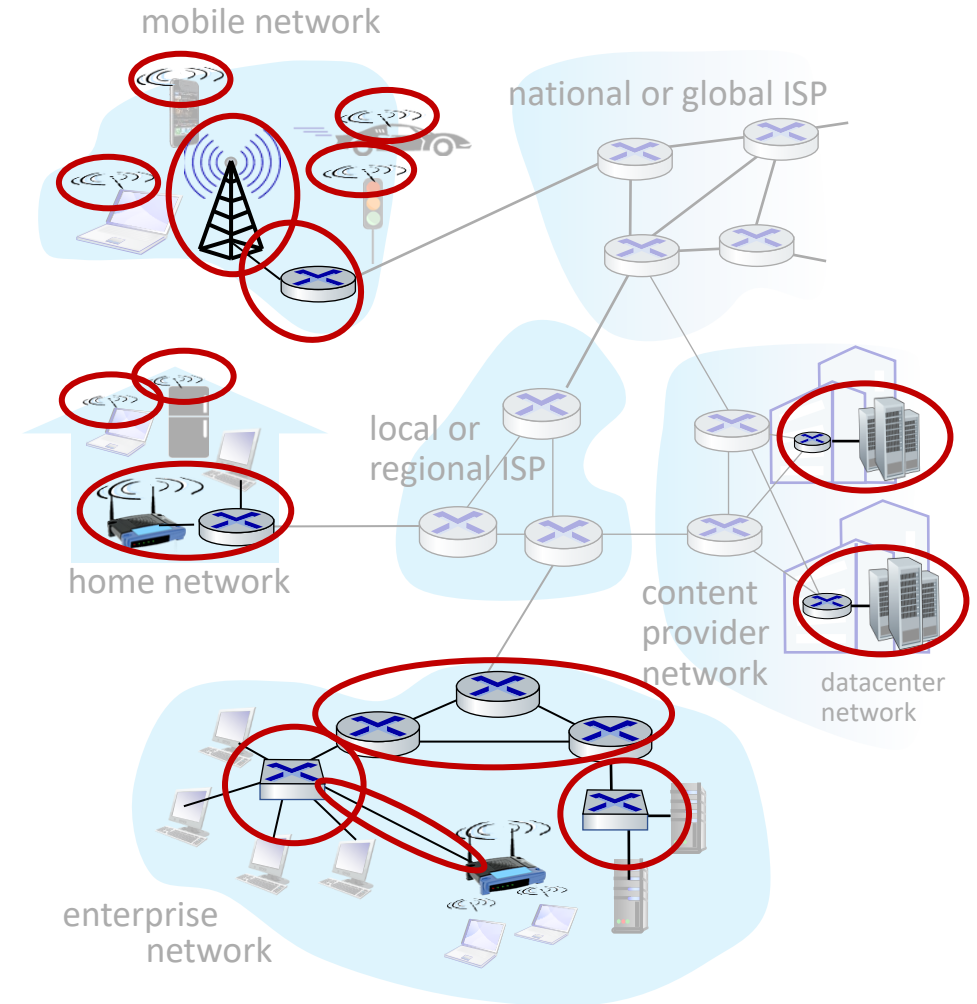
# A closer look at Internet structure

## Network edge:

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## Access networks, physical media:

- wired, wireless communication links



# A closer look at Internet structure

## Network edge:

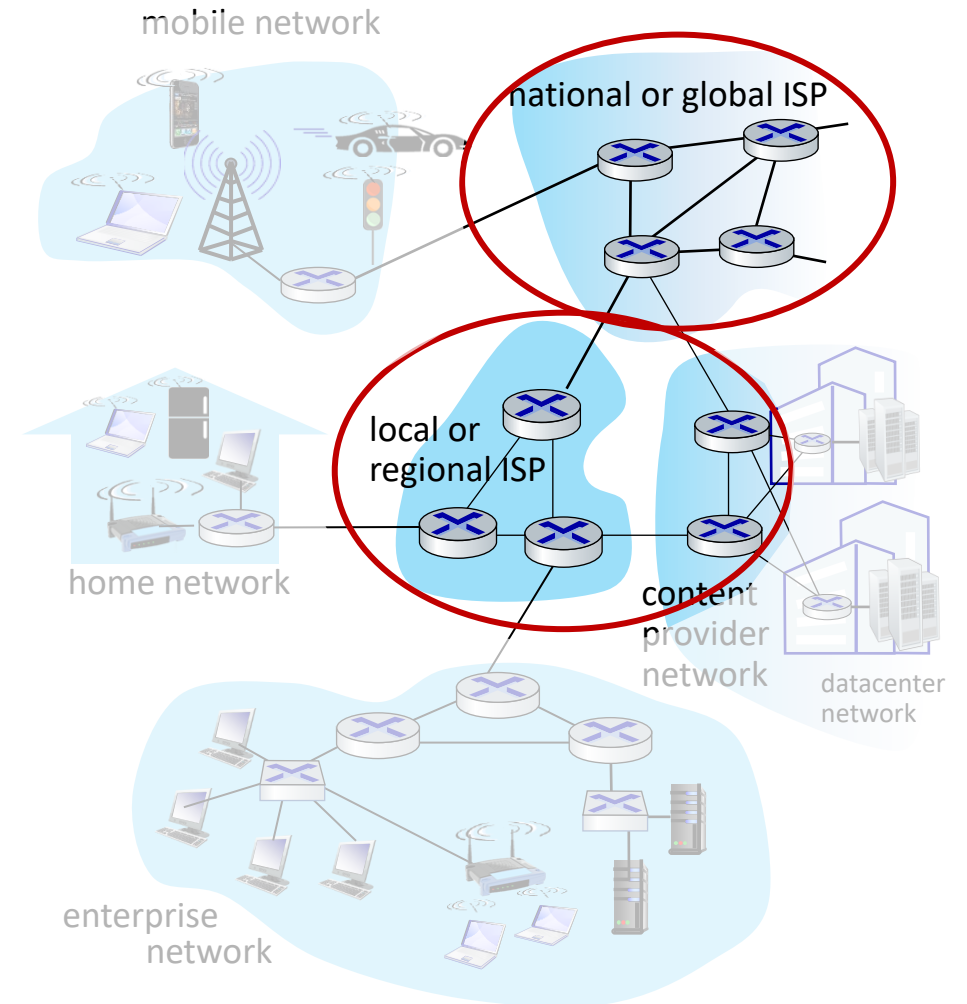
- hosts: clients and servers
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## Access networks, physical media:

- wired, wireless communication links

## Network core:

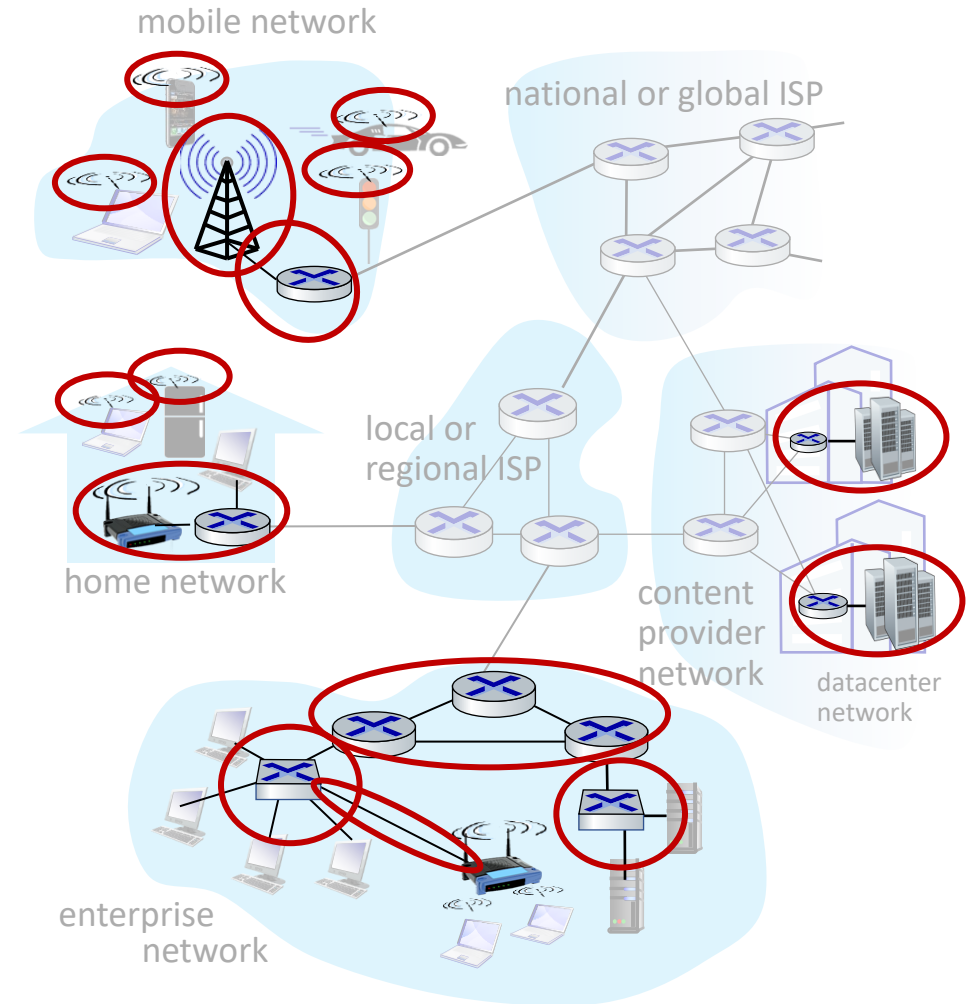
- interconnected routers
- network of networks



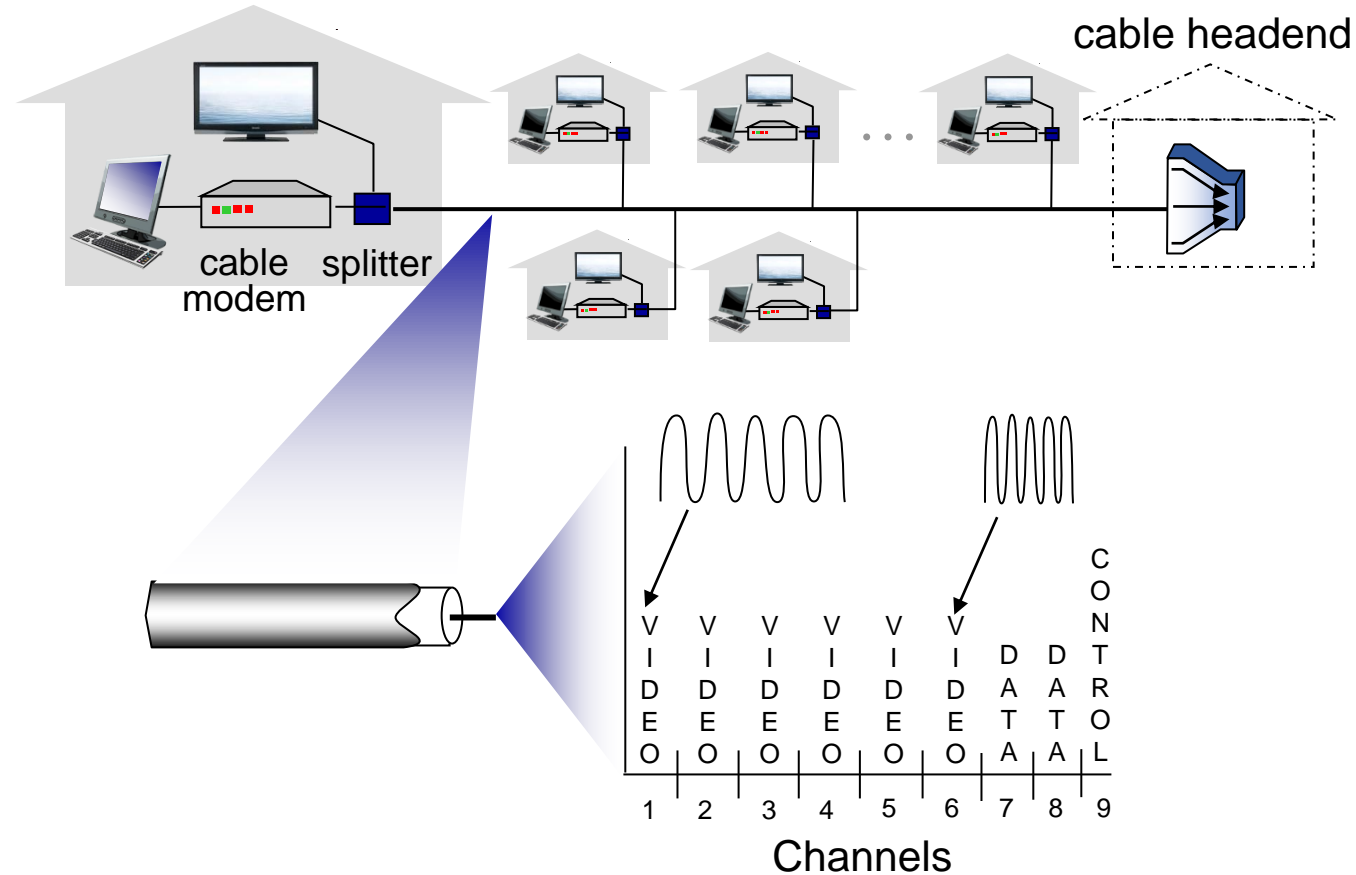
# Access networks and physical media

*Q: How to connect end systems to edge router?*

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

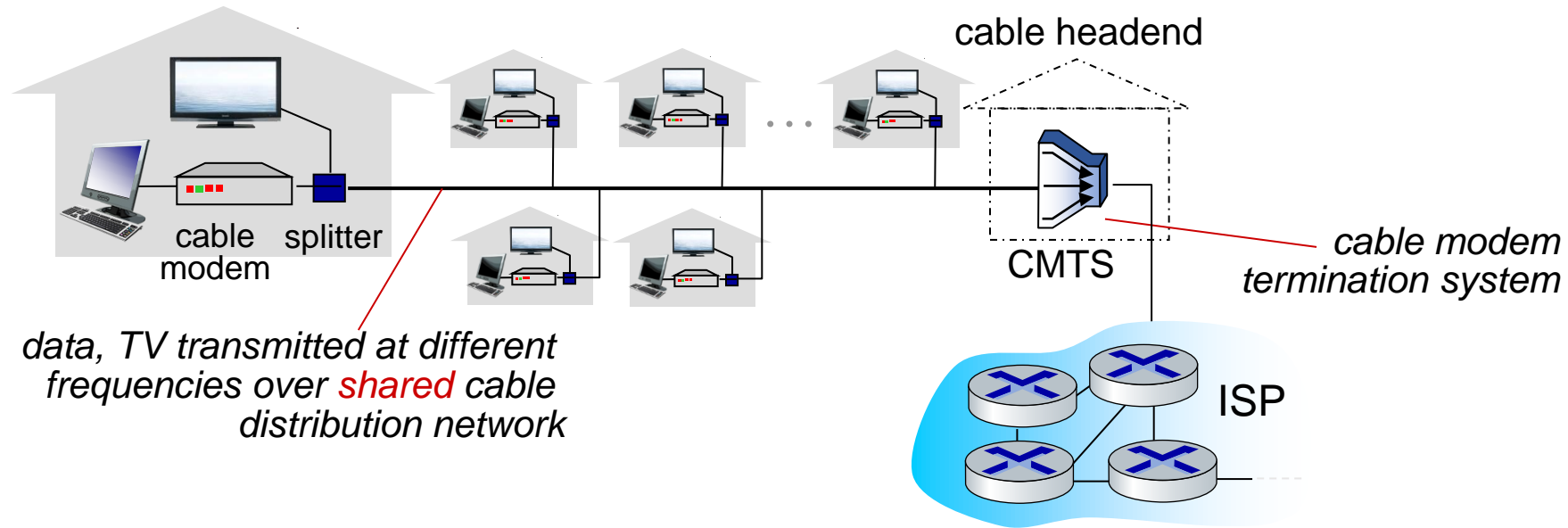


# Access networks: cable-based access



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

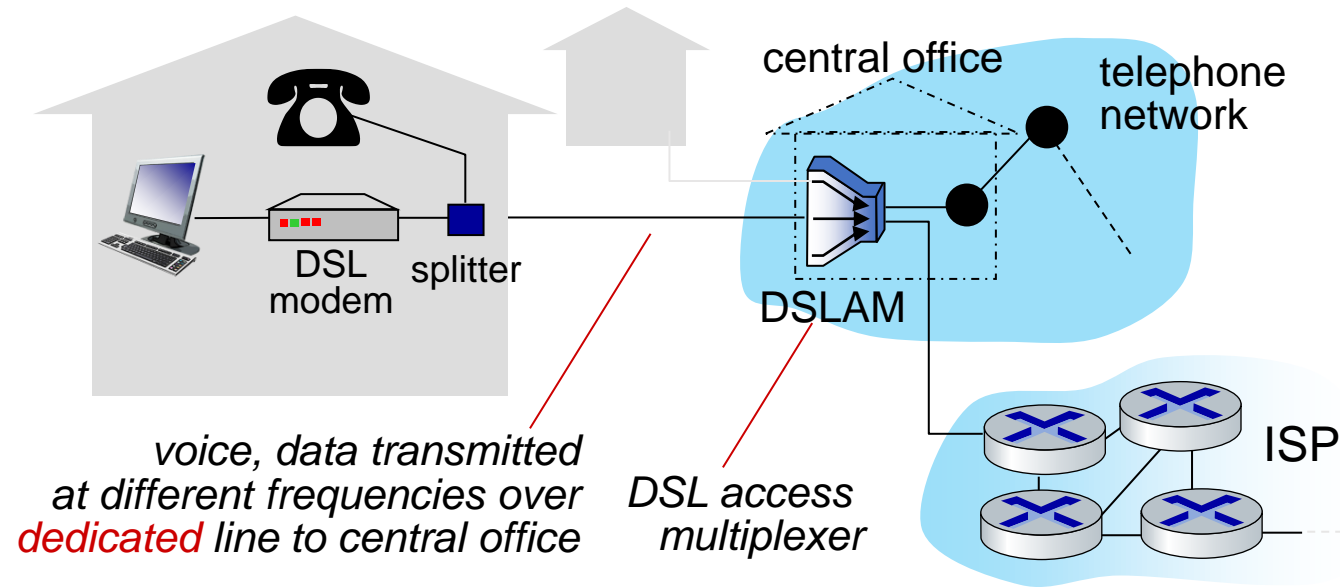
# Access networks: cable-based access



## ■ HFC: hybrid fiber coax

- asymmetric: up to 40 Mbps – 1.2 Gbs 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

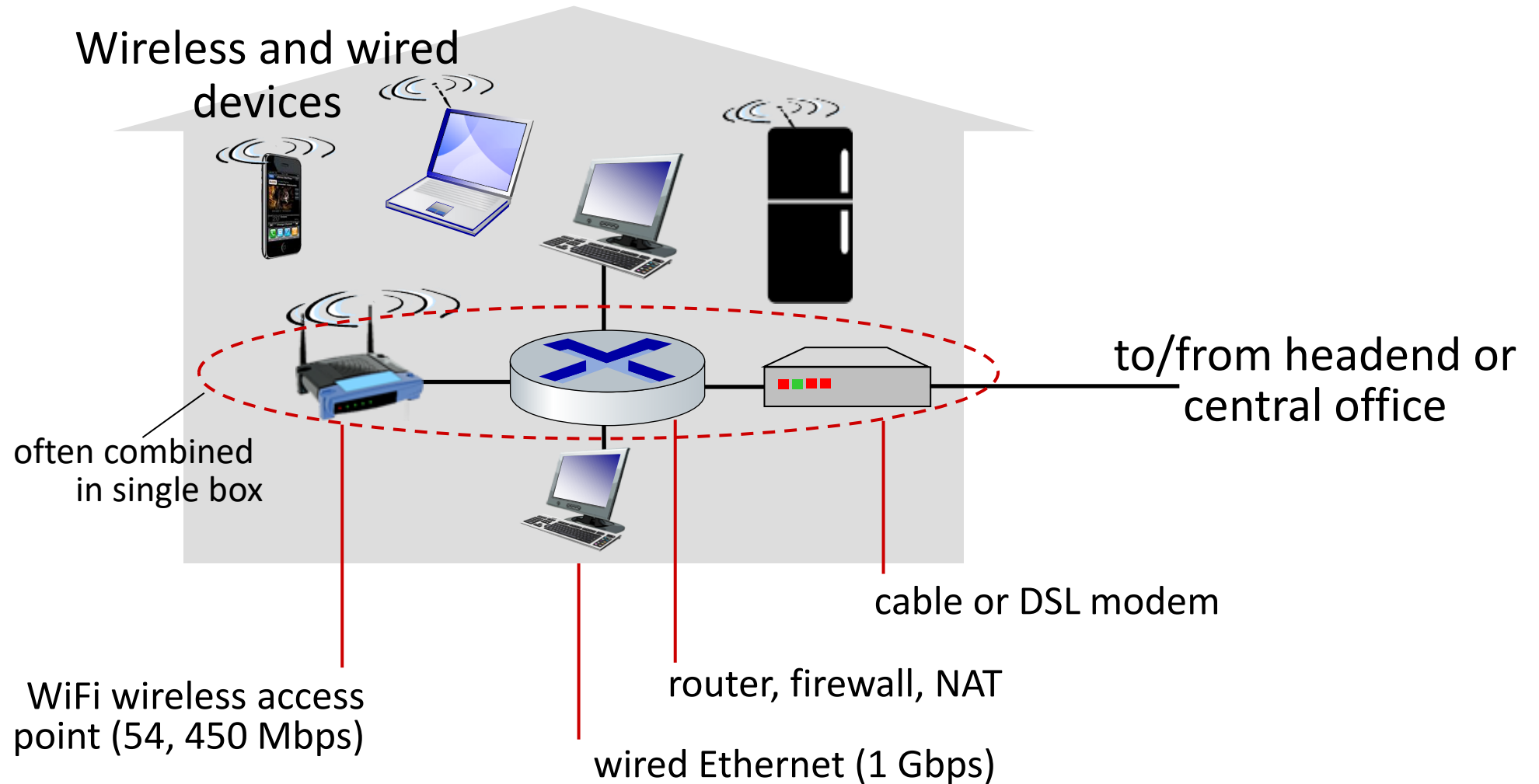
# Access networks: digital subscriber line (DSL)



- 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



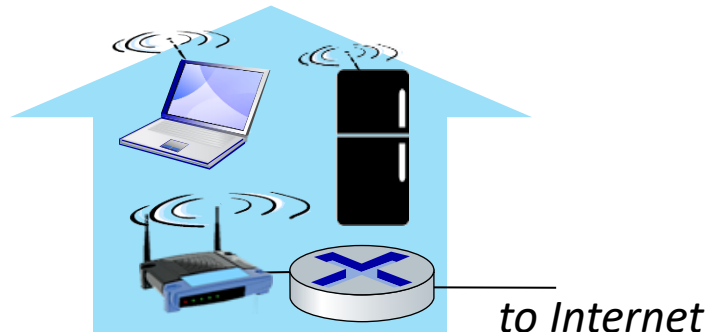
# Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

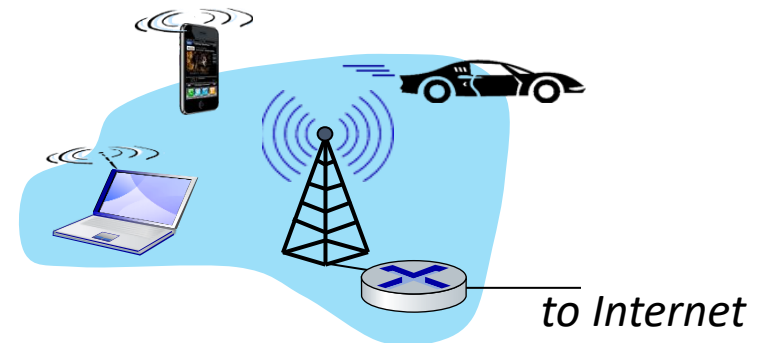
## Wireless local area networks (WLANs)

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

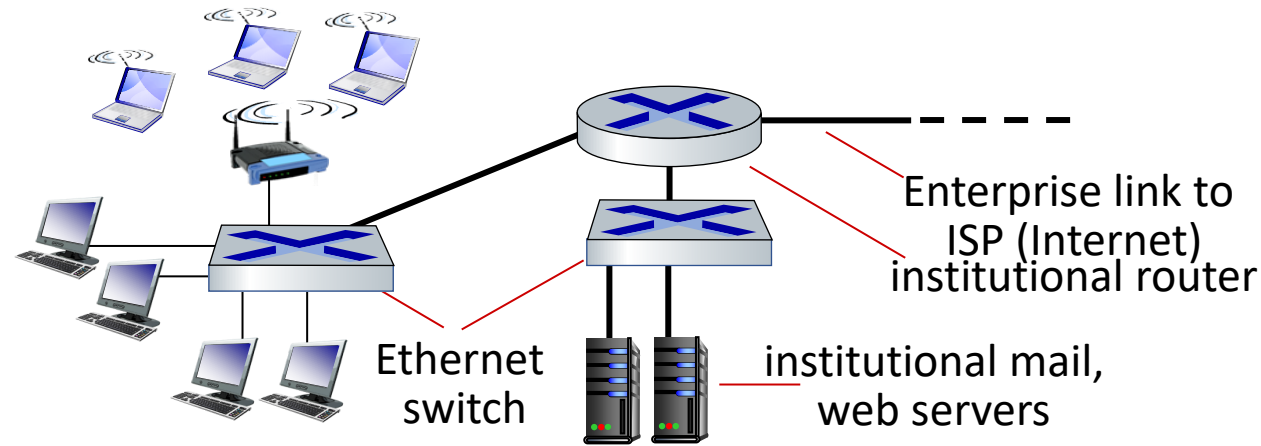


## Wide-area cellular access networks

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



# Access networks: enterprise networks



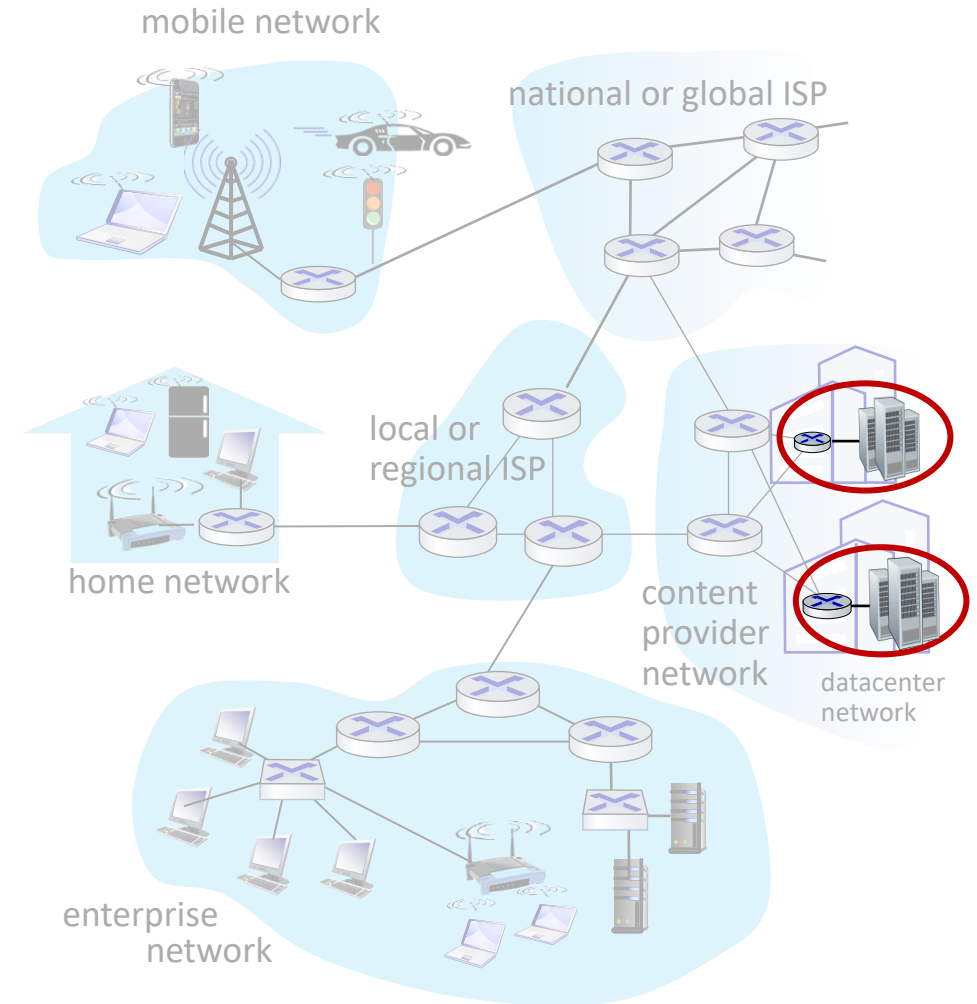
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
  - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps

# Access networks: data center networks

- high-bandwidth links (10s to 100s Gbps) connect hundreds to thousands of servers together, and to Internet



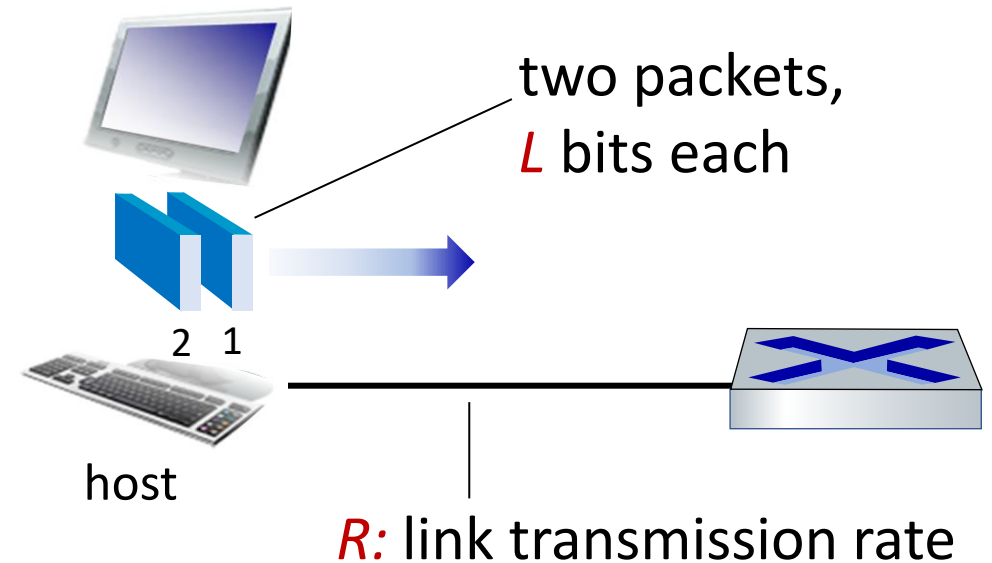
Courtesy: Massachusetts Green High Performance Computing Center ([mghpcc.org](http://mghpcc.org))



# 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*



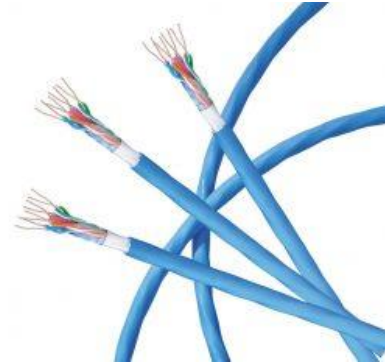
$$\begin{array}{l} \text{packet} \\ \text{transmission} \\ \text{delay} \end{array} = \begin{array}{l} \text{time needed to} \\ \text{transmit } L\text{-bit} \\ \text{packet into link} \end{array} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

# 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

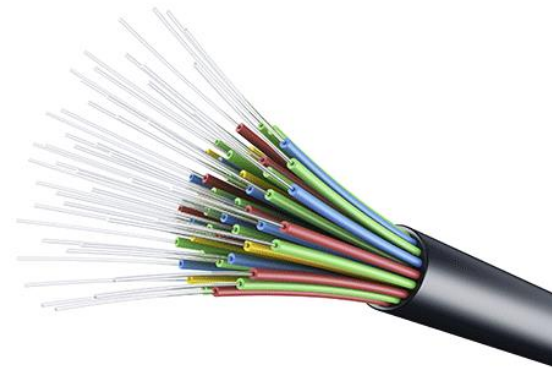
## Coaxial cable:

- 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 cellular)
  - 10’s Mbps over ~10 Km
- **Bluetooth**: cable replacement
  - short distances, limited rates
- **terrestrial microwave**
  - point-to-point; 45 Mbps channels
- **satellite**
  - up to 45 Mbps per channel
  - 270 msec end-end delay



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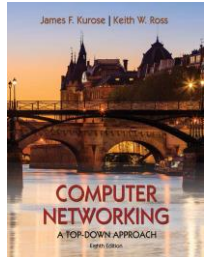
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