

Advanced Computer Networks

Introduction: Basics of Computer Networks

Part 1

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Fall 1401

Introduction

Lecture goal:

- A Review of basic concepts in computer networking

- **Note:** The slides are adapted from the book and supplementary slides of:
- Kurose, J.F. and Ross, K.W. Computer Networking: A Top-Down Approach. Addison Wesley. 2020.

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Overview/roadmap:

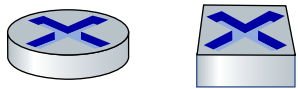
- What is the Internet? What is a protocol?
- **Network edge:** hosts, access network, physical media
- **Network core:** packet/circuit switching, internet structure
- **Performance:** loss, delay, throughput
- Protocol layers, service models

The Internet: a “nuts and bolts” view



Billions of connected computing *devices*:

- *hosts* = end systems
- running *network apps* at Internet's “edge”



Packet switches: forward packets (chunks of data)

- *routers, switches*

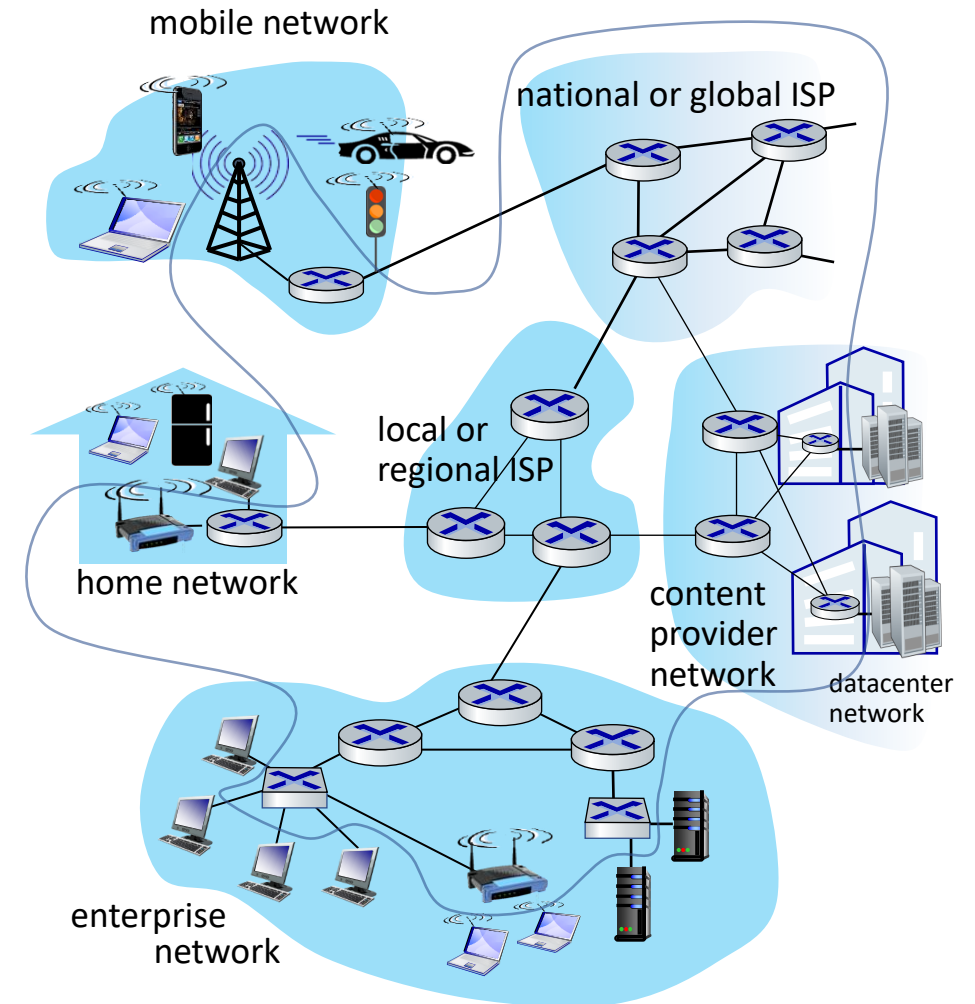
Communication links

- fiber, copper, radio, satellite
- transmission rate: *bandwidth*



Networks

- collection of devices, routers, links: managed by an organization



“Fun” Internet-connected devices



Amazon Echo



Internet refrigerator



IP picture frame



Pacemaker & Monitor



Tweet-a-watt:
monitor energy use

bikes



Security Camera



Slingbox: remote control cable TV



Web-enabled toaster +
weather forecaster



AR devices



cars



scooters



Internet phones



Gaming devices



sensorized,
bed
mattress

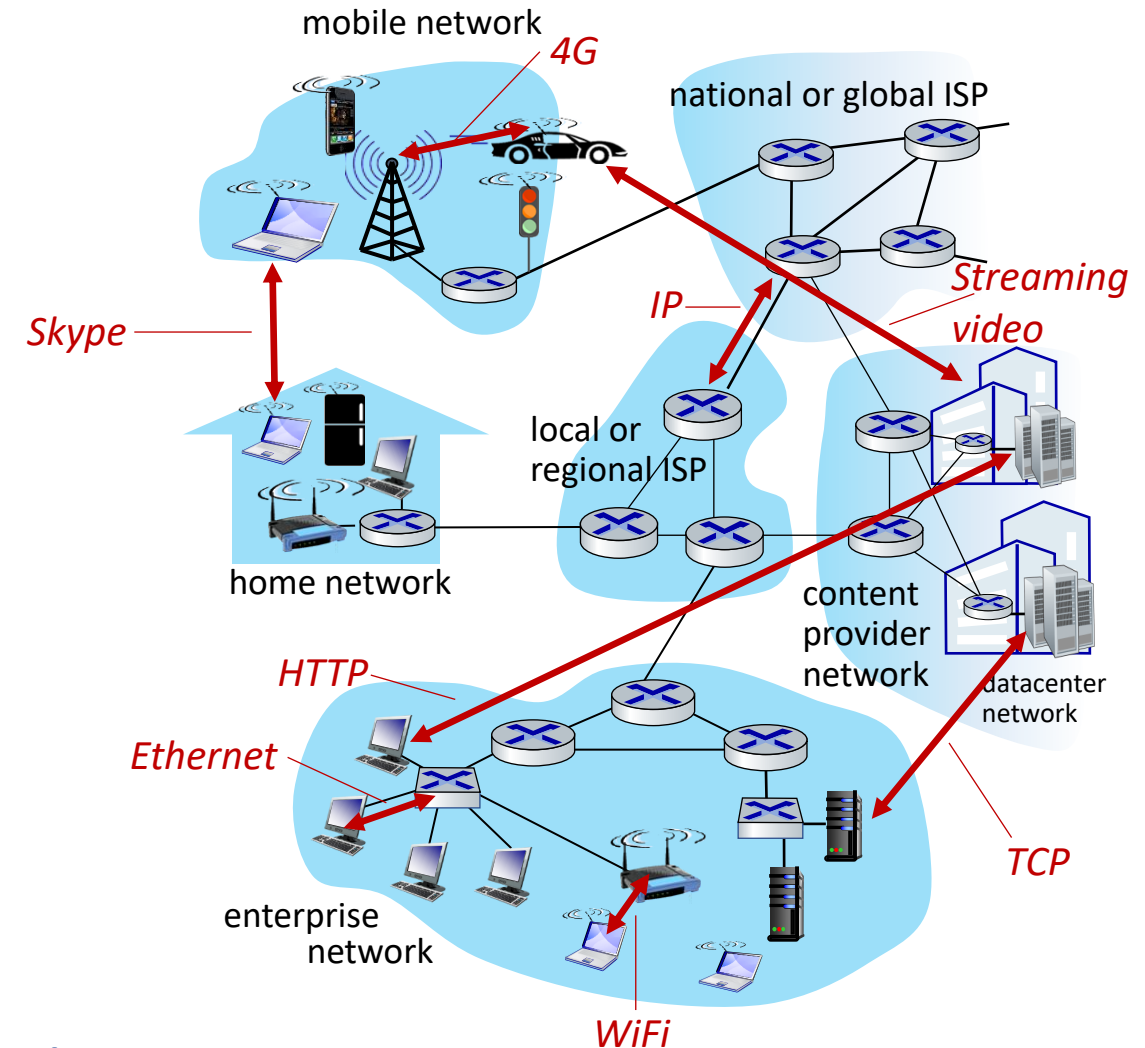


Fitbit

Others?

The Internet: a “nuts and bolts” view

- *Internet: “network of networks”*
 - Interconnected ISPs
- *protocols* are everywhere
 - control sending, receiving of messages
 - e.g., HTTP (Web), streaming video, Skype, TCP, IP, WiFi, 4G, Ethernet
- *Internet standards*
 - RFC: Request for Comments
 - IETF: Internet Engineering Task Force
 - IEEE 802: Link and Physical layer



The Internet: a “nuts and bolts” view

■ *Internet standards*

- **IETF:** Internet Engineering Task Force (ietf.org)
 - In short: The committee behind standardization of the Internet.
 - Description: A large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet.
 - Goal and Mission: The mission of the IETF is to make the Internet work better by producing high quality, relevant technical documents that influence the way people design, use, and manage the Internet.
- The IETF (Internet Engineering Task Force) is a standardization body focused on the development of protocols used on **IP-based networks**.



The Internet: a “nuts and bolts” view

■ *Internet standards*

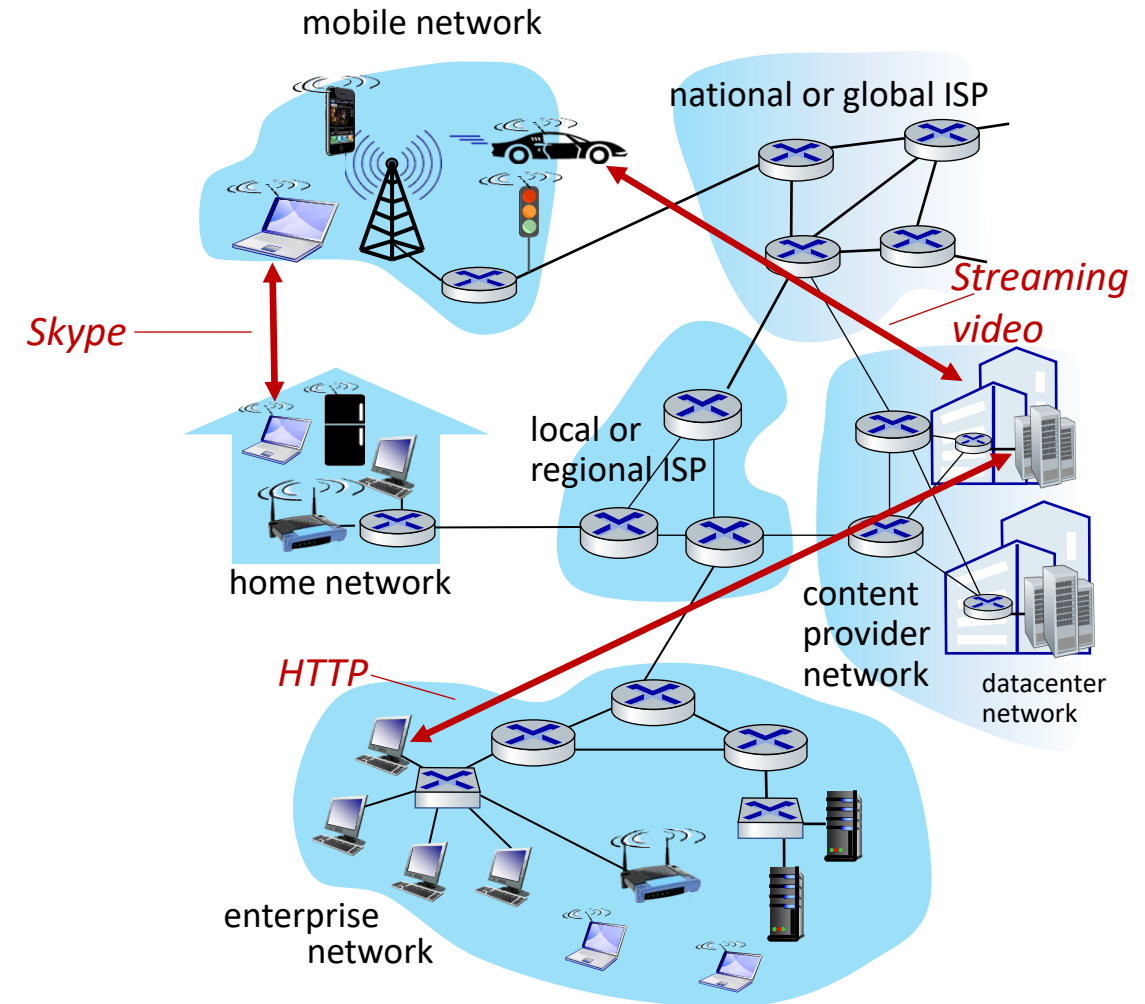
- **RFC:** Request for Comments

In short: The standards in Internet

- RFCs produced by the IETF cover many aspects of computer networking.
- They describe the Internet's technical foundations, such as addressing, routing, and transport technologies. RFCs also specify protocols like TLS 1.3, QUIC, and WebRTC that are used to deliver services used by billions of people every day, such as real-time collaboration, email, and the domain name system.
- **Only** some RFCs are standards. Depending on their maturity level and what they cover, RFCs are labeled with different statuses: Internet Standard, Proposed Standard, Best Current Practice, Experimental, Informational, and Historic.
- The first document in this series, RFC 1, was written in 1969. (<https://www.rfc-editor.org/rfc/rfc1>)

The Internet: a “services” view

- *Infrastructure* that provides services to applications:
 - Web, streaming video, multimedia teleconferencing, email, games, e-commerce, social media, inter-connected appliances, ...
- provides *programming interface* to distributed applications:
 - allowing sending/receiving apps to “connect” to, use Internet transport service
 - provides service options, analogous to postal service



What's a protocol?

Human protocols:

- “what’s the time?”
- “I have a question”
(Question asking protocol)
- introductions

Rules for:

- ... specific messages sent
- ... specific actions taken
when message received,
or other events

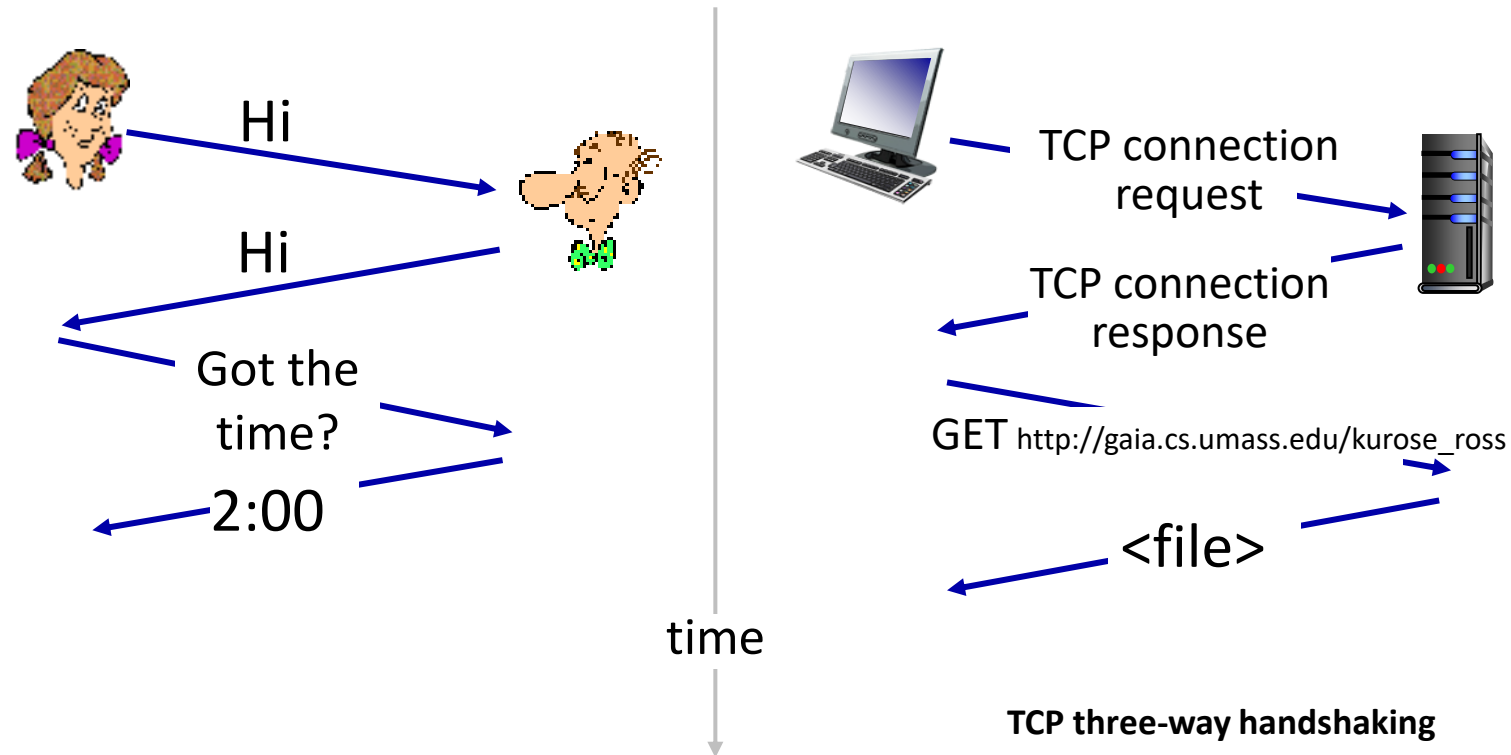
Network protocols:

- computers (devices) rather than humans
- all communication activity in Internet
governed by protocols

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

What's a protocol?

A human protocol and a computer network protocol:

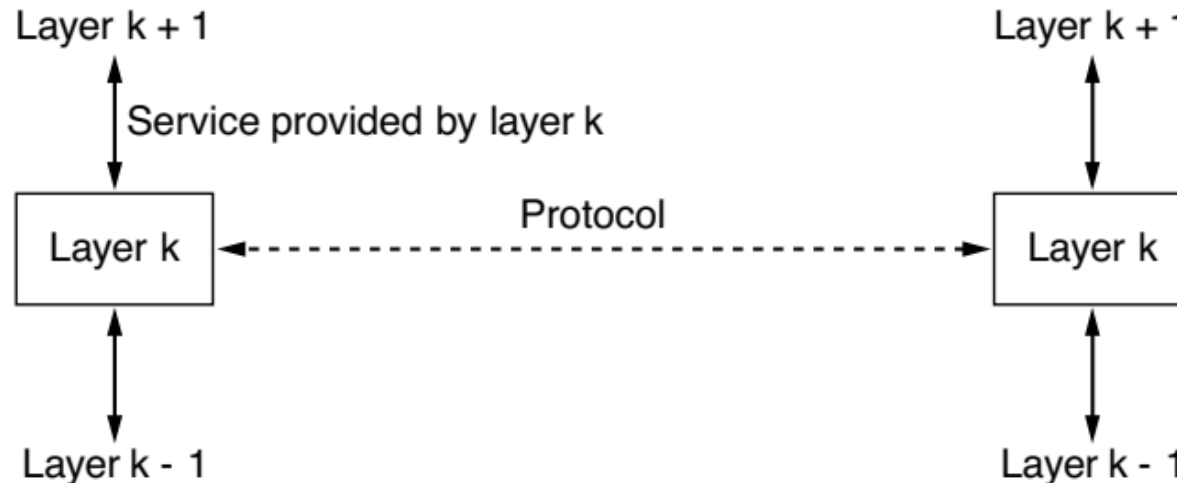


Q: other human protocols?

What's a protocol?

The relation between service and protocol

- A service is offered by a layer to its adjacent layer. Example: Reliable in-order transmission of data messages.
- A protocol works between to peer layers in two devices. Example: TCP



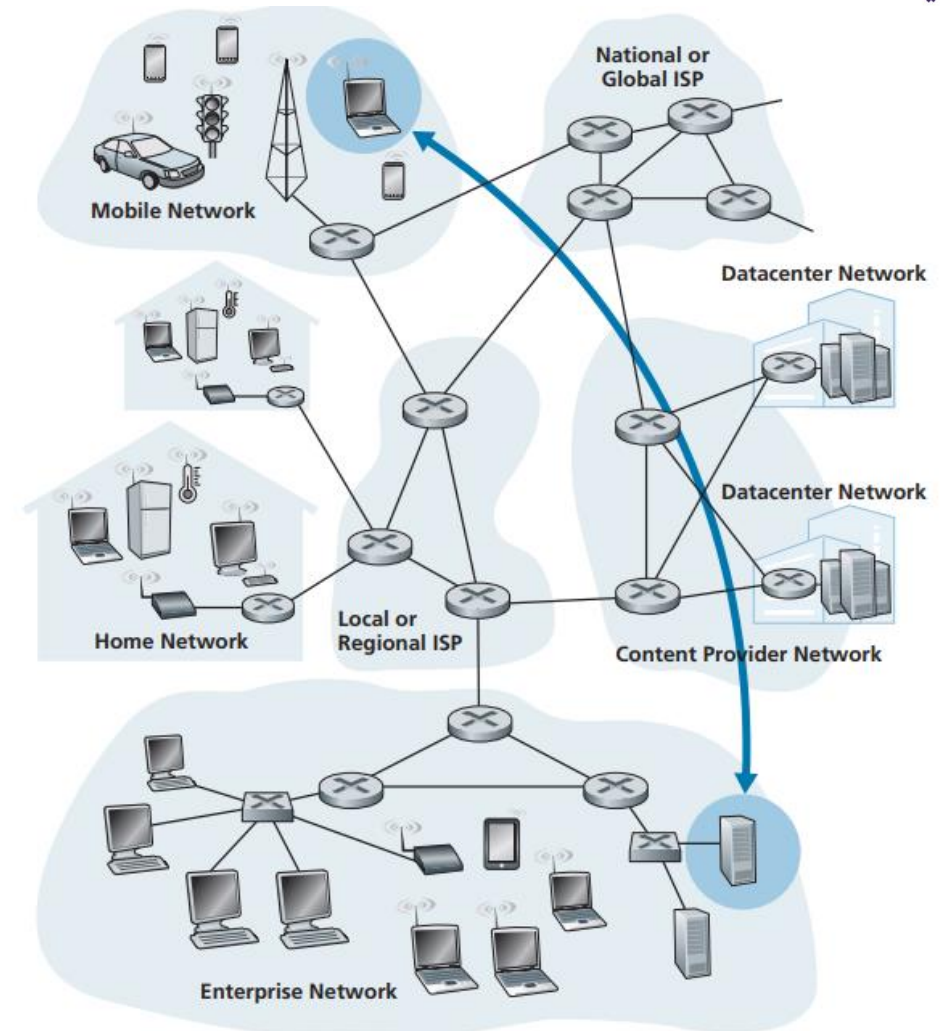
Introduction: roadmap

- 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:

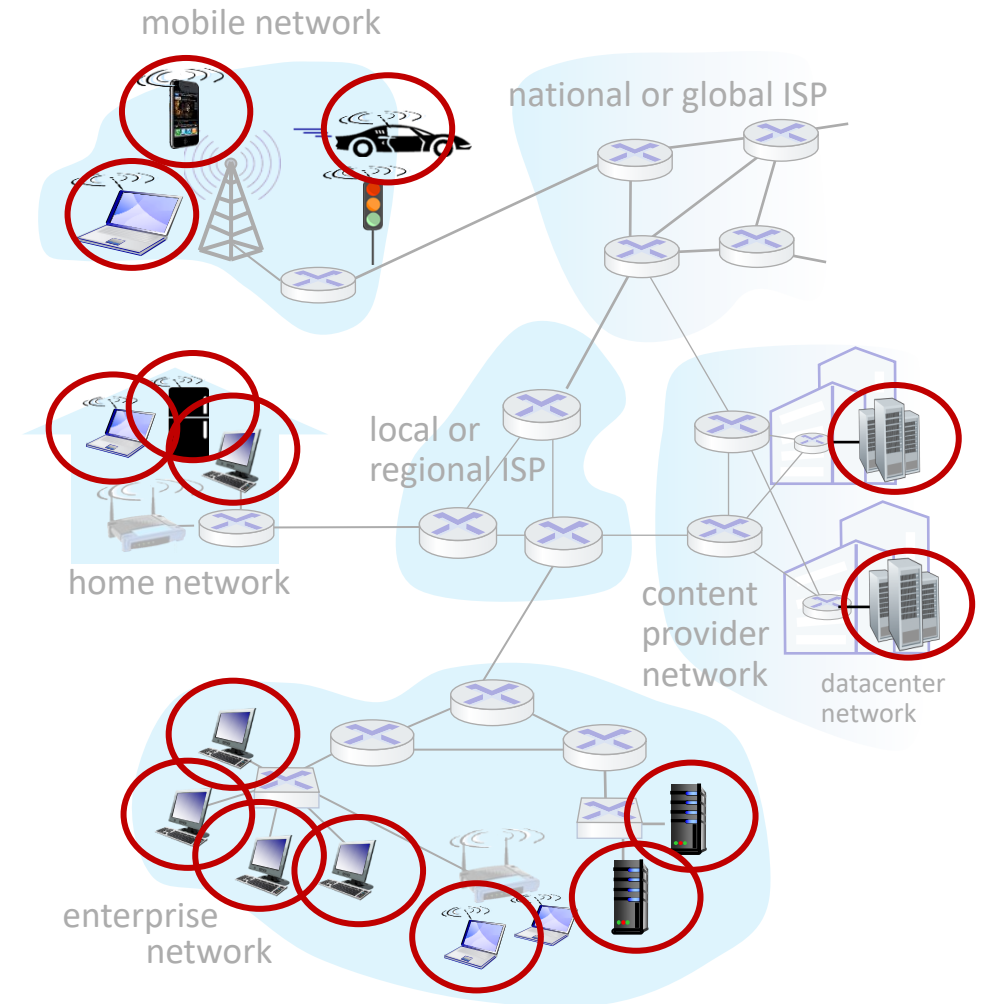
- End-system interaction
- They are referred to as end systems because they sit at the edge of the Internet, as shown in the Figure.



A closer look at Internet structure

Network edge:

- *End-system = host*
- hosts : clients and servers
- They are named hosts as they run applications.
- servers often in data centers



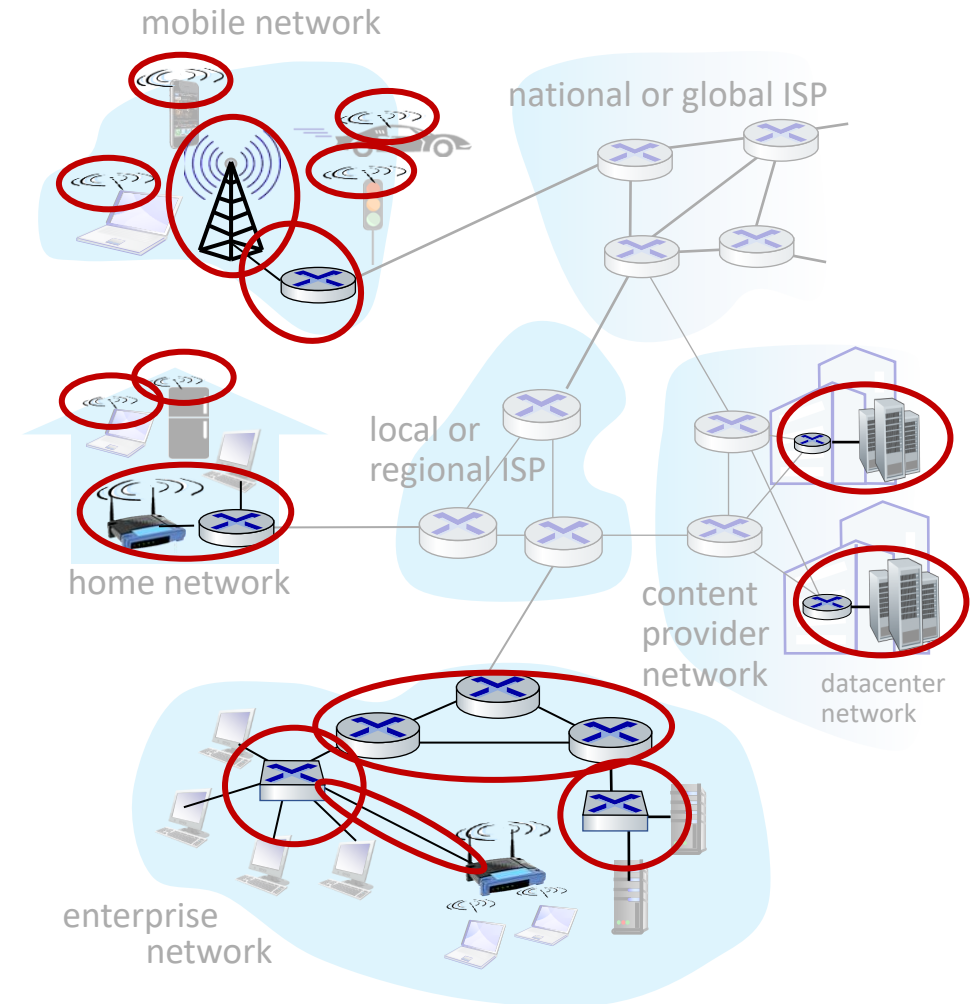
A closer look at Internet structure

Network edge:

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

Access networks, physical media:

- wired, wireless communication links



A closer look at Internet structure

Network edge:

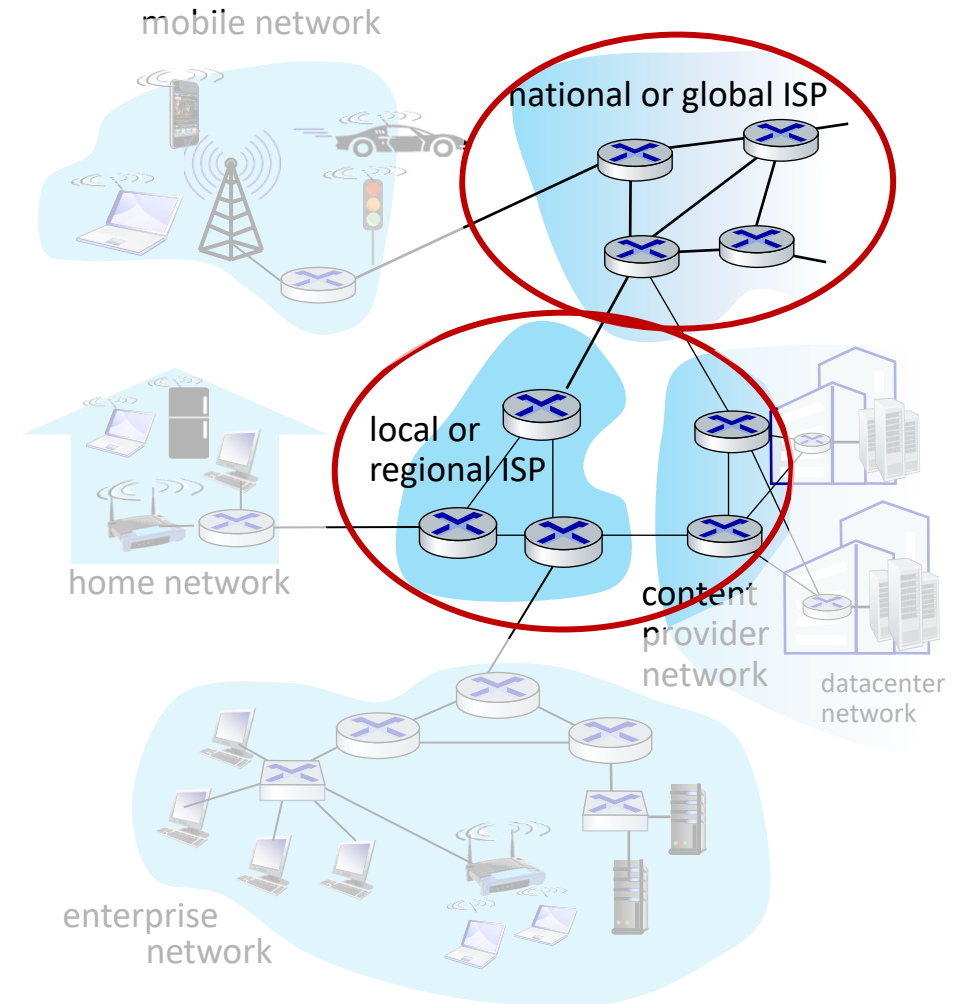
- hosts: clients and servers
- servers often in data centers

Access networks, physical media:

- wired, wireless communication links

Network core:

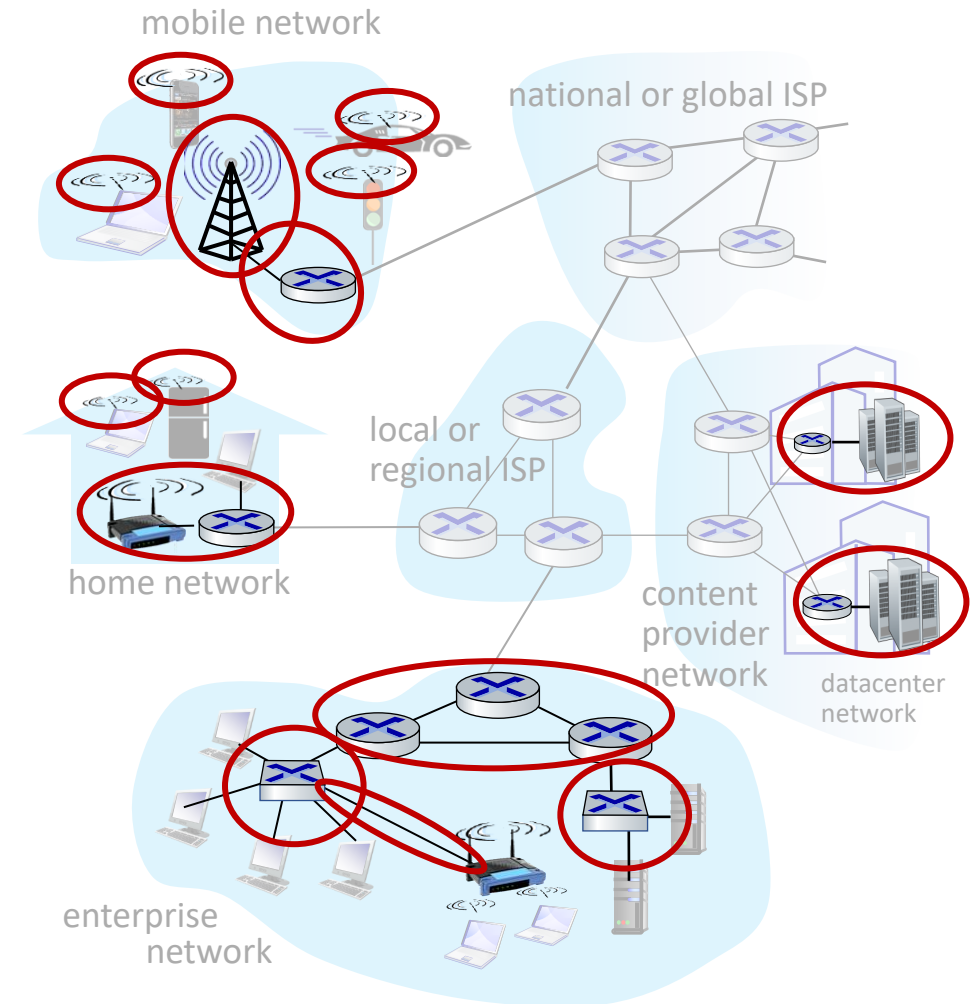
- interconnected routers
- network of networks



Access networks and physical media

Q: How to connect end systems to edge router?

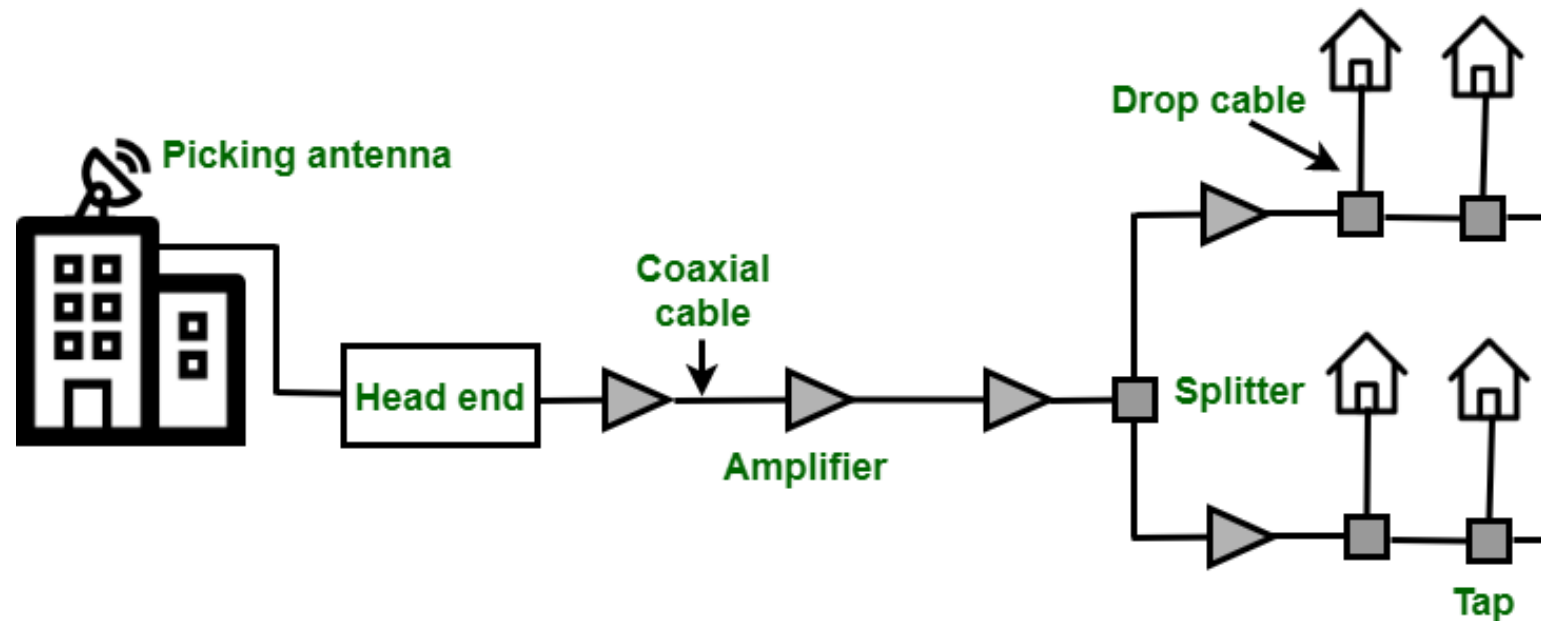
- residential access nets
- institutional access networks (school, company)
- mobile access networks (WiFi, 4G/5G)



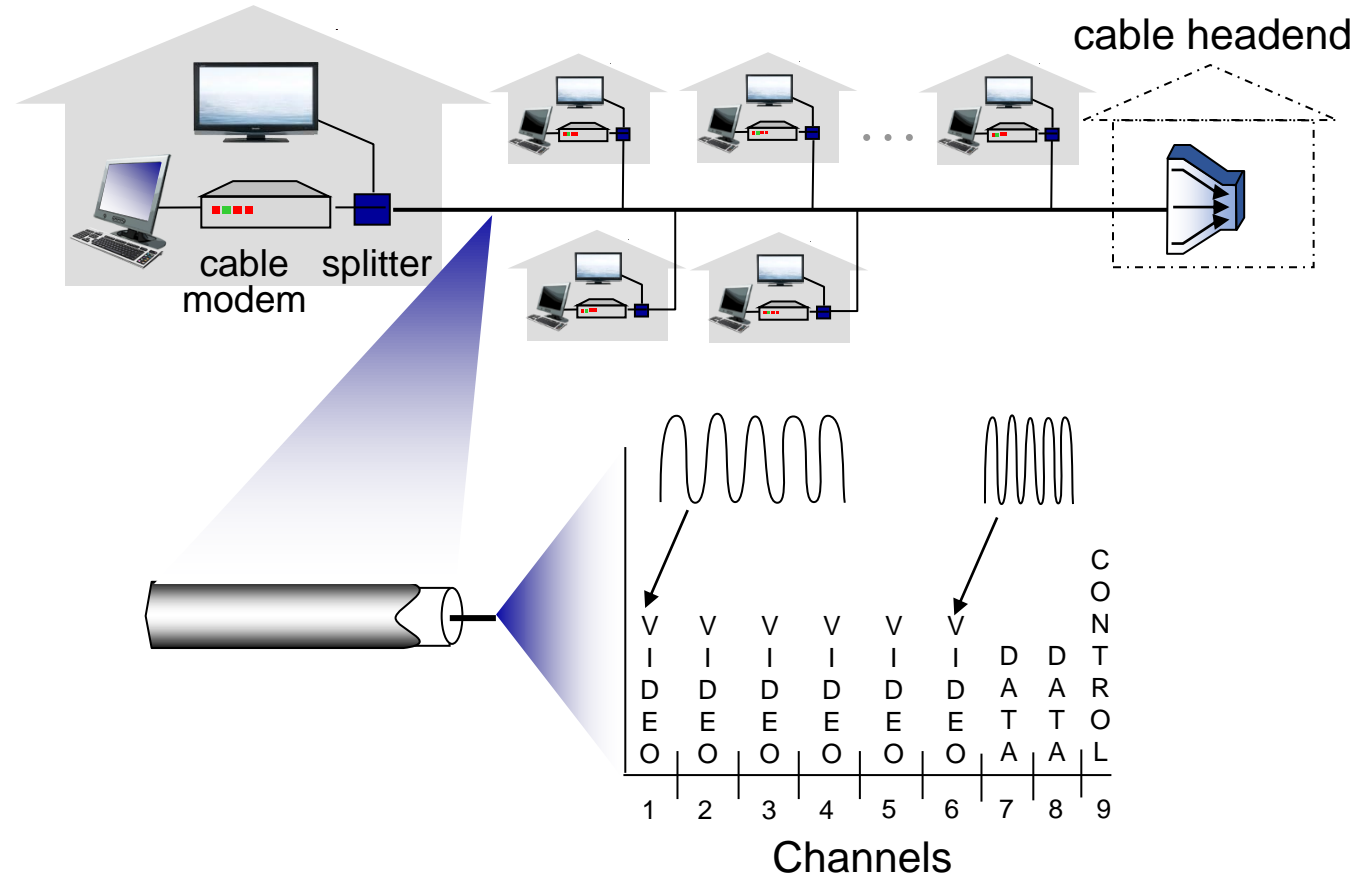
Access networks: cable-based access

Cable TV:

- A previously popular and wide-spread method of delivering on-demand video and TV services.



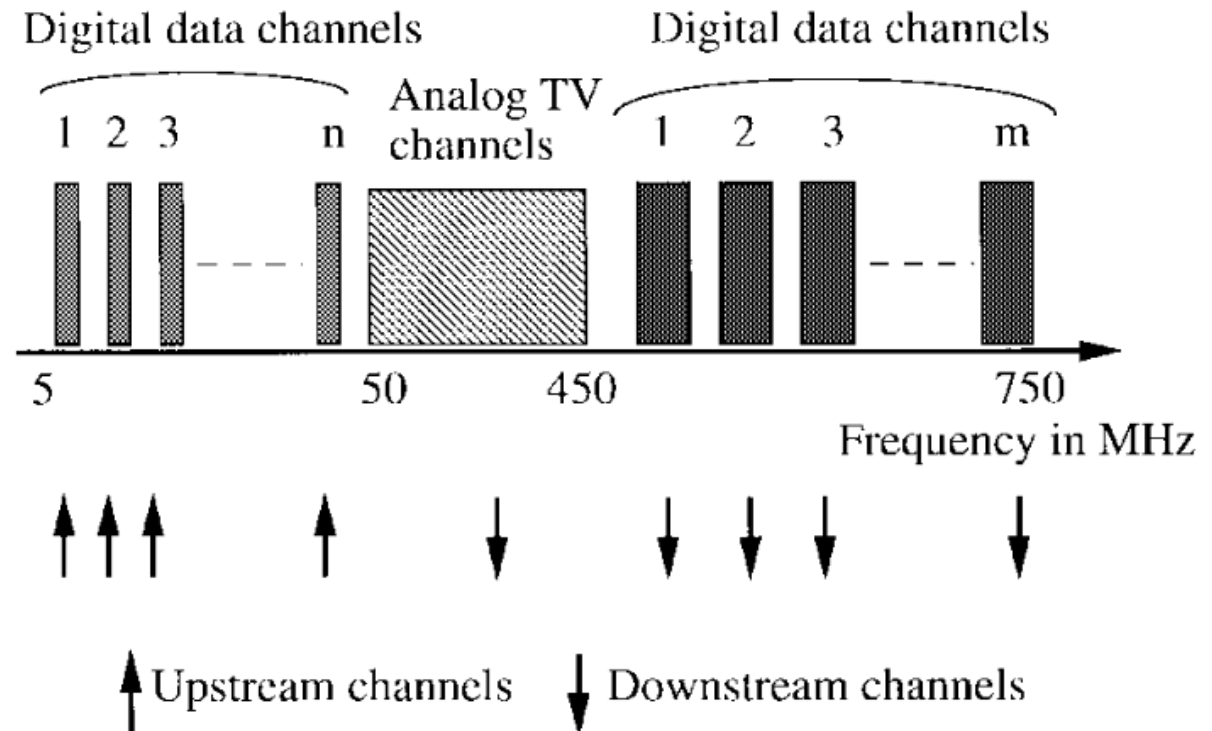
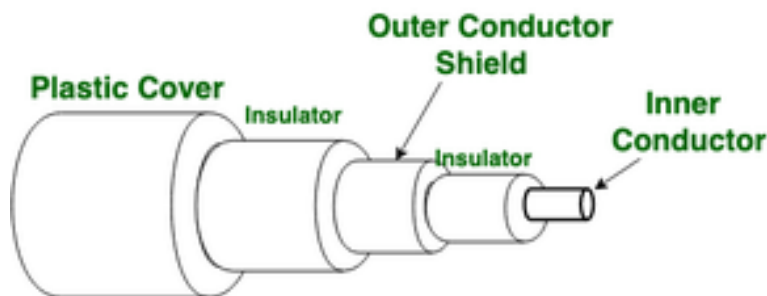
Access networks: cable-based access



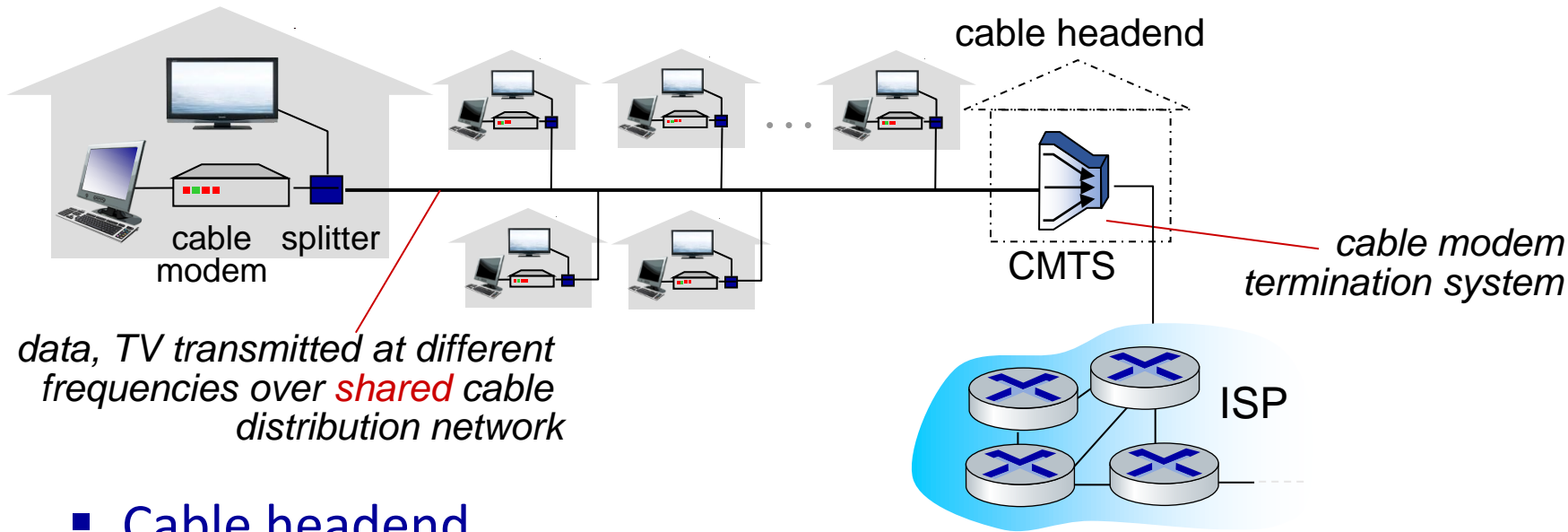
frequency division multiplexing (FDM): different channels transmitted in different frequency bands

Access networks: cable-based access

Coaxial Cable:



Access networks: cable-based access



A CMTS

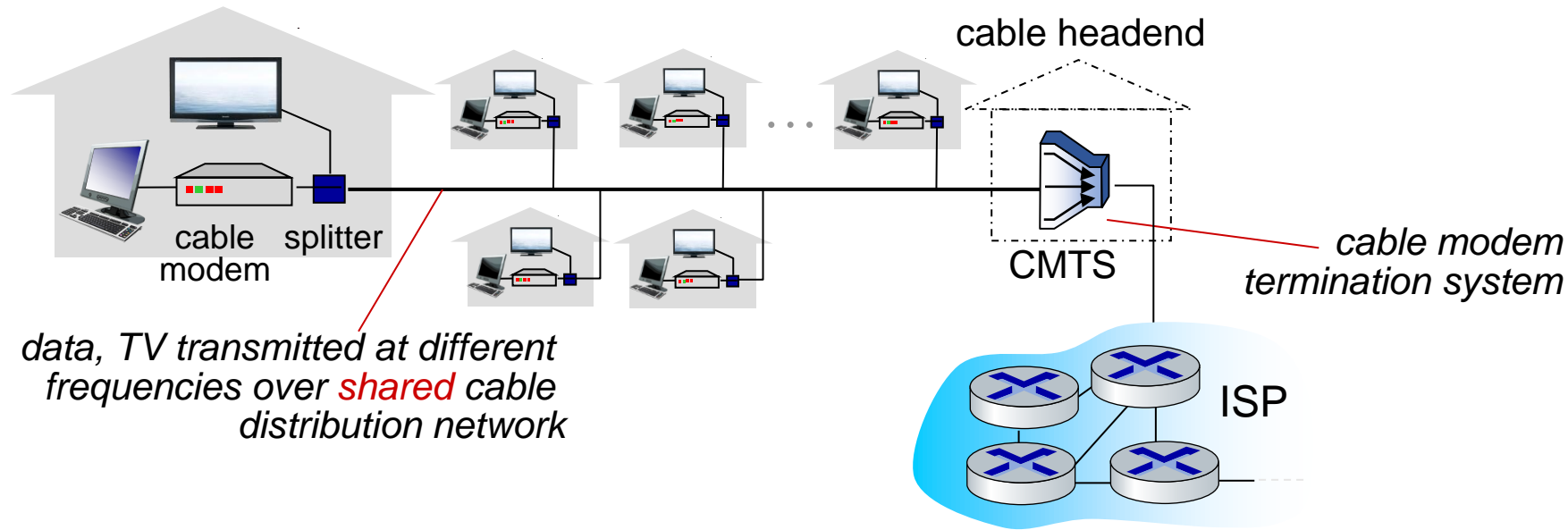
■ Cable headend

- A cable television headend is a master facility for receiving television signals for processing and distribution over a cable television system.

■ CMTS

- One way to think of a CMTS is to imagine a router with Ethernet interfaces (connections) on one side and coaxial cable RF interfaces on the other side.
- The RF/coax interfaces carry RF signals to and from the subscriber's cable modem.

Access networks: cable-based access



■ HFC: hybrid fiber coax

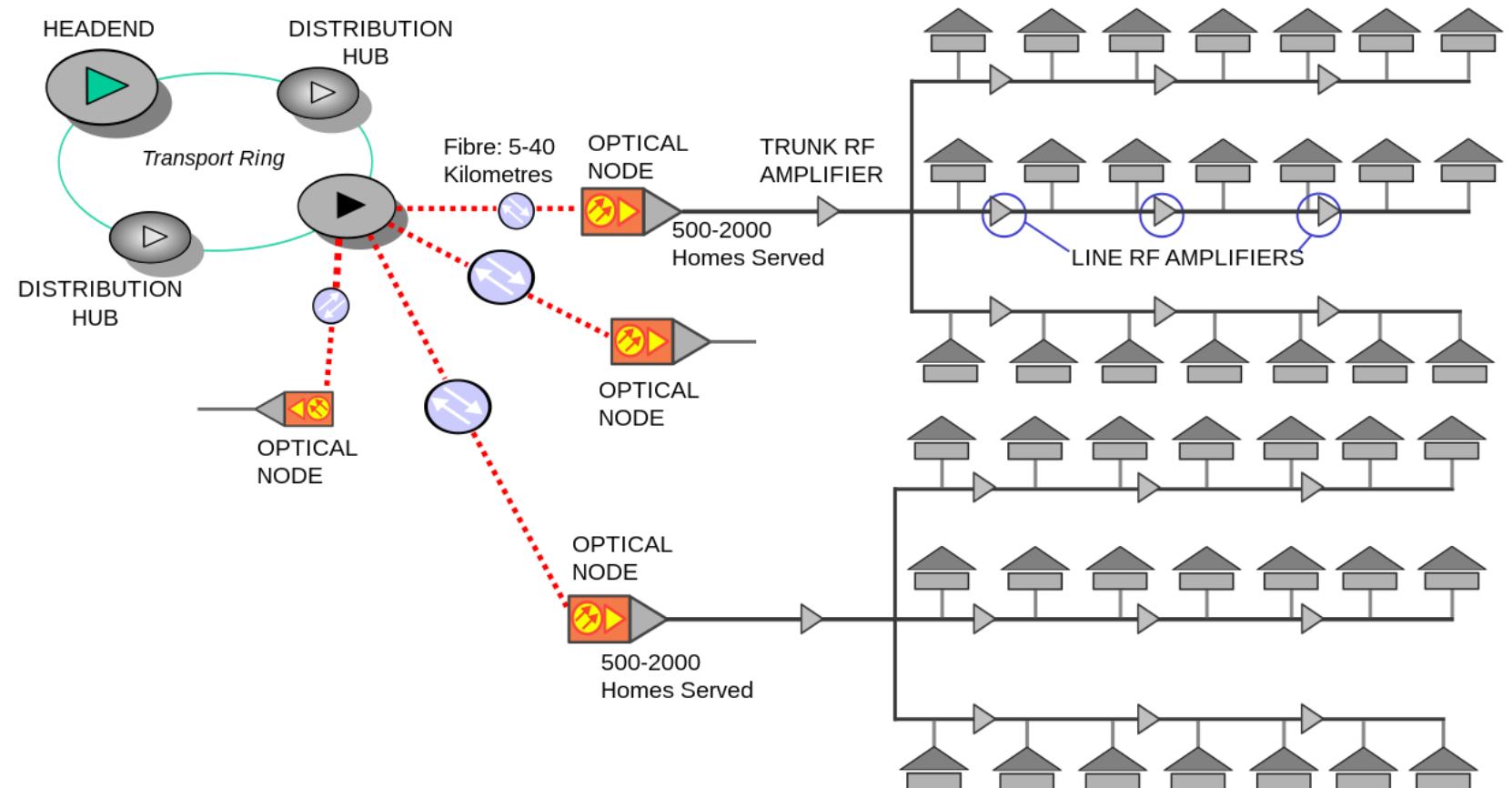
- asymmetric: up to 40 Mbps – 1.2 Gbps downstream transmission rate, 30-100 Mbps upstream transmission rate

■ network of cable, fiber attaches homes to ISP router

- homes *share access network* to cable headend

Access networks: cable-based access

- HFC: hybrid fiber coax

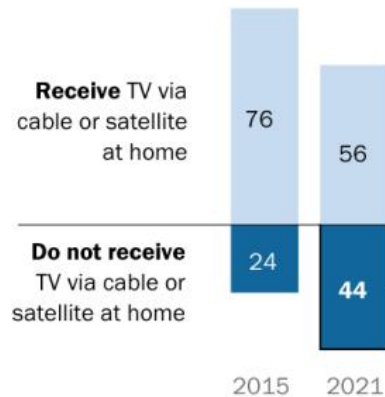


Access networks: cable-based access

■ Popularity of cable TV and satellite

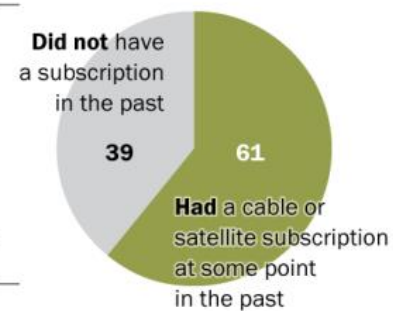
The share of Americans who receive TV via cable or satellite at home has fallen ...

% of U.S. adults who say they ...



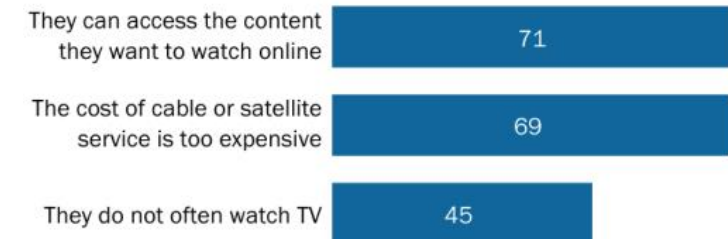
... and a majority of those without subscriptions used to have one

Among those who **do not** receive TV via cable or satellite at home, the % who say they ...



Nonsubscribers cite the availability of content online and cost as reasons they do not subscribe to cable or satellite TV

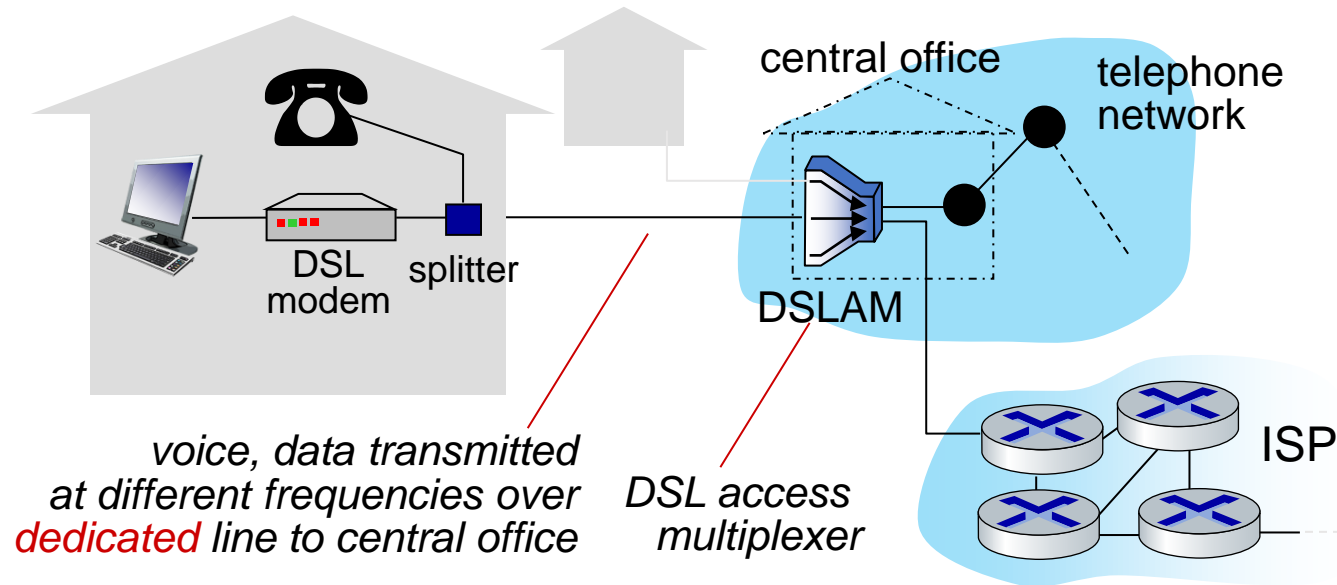
Among those who **do not** receive TV via cable or satellite at home, the % who say these are reasons they do not have a subscription



Note: Respondents who did not give an answer are not shown.
Source: Survey of U.S. adults conducted Jan. 25–Feb. 8, 2021.

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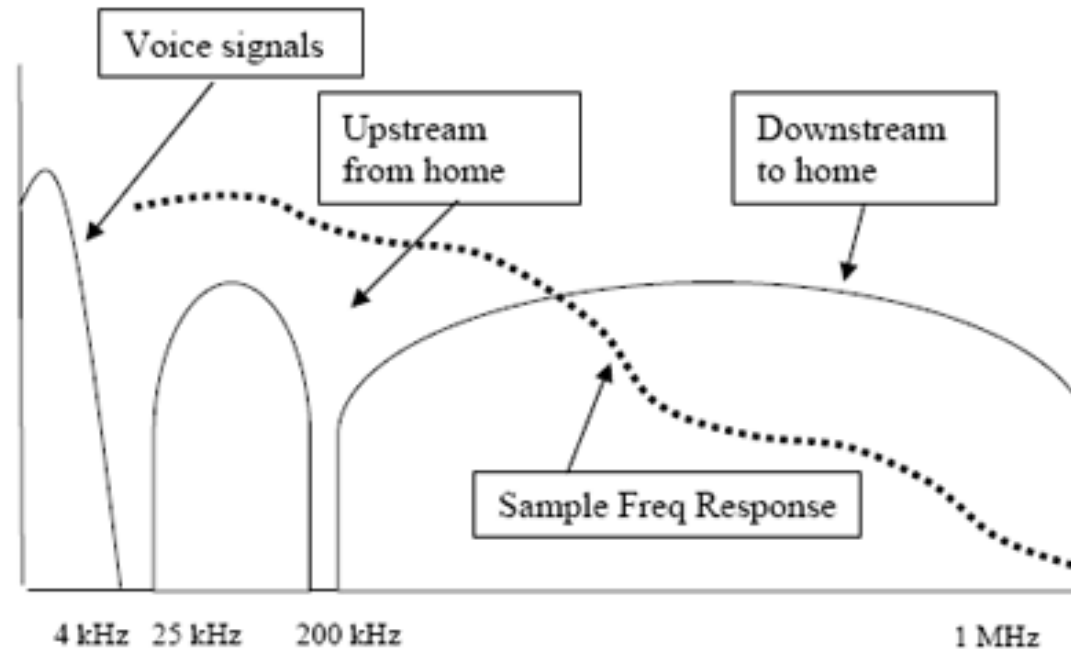
Access networks: digital subscriber line (DSL)



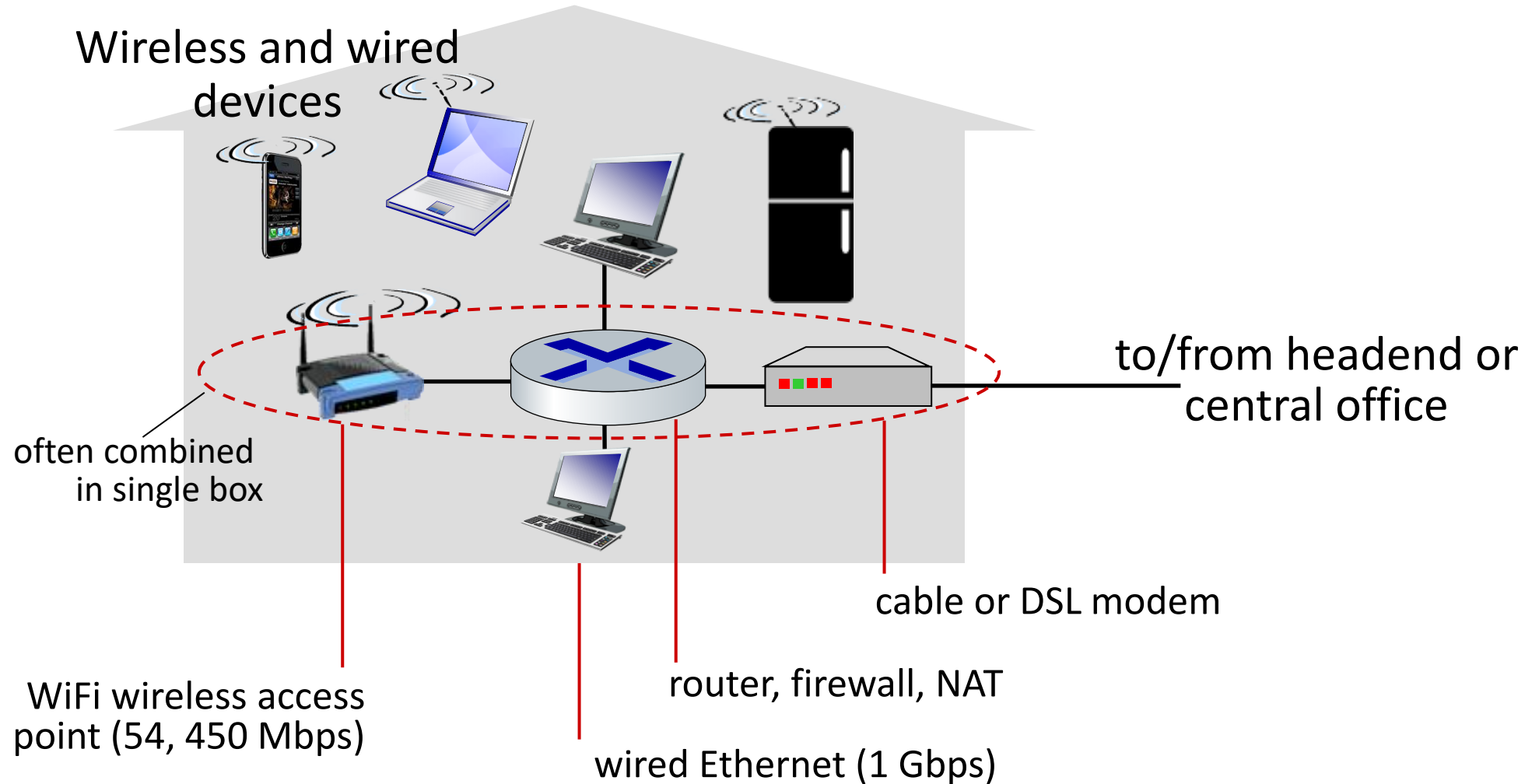
- use *existing* telephone line to central office DSLAM
 - data over DSL phone line goes to Internet
 - voice over DSL phone line goes to telephone net
- 24-52 Mbps dedicated downstream transmission rate
- 3.5-16 Mbps dedicated upstream transmission rate

Access networks: digital subscriber line (DSL)

- Frequency response of fixed telephone twisted pair with frequency
 - Lower frequencies used for voice
 - Upper frequencies used for Data (ADSL)



Access networks: home networks



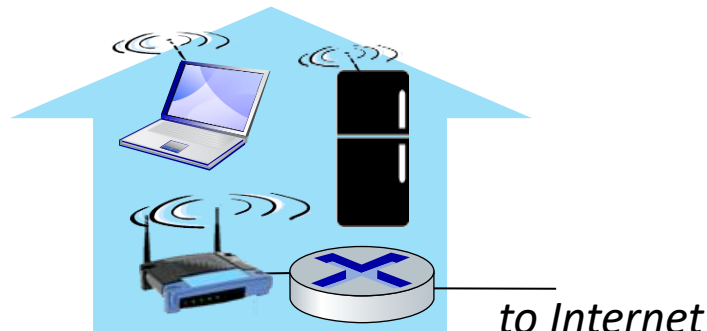
Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

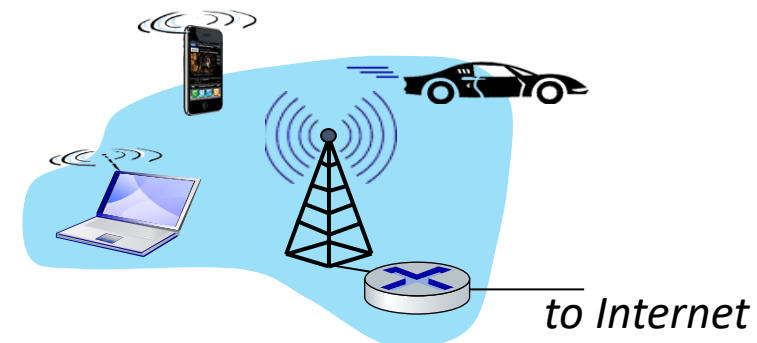
Wireless local area networks (WLANs)

- 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 and active in some regions)



Wireless access networks



IEEE standards

- IEEE (Institute of Electrical and Electronics Engineers) is the world's largest technical professional organization dedicated to advancing technology.
- Despite its name, IEEE now is an organization with broad coverage including societies and sub-groups related to disciplines such as computer, nanotechnology, medicine, and transportation.
- IEEE introduces family of IEEE 802 standards to develop related standards to computer networking.



Wireless access networks



IEEE 802

- IEEE 802 is a family of Institute of Electrical and Electronics Engineers (IEEE) standards for local area networks (LAN), personal area network (PAN), and metropolitan area networks (MAN).
- The services and protocols specified in IEEE 802 map to the lower two layers (data link and physical) of the seven-layer Open Systems Interconnection (OSI) networking reference model.
- IEEE 802 divides the OSI data link layer into two sub-layers: logical link control (LLC) and medium access control (MAC).

Wireless access networks



IEEE 802 (Selected working groups)

- IEEE 802.1: Higher Layer LAN Protocols Working Group
- IEEE 802.2: LLC (Disbanded)
- IEEE 802.3: Ethernet
- IEEE 802.11: Wireless LAN (Local Area Network)
- IEEE 802.15: Wireless PAN (Personal Area Network)
 - IEEE 802.15.1: Bluetooth
 - IEEE 802.15.4: Low rate WPAN (e.g.: Zigbee)
 - IEEE 802.15.6: Body area networks

Wireless access networks

WiFi Networks and Standards

- Summary of IEEE 802.11 standards

IEEE 802.11 standard	Year	Max data rate	Range	Frequency
802.11 b	1999	11 Mbps	30 m	2.4 Ghz
802.11 g	2003	54 Mbps	30 m	2.4 Ghz
802.11 n (WiFi 4)	2009	600	70 m	2.4, 5 Ghz
802.11 ac (WiFi 5)	2013	3.47 Gbps	70 m	5 Ghz
802.11 ax (WiFi 6)	2020 (expected)	14 Gbps	70 m	2.4, 5 Ghz
802.11 af	2014	35–560 Mbps	1 Km	unused TV bands (54–790 MHz)
802.11 ah	2017	347 Mbps	1 Km	900 Mhz

Wireless access networks



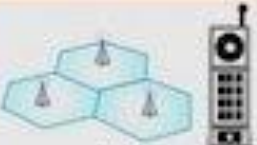












IEEE 802/IETF Relationship

- RFC 7241 describes the standardization cooperation between Project 802 of the Institute of Electrical and Electronics Engineers (IEEE) and the Internet Engineering Task Force (IETF).
- The IETF benefits from coordination by obtaining improved access to IEEE 802 expertise in the widely deployed and widely used IEEE 802 Local Area Network architecture.
- IEEE 802 benefits from coordination by obtaining improved access to IETF expertise on IP datagram encapsulation, routing, transport, and security, as well as specific applications of interest to IEEE 802.

Wireless access networks

Cellular Networks and Standards

- Evolution of cellular networks: 3GPP is an important standardization organization here.

1G	2G	3G	4G	5G
				
speed in kilobit per second 2.4 Kbps	speed in kilobit per second 64 Kbps	speed in kilobit per second 2,000 Kbps	speed in kilobit per second 100,000 Kbps	speed in kilobit per second 1Gbps
				
Analog Voice	Digital Voice + Simple Data	Mobile Broadband	Faster and Better	Real World Applications
				
			Richer Content (Video) More Connections	