Network performance

Networks: speed at a premium

→ if slow typically not used in practice

→ e.g., cryptographic protocols tend to be turned off at routers due to overhead

Network design approach:

→ emphasis on lightweight network core

→ push heavyweight stuff toward the edge (i.e., host/server)

→ called end-to-end paradigm

→ historically: guided Internet design and evolution

→ other approaches have been tried and failed

Performance yardsticks:

- bandwidth in bps (bits-per-second)
  - → from bandwidth of physical media (Hz) to bps
  - → link bandwidth ignoring slow-down due to resource contention protocols
- throughput (bps): includes software layer overhead
  - → firmware in NIC and device driver in OS
  - → in practice: app/user space overhead lead to further slow-down
- latency and delay in msec (millisecond)
  - → latency: signal propagation speed (SOL)
  - → processing and buffering delay (queueing)
- jitter: delay variation
  - → average delay small but max delay large
  - → bad for multimedia

Meaning of "high-speed" networks:

- signal propagation speed is bounded by SOL (speed-of-light)

  → ∼186K miles/s (∼300K km/s)

  → optical fiber, copper: slower than SOL

- Ex.: latency from Purdue to West Coast

  → for 2000 miles: ∼10 msec (= 2000/186000)

  → lower bound

- Ex.: geostationary satellites at ∼22.2K miles

  → latency: ∼120 msec

  → end-to-end (one-way): ∼240 msec

  → round-trip (two-way): ∼480 msec

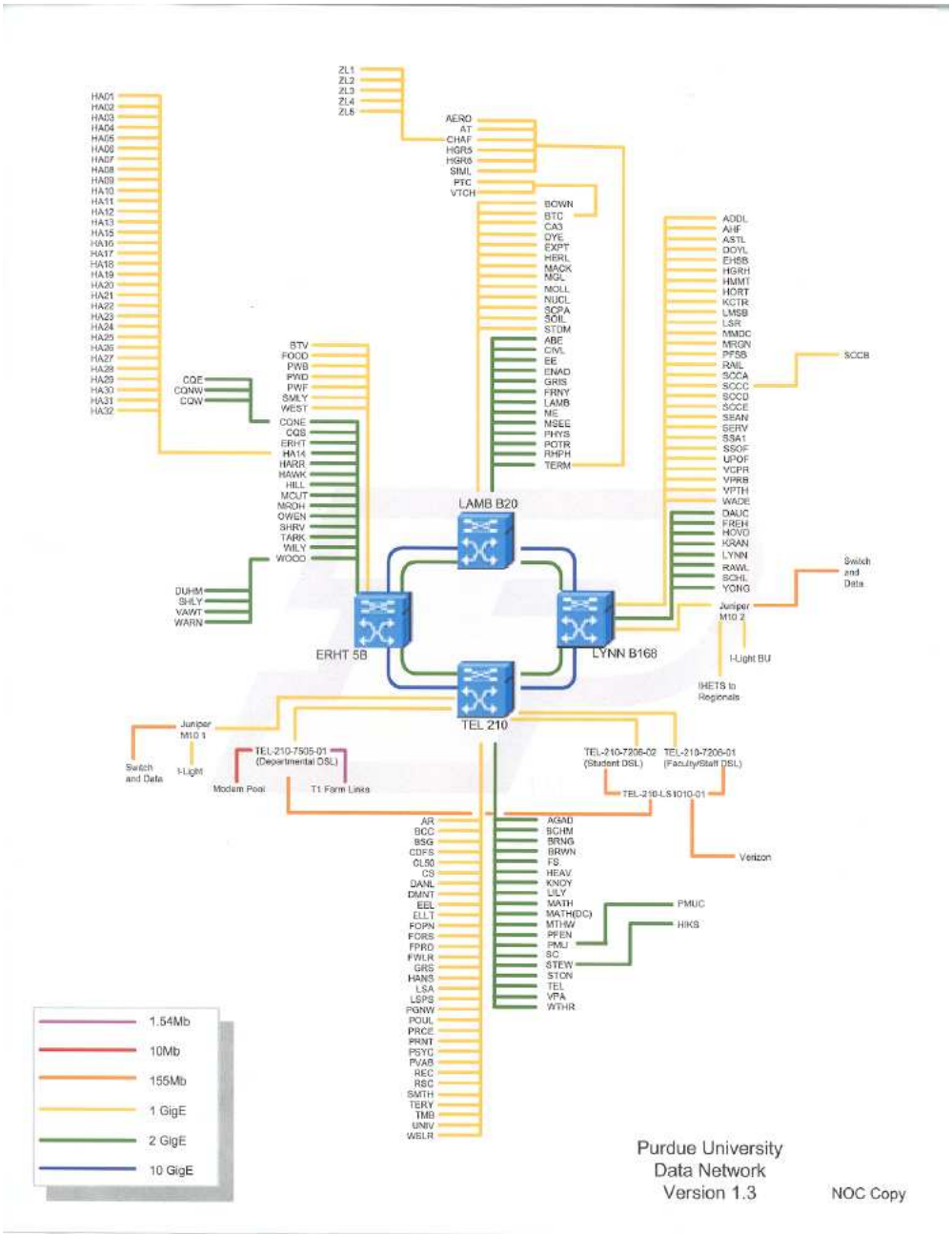
  → roughly: half a second

  → fundamental limitation faced by apps

Meaning of high-speed:

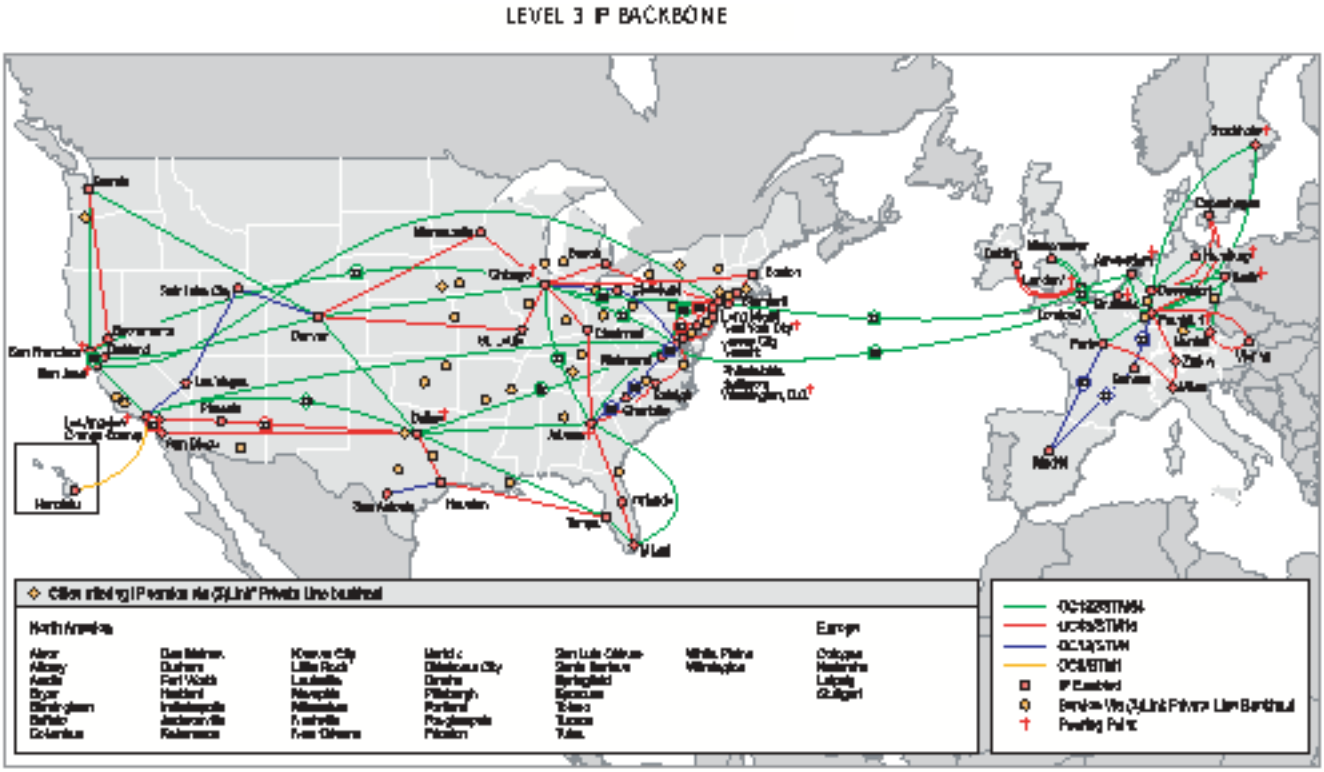
- a single bit cannot go faster
  - → can only increase bandwidth (bps): bits packed into 1 second
  - → analogous to widening highway, i.e., more lanes
  - → also called broadband
- interpretation of high-speed ⇔ many lanes
  - → effect: completion time of large files shorter
  - → in this sense, "higher" speed
  - → for small files: marginal benefit
  - → Internet workload: most files are small, minority is very large
  - → but: minority consumes bulk of network bandwidth

Example network pics: Purdue's backbone network



Level 3 (tier-1 ISP) backbone network: www.level3.com

→ now part of CenturyLink



→ 10 Gbps backbone (green): same speed as Purdue

→ outdated pic: faster backbone speeds now (40, 100, 400 Gbps)

What is traveling on the wires?

Mixture of:

> Bulk data (data, image, video, audio files), voice, streaming video/audio, real-time interactive data (e.g., games, social media, etc.), AI related traffic.

→ bulk of Internet traffic has been TCP file traffic

→ primarily a giant client/server system

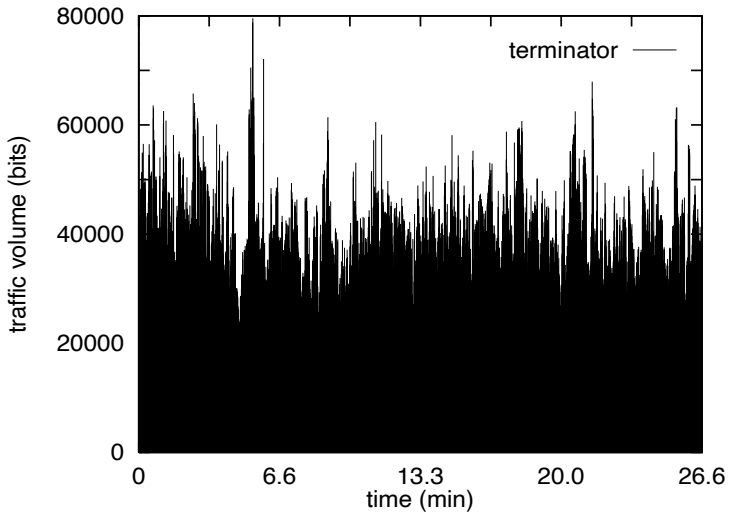
Multimedia (video/audio) streaming: rapid rise

→ streaming video: e.g., YouTube, Netflix

→ real-time: e.g., VoIP, video conferencing, games

→ target of traffic delimiting and shaping (e.g., fine print of "unlimited" data plans)

Example: traffic is "bursty": MPEG compressed real-time video



Reason:

- video compression

  $\rightarrow$ utilize inter-frame compression

- burstiness is not good for networks

Example: 90/10 (or 80/20) property

→ called "mice and elephants"

→ spikes caused by elephants

→ target of active traffic control (e.g., TCP)

→ most flows are mice

→ limited efficacy of feedback control

How to make sense of all this?

We will investigate three aspects:

- Architecture

  → system design, real-world manifestation

- Algorithms

  → how do the components work

- Implementation

  → how are they actually implemented

  → additional complications

Key concern and common thread: performance

→ slow means likely not used in practice

→ performance heavily influences architecture, algorithm, implementation