

National University of Computer & Emerging Sciences

CS 3001 - COMPUTER NETWORKS

Lecture 02 Chapter 1

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Office Hours: 11:30 am till 01:00 pm (Every Tuesday & Thursday)

Course Administration

Course Information

Program: BS

Credit Hours: 3+1 (Theory + LAB (Separate Instructor))

Type: Core

Class Meeting Time: Sec 6C & 6A , Tuesday & Thursday 08:30 am till 11:30 am

Course Website: Google Classroom [6C](#) , [6A](#)

Class Venue: NB-307

Prerequisites: CS 218 , CL 218

Instructor Email: nauman.moazzam@lhr.nu.edu.pk

TA Name: Rija Sohail

TA Email: I215645@lhr.nu.edu.pk

Course Information (Subject to Change)

Assignments: 6	(10%)
Quizzes: 6 (Best 5 out of 6)	(15%)
Midterm / Sessional: 2	(15% + 15% = 30%)
Final Exam: 1	(45%)
Total:	(100%)

Grading Policy

Absolute Grading as per Department policy for Core Courses

Chapter 1: roadmap

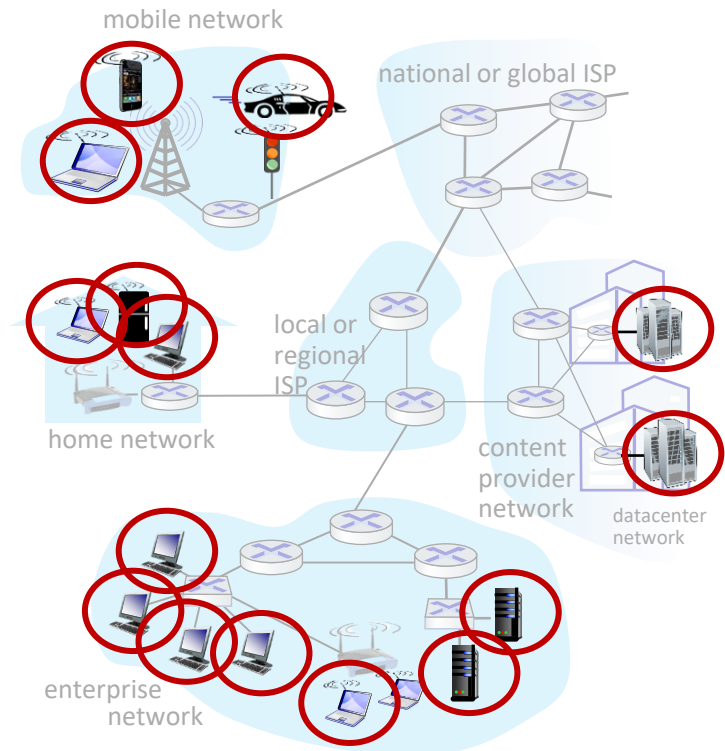
- What *is* the Internet?
- What *is* a protocol?
- **Network edge:** hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History



A closer look at Internet structure

Network edge:

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



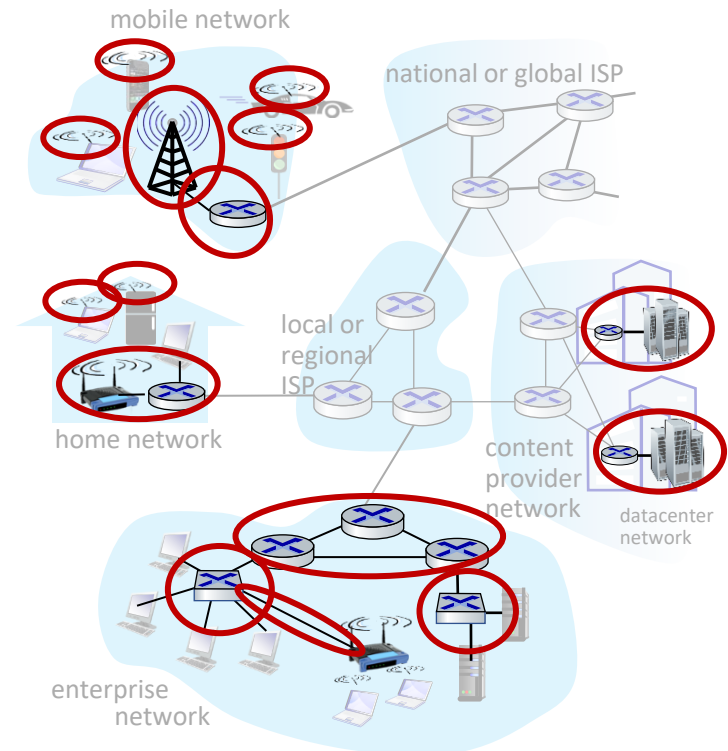
A closer look at Internet structure

Network edge:

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

- wired, wireless communication links



A closer look at Internet structure

Network edge:

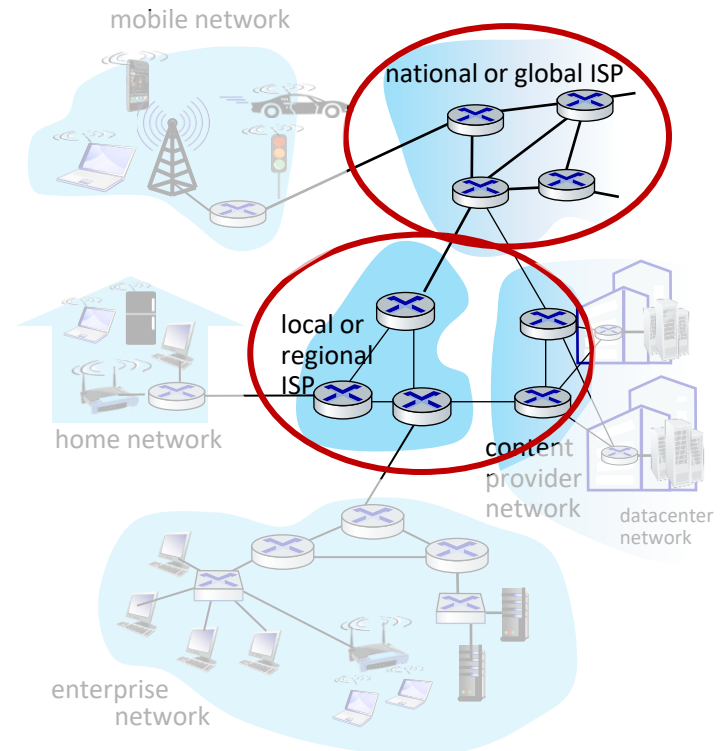
- hosts: clients and servers
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Access networks, physical media:

- wired, wireless communication links

Network core:

- interconnected routers
- network of networks



Network Edge (Client, Server, Peer)

Network edge comprises of the millions and billions of end systems / hosts and applications which reside in them

An end system (or host) can either request service (**client**) or provide service (**server**) or act as both interchangeably (**peer**).

Server

- A server is a service provider providing access to network resources:
 - A server can have multiple roles (e.g web servers, mail servers, print servers, Remote Access Servers (RAS), Directory Servers (DNS) etc)
 - Always on host
 - Permanent IP address
 - Most servers reside in large data centres

Client

- A client is a requestor of these services
 - May be intermittently on
 - may have dynamic IP address
 - do not communicate directly with each other

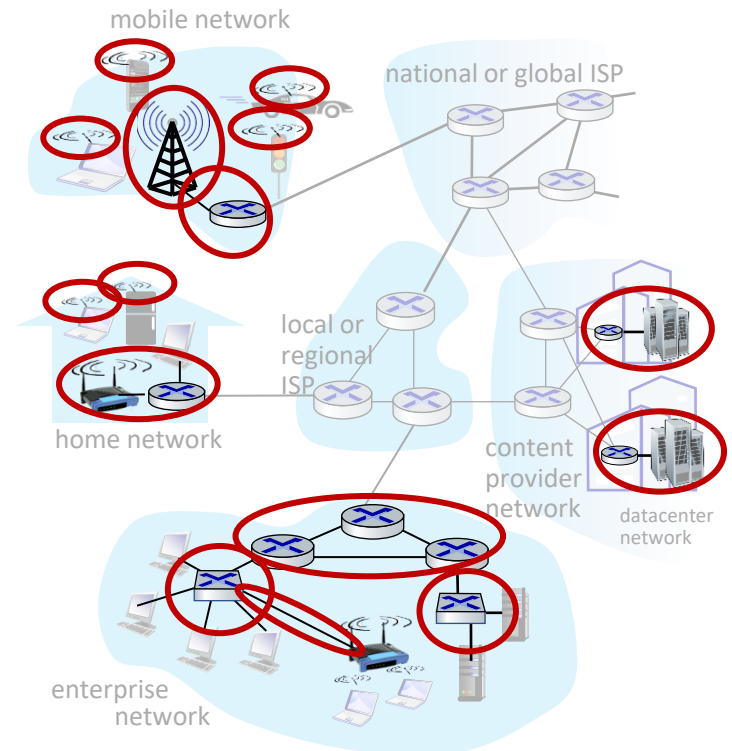
Peer

- A Peer-to-Peer network doesn't have dedicated servers. All hosts are equal and they both provide and request service i.e. they have both client & server functionalities.
 - Not always on server
 - arbitrary end systems directly communicate
 - peers are intermittently connected and change IP addresses
 - complex management
 - Examples are Skype, BitTorrent, Napster

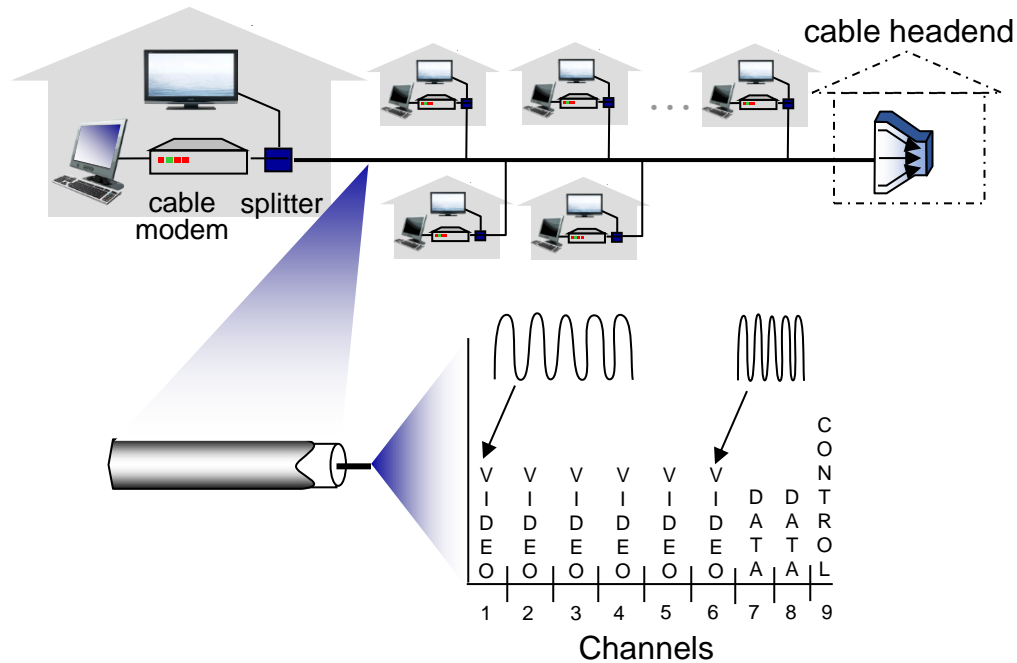
Access networks and physical media

Q: How to connect end systems to edge router?

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

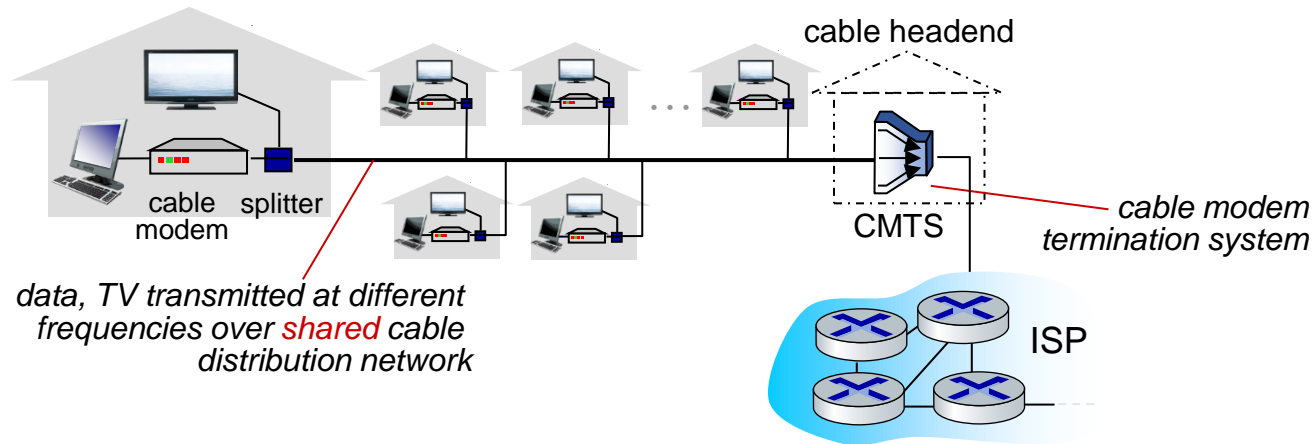


Access networks: cable-based access



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

Access networks: cable-based access



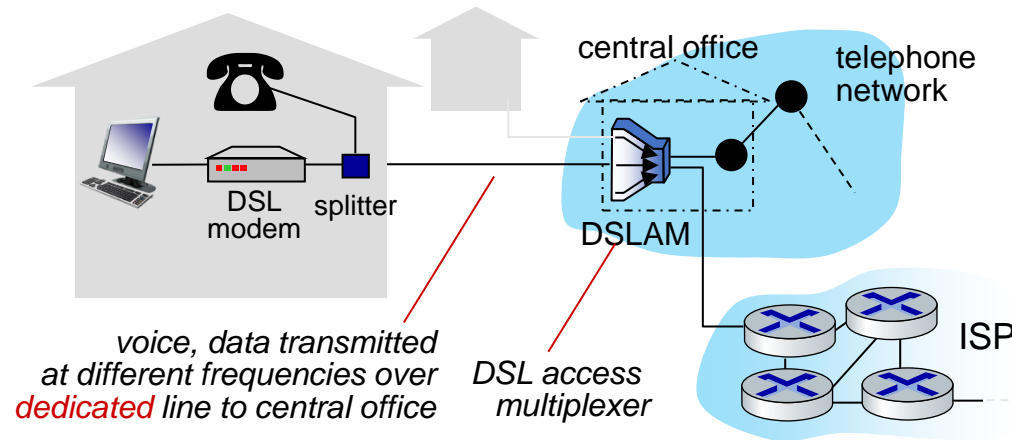
■ HFC: hybrid fiber coax

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

■ network of cable, fiber attaches homes to ISP router

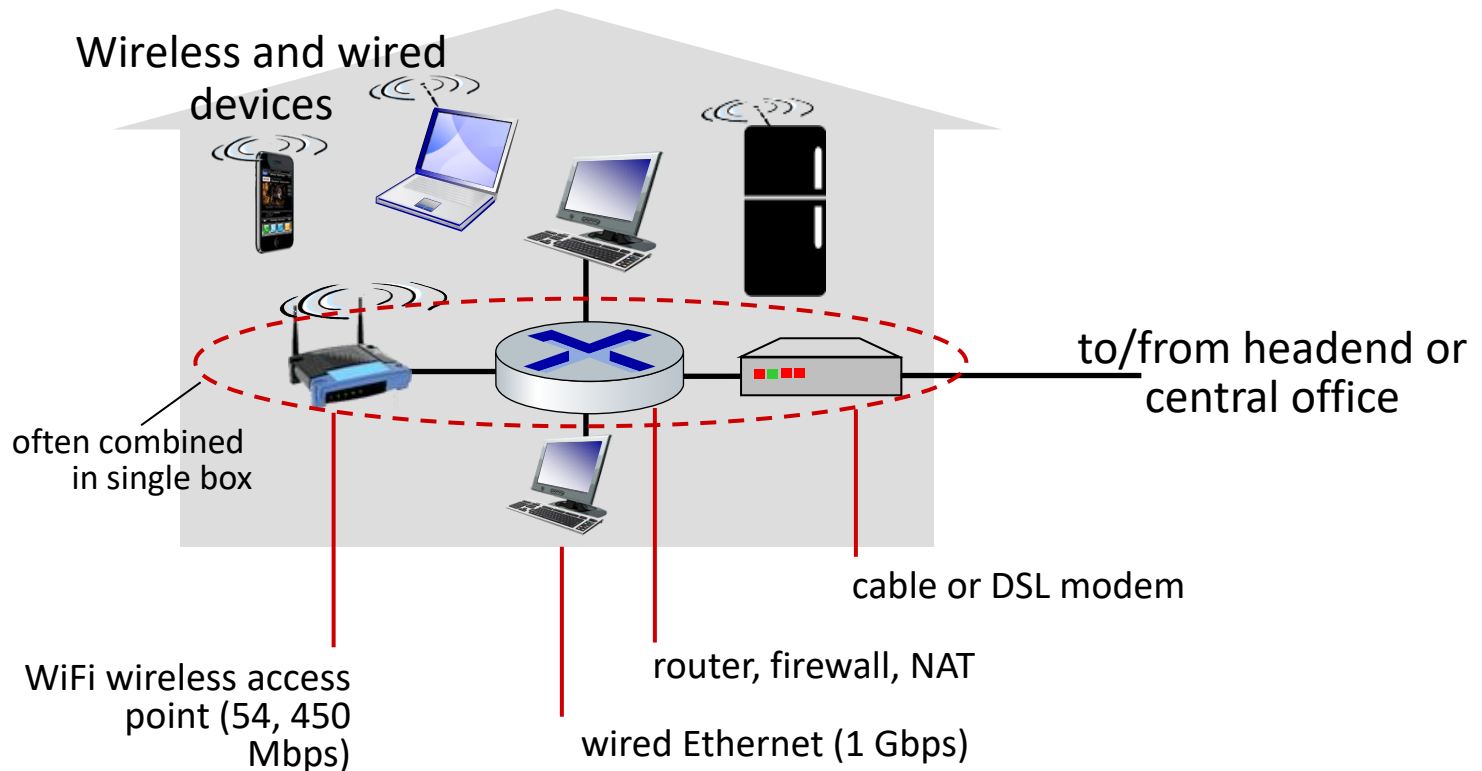
- homes *share access network* to cable headend

Access networks: 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



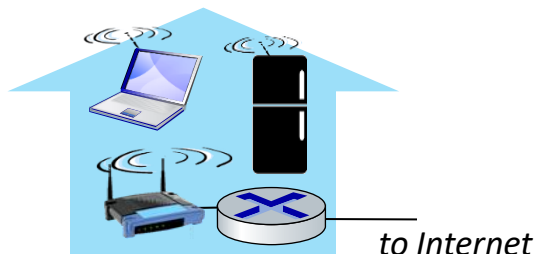
Wireless access networks

Shared *wireless* access network connects end system to router

- via base station aka “access point”

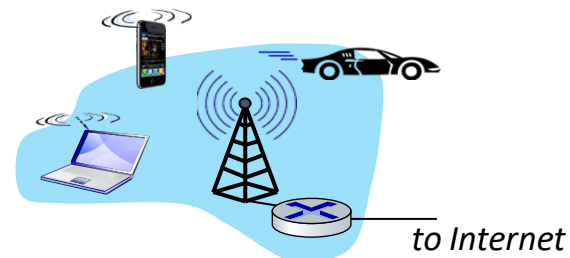
Wireless local area networks (WLANs)

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

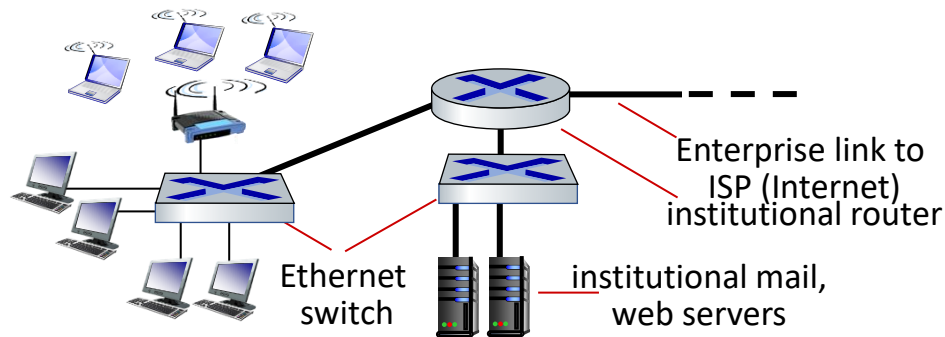


Wide-area cellular access networks

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



Access networks: enterprise networks



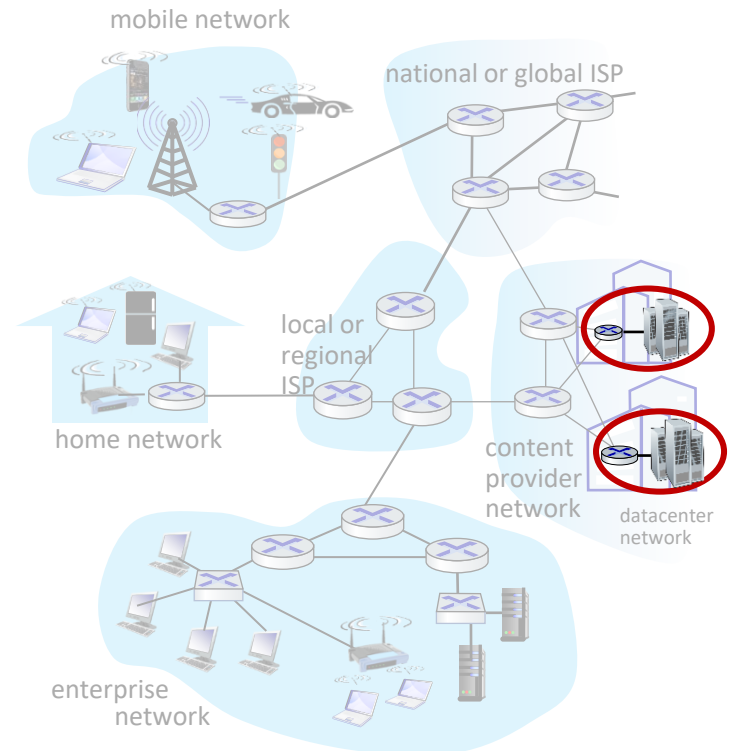
- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
 - Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
 - WiFi: wireless access points at 11, 54, 450 Mbps

Access networks: data center networks

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



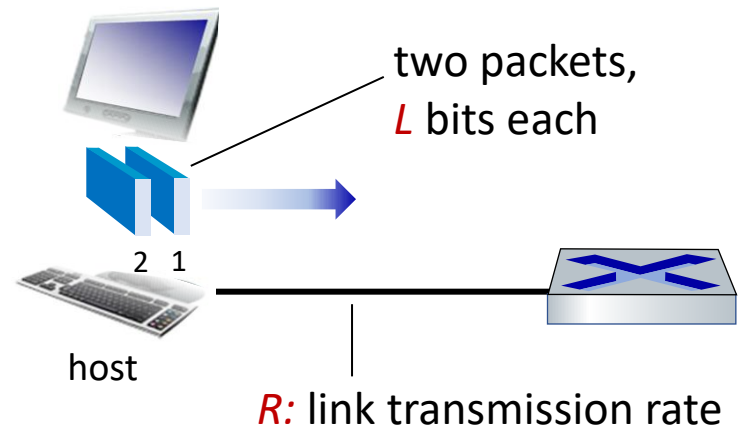
Courtesy: Massachusetts Green High Performance Computing Center (mghpcc.org)



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*



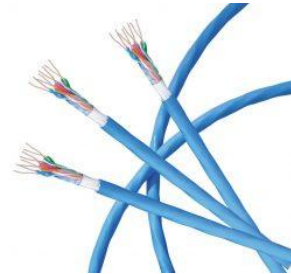
$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

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/5G cellular)
 - 10's Mbps (4G) over ~10 Km
- **Bluetooth:** cable replacement
 - short distances, limited rates
- **terrestrial microwave**
 - point-to-point; 45 Mbps channels
- **satellite**
 - up to < 100 Mbps (Starlink) downlink
 - 270 msec end-end delay (geostationary)

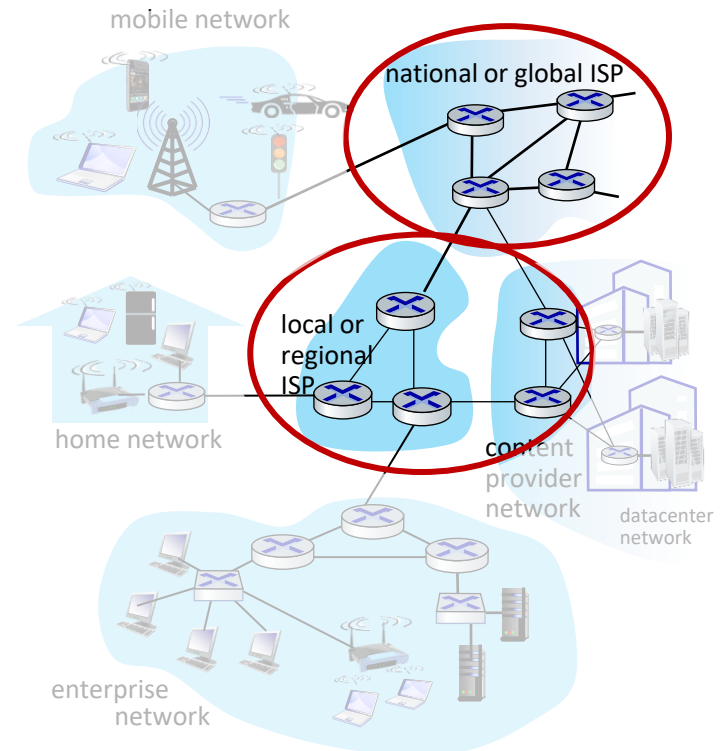
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The network core

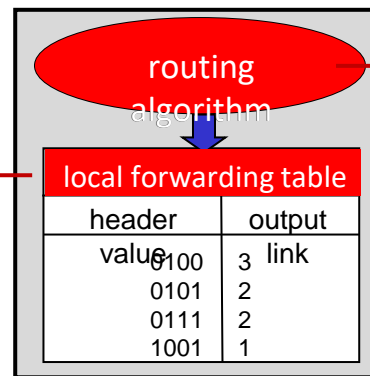
- mesh of interconnected routers
- **packet-switching**: hosts break application-layer messages into *packets*
 - network **forwards** packets from one router to the next, across links on path from **source to destination**



Two key network-core functions

Forwarding:

- aka “switching”
- *local* action: move arriving packets from router’s input link to appropriate router output link



destination address in arriving packet's header

Routing:

- *global* action: determine source-destination paths taken by packets
- routing algorithms

