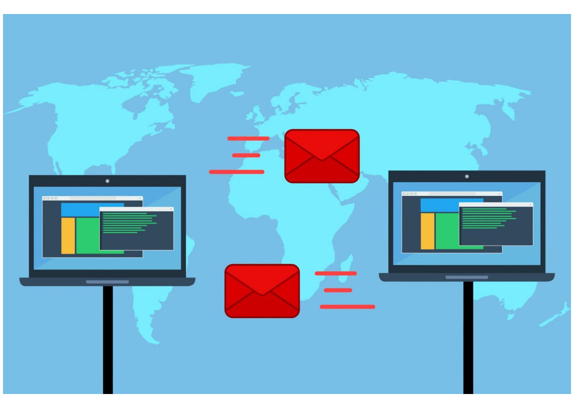
Chapter 01: Introduction

Communications: Comp-Comp vs. Person-Person

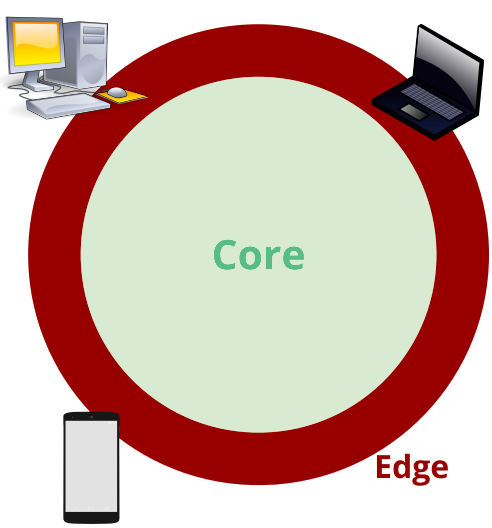


Protocols

Protocols defines the

- Format of messages
- Order of message exchanges (sent & received)
- Actions taken by recipient on receiving a message
- Actions taken by sender on transmitting a message

Network Edge vs. Network Core



Core: interconnected routers

Edge: hosts (computing nodes) connected to the network core

Two Primary Jobs of the Network Core

- Forwarding
  - **Local action** performed by *each individual router* within the Network Core, moving a packet from an incoming input link to appropriate output link
  - Mapping from input to output is done via a forwarding table
- Routing
  - **Global action** (by a routing algorithm) performed collectively by routers within the Network Core, determine the path(s) taken by packets from source to destination
  - Output of a routing algorithm is used to update the individual forwarding tables of affected routers

Turn-by-Turn Navigation Analogy

- **YouTube video at minute 3:00**
- **Routing** ⇒ Finding the best route from San Jose, CA to Southampton, MA
- **Forwarding** ⇒ "Micro" navigation instructions
  - "At the traffic light, make a right turn"
  - "Take the leftmost lane at the fork"
  - etc.

Sending "Data" From Source S to Destination D

- Circuit Switching
  - The data are "analog voice signals"
  - Used in old analog telephone network (prior to VoIP)
  - A dedicated path connecting **S** to D must first be established
  - All voice data are transmitted on this same path
- Packet Switching
  - The data are digital bits
  - Used in "modern" computer network (packet switching was implemented in 1960s)
  - No dedicated path required (as long as **D** is reachable from **S**)
  - Each packet may take a different path

Possible Issues with Packet Forwarding

- Recall that forwarding is a **local action** at a (specific) router
- Links connected to a router may operate at different speed (data transmission rate)
- **Packet delay:** when output link operates slower than its input link
  - Incoming packets may have to be temporarily stored in an internal buffer
- **Packet loss**: when the internal buffer is full and incoming packets cannot be saved and must be dropped
- These are important concepts to understand Chapter 3 (Transport Layer)

Packet Processing Time (at a router)

Four variables

- **Bits parsing time** (microseconds)
  - check integrity
  - output link lookup from the forwarding table
- Waiting in queue time before packet can be pushed out (*only this one can be zero*)
- **Transmission time**: the time needed for *all the bits* to be out of the router
- **Propagation time/travel time**: the needed for the bits to travel the output link (to reach its next router)

Transmission vs. Travel Time

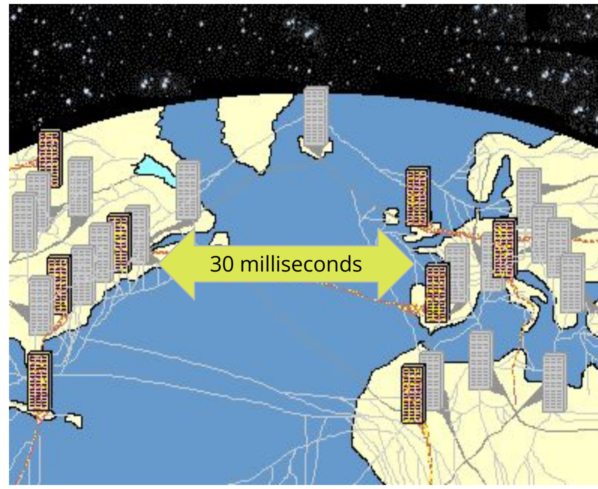
- Transmission Time *"how fast you talk"*
  - Total time for the packet bits to be out of the router
  - Depends on the *chip computing speed* within the router

$$d_{\text{trans}} = \frac{\text{packet length (bits)}}{\text{transmission rate (bps)}}$$

- Propagation Time or Travel time *"when your words will be heard"*
  - Total time for the packet bits to move inside the link (copper wire, air, fiber optics)
  - Depends on the *physical properties* of the media

$$d_{\text{prop}} = \frac{\text{length of link (m)}}{\text{propagation speed} (\approx 2 \times 10^8 \text{ m/sec})}$$

How fast is light speed?



Packet Queuing Time

- How long a packet must stay “inside” a router, depends
  - *R*: How fast the router can “consume” the packet (*bits/second*)
  - α: How frequently packets arrive at the router (*packets/second*)
  - *L*: How many bits in the packet (*bits/packet*)

$$\text{traffic intensity} = \frac{\alpha \cdot L}{R} \qquad \frac{\frac{\text{packets}}{\text{sec}} \cdot \frac{\text{bits}}{\text{packet}}}{\frac{\text{bits}}{\text{second}}} = \frac{\text{bits arrival rate}}{\text{bits service rate}}$$

(Router) Traffic Intensity

$$\rho = \text{traffic intensity} = \frac{\text{bits arrival rate}}{\text{bits service rate}}$$

- $\rho << 1$: queuing delay is small
- $\rho > 1$: more arrival than the amount which can be served
  - queuing delay is infinite
  - packet loss very likely
- Online animation

How to Structure a Huge Network?

- Breakdown the design into multiple layers
- Implementation of services in a high(er) layer depends on services provided by the lower layer
- Internet Layers
  - Application layer: exchange **messages** between apps — **SMTP, HTTP, IMAP**
  - Transport layer: data transfer from **process** to **process** — **TCP, UDP**
  - Network layer: routing decisions for data transfer from **host** to **host** — **IP**
  - Link layer: data transfer between **neighboring network elements** — **Ethernet, WiFi**
  - Physical layer: **bits transfer** via physical medium (wire, air, fiber optics)

Internet Layers

Application	*Exchange messages between two applications*
Transport	*Data transfer between two processes*
Network	*Data transfer between two hosts*
Link	*Data transfer between two neighboring network elements*
Physical	*Bit transfer on physical medium*