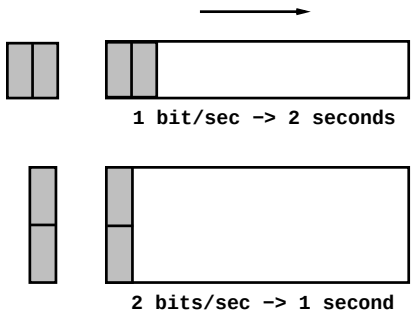
Bandwidth and Latency

Bandwidth

- Amount of data that can be *transmitted* per time unit
  $\Rightarrow$ *transmitted* = put into the pipe (wire)
- Example: 10Mbps (10 million bits per second)



High-*speed* networks — high-*bandwidth* network

Given a file of 1 giga bits in size –

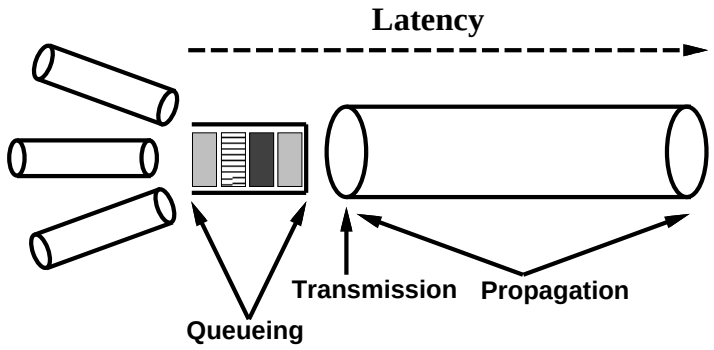
- Gigabit networks – 1 second transmission time
- Megabit networks – 1,000 seconds transmission time

Latency

- Time it takes to send a message from point A to point B
- Components of latency

  Latency = Propagation + Transmit + Queueing
  Propagation = Distance / Speed-of-Light
  Transmit = Packet-Size / Bandwidth

- Speed of light (electromagnetic wave)
  - 3.0×10^8 meters/second in a vacuum
  - 2.3×10^8 meters/second in a cable
  - 2.0×10^8 meters/second in a fiber
  - $C = \lambda \times f$



Performance

Network performance is measured in 2 fundamental ways

(1) Bandwidth (**throughput** – measured performance)

- Amount of data that can be *transmitted* per time unit
- Example: 10Mbps (10 million bits per second)

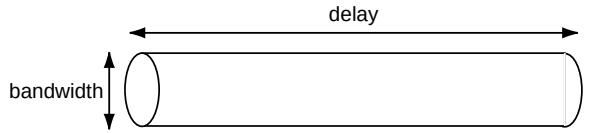
(2) Latency (delay)

- Time it takes to send message from point A to point B
- Components of latency

  Latency = Propagation + Transmit + Queueing
  Propagation = Distance / Speed-of-Light
  Transmit = Packet-Size / Bandwidth

- Speed of light
  - 3.0×10^8 meters/second in a vacuum
  - 2.3×10^8 meters/second in a cable
  - 2.0×10^8 meters/second in a fiber
- Notes
  - no queueing delays in direct link
  - process-to-process latency includes software overhead
  - **software overhead** can dominate when Distance is small

- **Relative importance** of bandwidth vs. latency – depending on applications
  - small message (e.g., 1 byte): [1ms vs 100ms] (**latency**) dominates [1Mbps vs 100Mbps]
  - large message (e.g., 25 MB): [1Mbps vs 100Mbps] (**BW**) dominates [1ms vs 100ms]
- **Delay $\times$ Bandwidth Product** – *volume of pipe*
  how many bits the sender must tx. before the 1st bit arrives at the receiver
  $\Rightarrow$ the amount of data that could be in transit



Example: 100ms RTT and 45Mbps BW $\approx$ 560 KB of data

Principle – keep the pipe full

- **Application needs** (vs. channel can support)
  - bandwidth: digital library (burst; the more the better) vs. video (peak rate; upper limit)
  - latency: one-way delay vs. latency varies from packet to packet (*jitter*)