Chapter 1

Overview:

- 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

The Internet

The Internet - billions of connected devices.

- **hosts** are end systems
- running network apps at internet edge
  Packet switches - forward packets (chunk of data)
- router, switches
  Communication links:
- fiber, copper, radio, satellite
- transmission rate: bandwidth
  Networks:
- collection of devices, routers and links that may be managed by an organization.

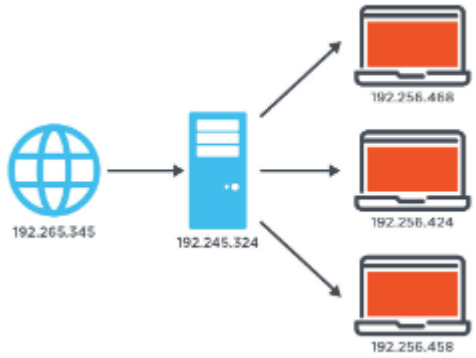
Any time you have an app that knows how to *build a packet* and *send* it to an *electrical interface* which *transmits it* via any transmission medium (wired, wireless, 5G, etc). Then you have an **Internet capable program**

The Internet is the network of networks, it's the connection of various ISPs (Internet Service Providers).

The Nuts and Bolts View	Services
Internet is a network of networks.	Infrastructure that provides services.
Protocols are ubiquitous, sending and receiving messages.	Programming Interfaces such as hooks and service options

The Nuts and Bolts View	Services
Internet Standards: RFC -- Request for Comments IETF -- Internet Engineering Task Force	

###What are Protocols



Protocols are everywhere:

- control sending, receiving of messages
- HTTP, streaming services, VOIPs, wifi, ethernet

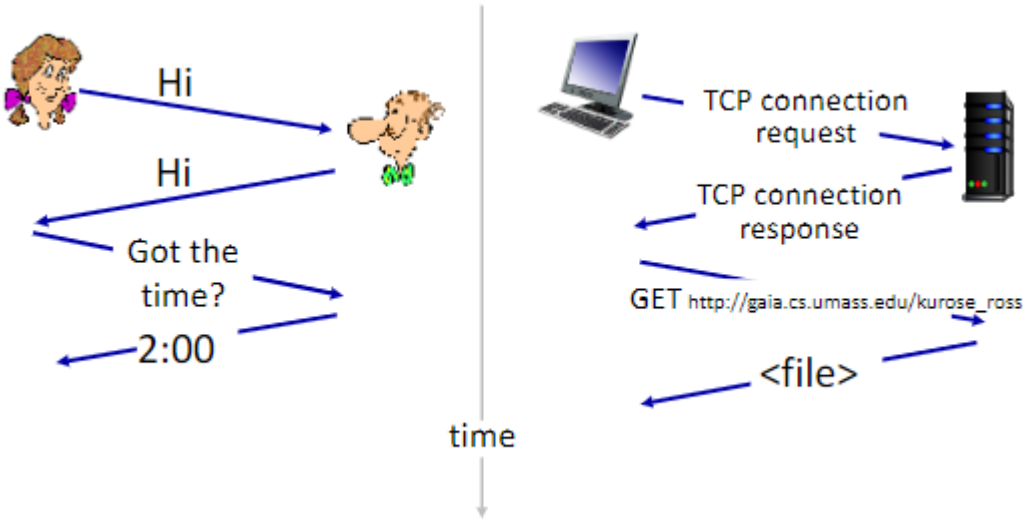
You can think of Human Protocols:

- "What's the time"
- "I have a question"
- Introductions

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.

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

Residential access nets, institutional access networks, and mobile access networks (WiFi, 4G, 5G) are all examples of how to connect end systems to edge routers

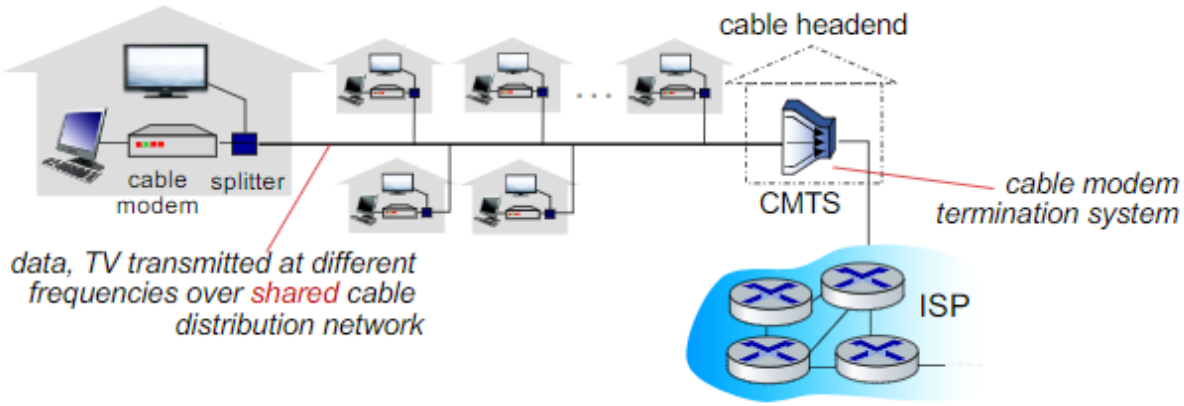
Cable-based access

frequency division multiplexing (FDM): different channels transmitted in different frequency bands.
HFC: hybrid fiber coax:

- Asymmetric: up to 40 Mbps -- 1.2 Gbs downstream transmission rate, 30-100 Mbps upstream transmission rate

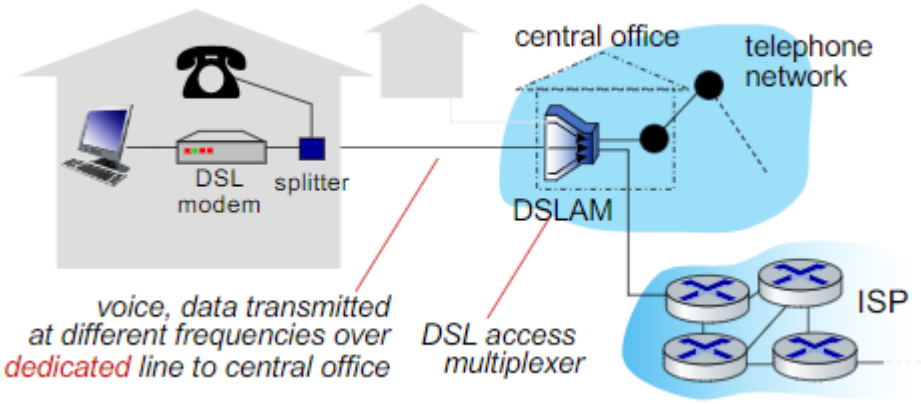
Network of cable:

- fiber attaches buildings to ISP routers
- Homes share access network to cable headend.



Digital Subscriber Line (DSL):

- use ***existing*** telephone line to central office DSLAM.
- 24-52 Mbps dedicated downstream transmsision rate.
- 3.5-16 Mbps dedicated upstream transmission rate.



Home Networks:

- Wireless devices, routers, ethernet cables, DSL modem, WiFi

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

- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate

Wireless Local Area Networks (WLANs)	Wide-Area Cellular Access Networks
typically within or around building	Provided by mobile network operators
802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate	10's Mbps, 4G, 5G

Enterprise networks

- Companies, Universities and other organizations
- Mix of wired, wireless link technologies, connecting a mix of switches and router
  - Ethernet: wired access at 100Mbps, 1 Gbps, 10 Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps

Host: Send *Packets* of data

Host sending function:

- takes application message
- breaks into smaller blocks of data called ***packets***
- transmits packet into access network at transmission rate R
- link transmission rate or link capacity, or 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***: propogates between transmitter/receiver pairs
- ***physical link***: what lies between transmitter & receiver
- ***guided media***: signals propagate in solid media
- ***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 Ethernet

Links: Physical media

Coaxial cable:

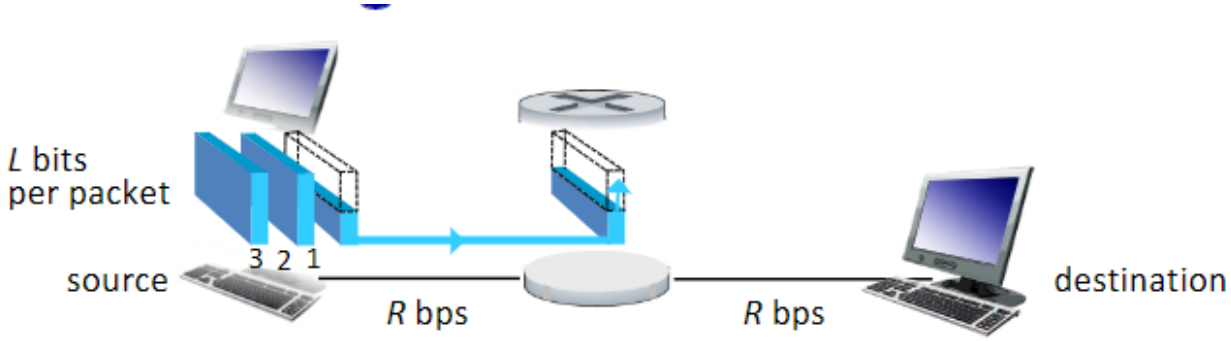
- two concentric copper conductors
- bidirectional
- broadband
  multiple frequency channels on cable
  100's Mbps per channel
  Fiber Optic cable:
- carries light pulses, each pulse is a bit
- high-speed point to point transmission
- low error rate:
  repeaters spaced far apart
  immune to electromagnetic noise
  Wireless radio:
- signal carried in electromagnetic spectrum
- **no** phsyical wiring
- broadcast (sender to receiver)
- propagation environment effects:
  reflection
  obstructon by objects
  * interference
  Radio link types:
- terrestrial microwave
  - Up to 45 Mbps channels
- Wireless LAN **(WiFi)**
  - Up to 100's Mbps
- Wide-area (e.g. cellular)
  - 4G cellular
- Satellite
  - Up to 45 Mbps per channel
  - 270 msec end-end delay
  - geosynchronous versus low-earth orbit

The network core

Mesh of interconnected routers
Packet-switching: hosts break application-layer messages into packets

- forward packets from one router to the next, across links on path from source to destination.
- each packet transmitted at full link capacity.

Packet-switching: store and forward



One-hop numerical example:

- L = 10 Kbits
- R = 100 Mbps
- one-hop transmission delay = 0.1 msec

Transmission delay: takes L/R seconds to transmit (push out) L-bit packet into link at R bps
Store and forward: entire packet must arrive at router before it can be transmitted on next link
End-end delay: 2L/R (above), assuming zero propagation delay (mroe on delay shortly)