# The Internet

The hardware, standards, and services required to create a massively interconnected network of devices

Hardware:

* End Systems (Hosts)
  + PCs, laptops, servers, etc
* Communication links
  + Fiber, copper, radio, satellite, etc
* Packet switches + routers

Standards

* Facilitate communication between devices
* Different protocols control sending and receiving different messages
  + TCP, IP, HTTP, Skype
* Protocols
* Define:
  + Format of message
  + Order of messages
  + Actions taken on transmitting or receiving message
* Defined by:
  + IETF: Internet Engineering Task Force
  + RFC: Request for Comments
* All internet communication governed by protocols:
  + Eg: Transmission Control Protocol
    - Enable reliable communication between end systems
  + Eg: Internet Protocol
    - To communication between routers and end systems

Services

* Infrastructure that provides services to applications
* Provides programming interface to applications

Network Edge

* End systems and hosts (clients and servers)
* Edge router
* Many ways to connect:
  + Residential access nets
  + Instituional networks
  + Mobile networks
* DSL (Digital Susbriber Line)
  + Shares phone line, voice split from data
    - Uses different frequencies for different types of data
    - High-speed DL = high frequency
    - Medium-speed UL = medium frequency
    - Voice = low frequency
  + <24 Mbps DL, <2.5 Mbps upload
  + 5 – 10 mile dedicated connections to central office using twisted-pair cables
* Cable
  + Cable TV infrastructure
    - Shared cables between homes connected to headend
    - Every packet sent by head travels to every home
    - Their activity affects your bandwidth
    - Accomplished via frequency division multiplexing
  + <100 Mbps DL, <10 Mbps upload
  + Hybrid fiber coax
* Enterprise: LAN
  + 10+ Gbps download and upload
* Home / Enterprise:
  + Connects end system to router
  + Wireless LAN
    - ~100ft
    - 802.1 b/g/n/ac protocols, different transmission rates
    - Different WiFi cards and routers support specific set of protocols
* Wire-area wireless
  + 10+km from cellular tower
  + Between 1 and 10 Mbps
  + Different protocols
    - 3G, LTE, 4G

Physical Media

* Twisted-pair copper wire
  + Least expensive, most commonly used
  + Copper wires twisted around each other
  + Many pairs often twisted into a single cable
  + Between 10 Mbps and 10 Gbps
    - Length affects data rate
    - Can be 100+ feet long
  + Ethernet cables
* Coaxial cable
  + Two copper wires
    - One in another septered by insulation
  + Used for cable
  + Carries multiple signals simulatenously on different frequencies
* Fiber optics
  + Carries light pulses, each one a bit of data
  + 10 Gbps to 10+ Tbps
    - Speed of light in glass (~200,000 km/s
  + High cost
* Radio
  + Issues incude reflection, interferecne, obstruction
  + Microwave: 45 Mbps
  + WiFi: 11 Mbps to 1.3 Gbps+
  + Wide-area cellular: 10+ Gbps
  + Satellite: Kbps to 4 Mbps, high latency

Network Core

* Mesh of interconnected routers
* Hosts break data into packets
  + Packets of length L bits
  + Trasnmitted into netwrk at rate R’[
  + Delay = L / R
* Routers forward packets to next router along way to destination to destination
* Switch waits till it has received whole packet to begin next
  + Adds to latency
  + Has to store packets as they come in
* P packets of L bytes
* N routers with rate R
* N \*L / R + (P – 1) \* L / R
* Queing delay
  + If arrival bit rate exceeds transmission rate, have to buffer packets
* Routing Packets
  + Router decies which is the next router
  + Done differently in different systems
  + IP Routing
    - Internet uses IP addresses
    - Routers have forwarding tables that map links to destination addresses
* Circuit Switching
  + Alternative to packet switching, used for telephone networks
    - Reserves end-to-end pipeline between source and destination

Structure of Internet

* Network of networks of networks
  + End system connected to Internet via via ISP
  + ISPs interconnected

# Delay

Dnodal = dproc + dqueue + dtrans + dprop

Processing delay

* Negligible, typical microseconds
* Checking for bit-level errors and routing packet

Queuing delay

* Variable, depends on packets in queue
* Microseconds to milliseconds

Transmission Delay

* Time to push a packet out onto medium
* L / R
* Milliseconds to microseconds

Propagation Delay

* Distance / Speed

Packet Loss

* Queues have finite capacity
* Lost packets retransmitted by previous node, origin, or none at all
* Also dropped if corrupted

Throughput

* Rate at which bits transferred between sender and receiver

# Protocol Layers

Why?

* Explicit structure allows idicnation of complex system
* Eases maintenance

Application:

* Supports network applications
* FTP, SMTP, HTTP

Transport