CSE331: Introduction to Networks and Security

Lecture 2

Fall 2004

Announcements

- Homework 1 is due Sept. 15th
  - Available on the web page
- Lectures notes only available from within upenn.edu domain
- Course newsgroup
  - upenn.cis.cse331

Today: Introduction to Networks

- What is a network?

  – A network is a collection of devices that communicate through some medium to exchange information.

- E-mail & News
- File transfer
- World-wide Web
- Chat/Messaging
- Networked audio/video
- Remote terminals
- Telephony
- Games

The Four Major Networks

- Telephone
- Television
- Radio

} Special Purpose

- Internet (grew out of ARPANET–late 1960's)
- Starting to see hybrids…

- Computer networks
  - General purpose programmable hardware
  - Support many different applications

How to build such a network?

- Connectivity
- Efficient Resource Sharing
- Functionality
- Performance
- *Security*

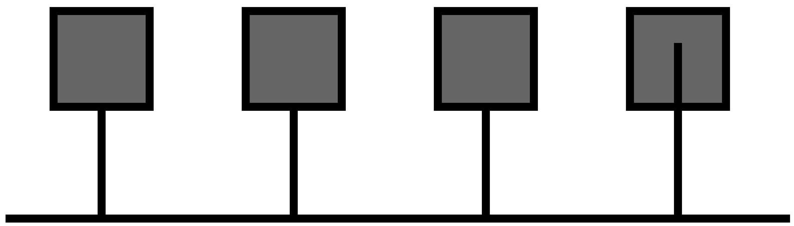
Requirement: Connectivity

- Goal of a network is to get information from one place to another
  - Source
  - Destination

  } Specified by an *address*
  - *Nodes* or *Hosts*
- Network paths
  - Can be *direct* or *indirect*
  - Can be *static* or *dynamic*

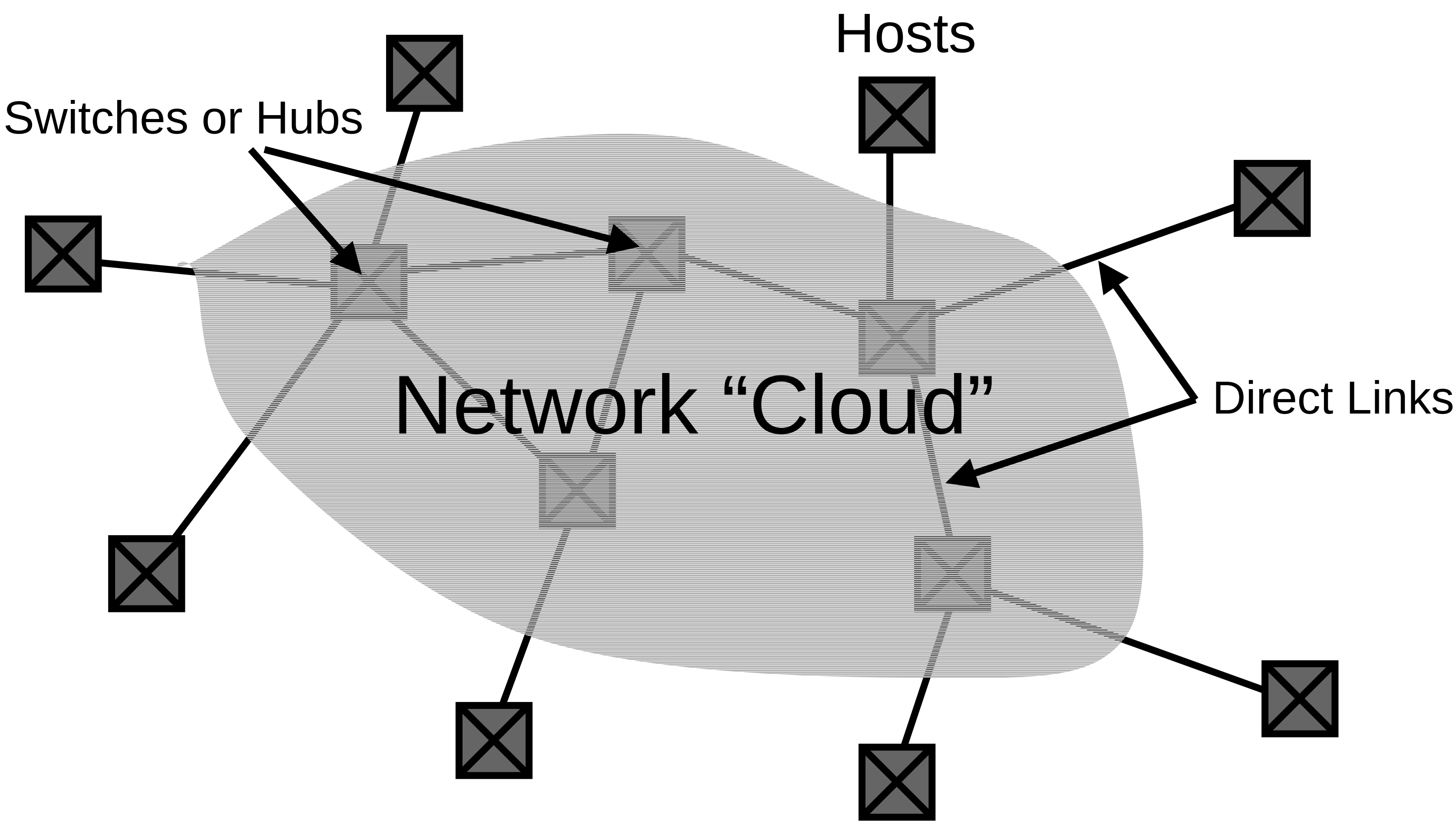
Connectivity: Direct Links

Point to Point
e.g. telephone

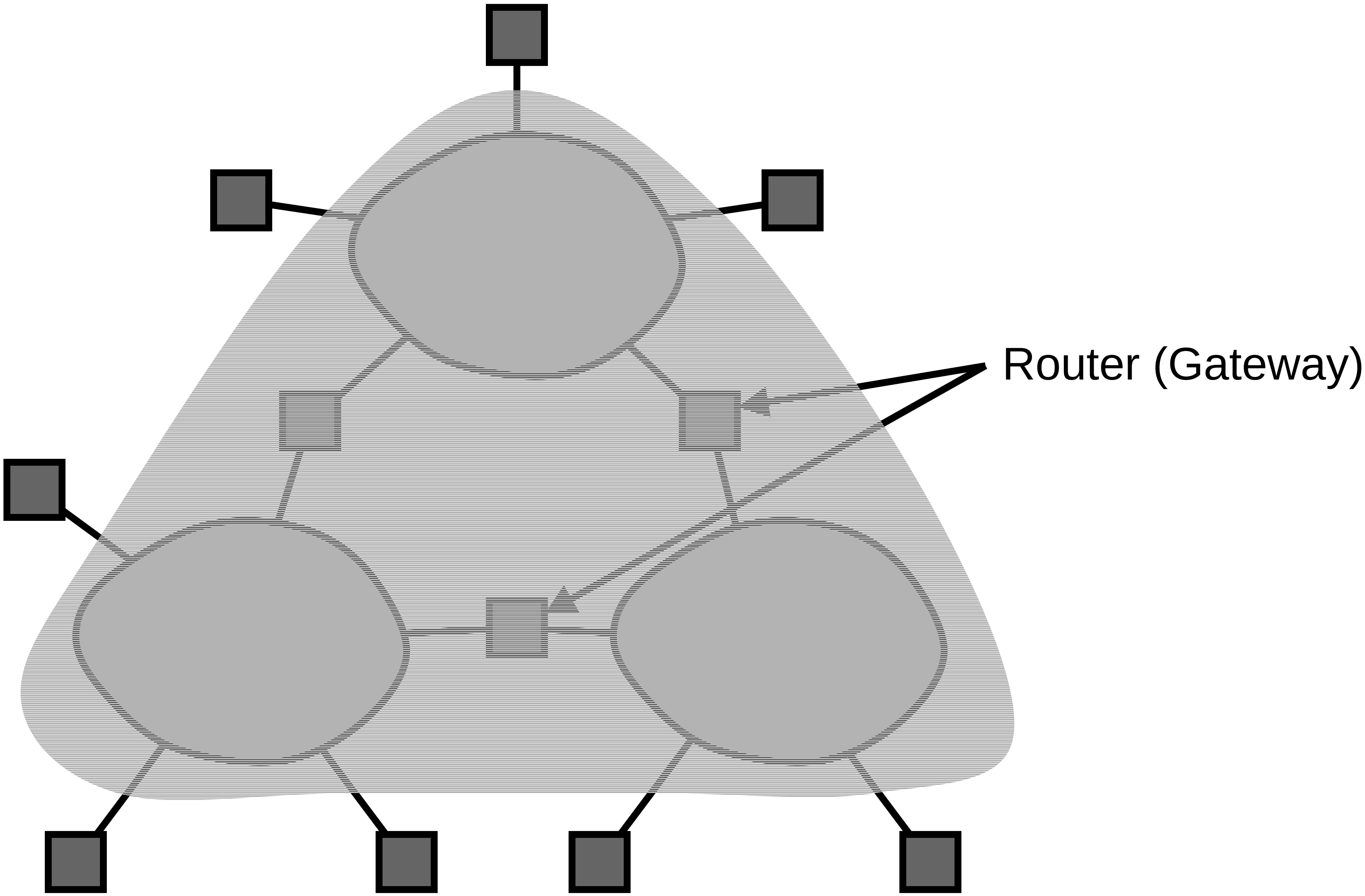


Multiple Access
e.g. Ethernet

Connectivity: Switched Networks

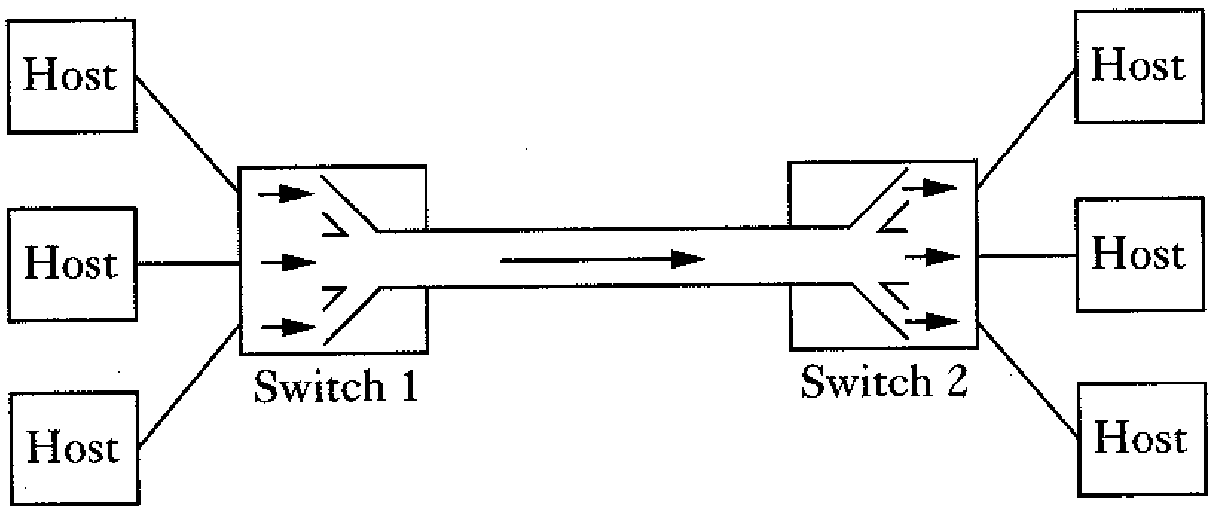


Connectivity: Internetworks



Resource Sharing: Multiplexing

- How can multiple hosts share the network if they want to use it at the same time?
  - Sharing links
  - Sharing switches

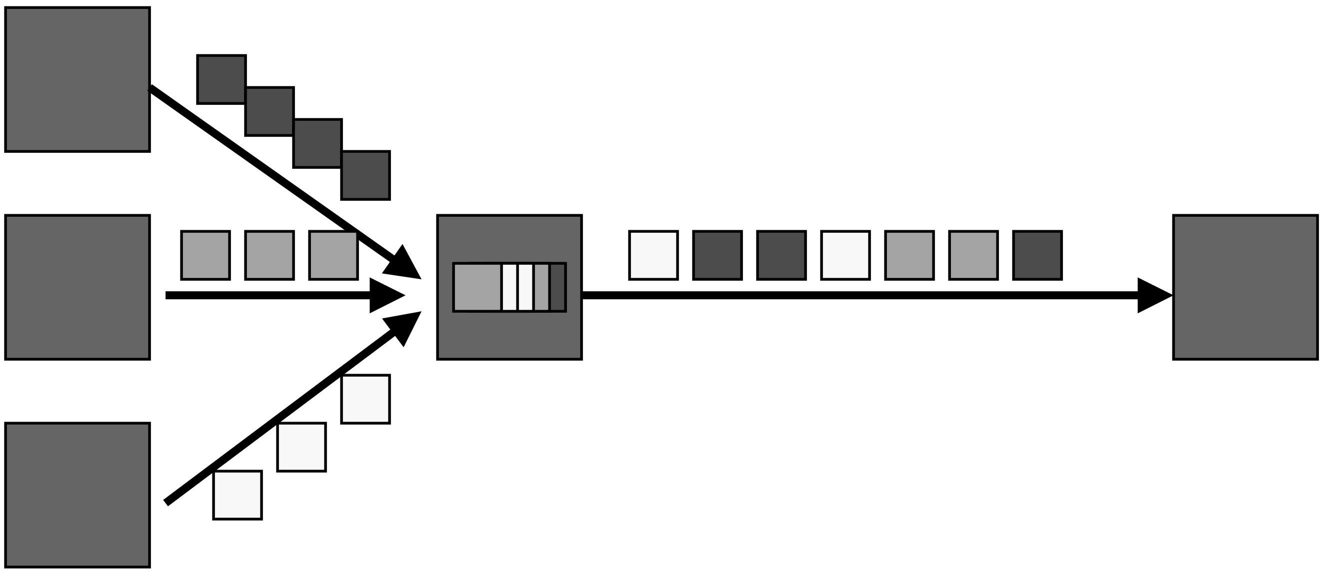


Multiplexing: STDM & FDM

- Synchronous Time-division Multiplexing (STDM)
  - “Time sharing”
  - Divide time into equal sized quanta
  - Round-robin
- Frequency-division Multiplexing (FDM)
  - Transmit all flows at different frequencies
  - Radio or Television
- Limitations:
  - Wasted resources
  - Maximum # flows can’t be changed

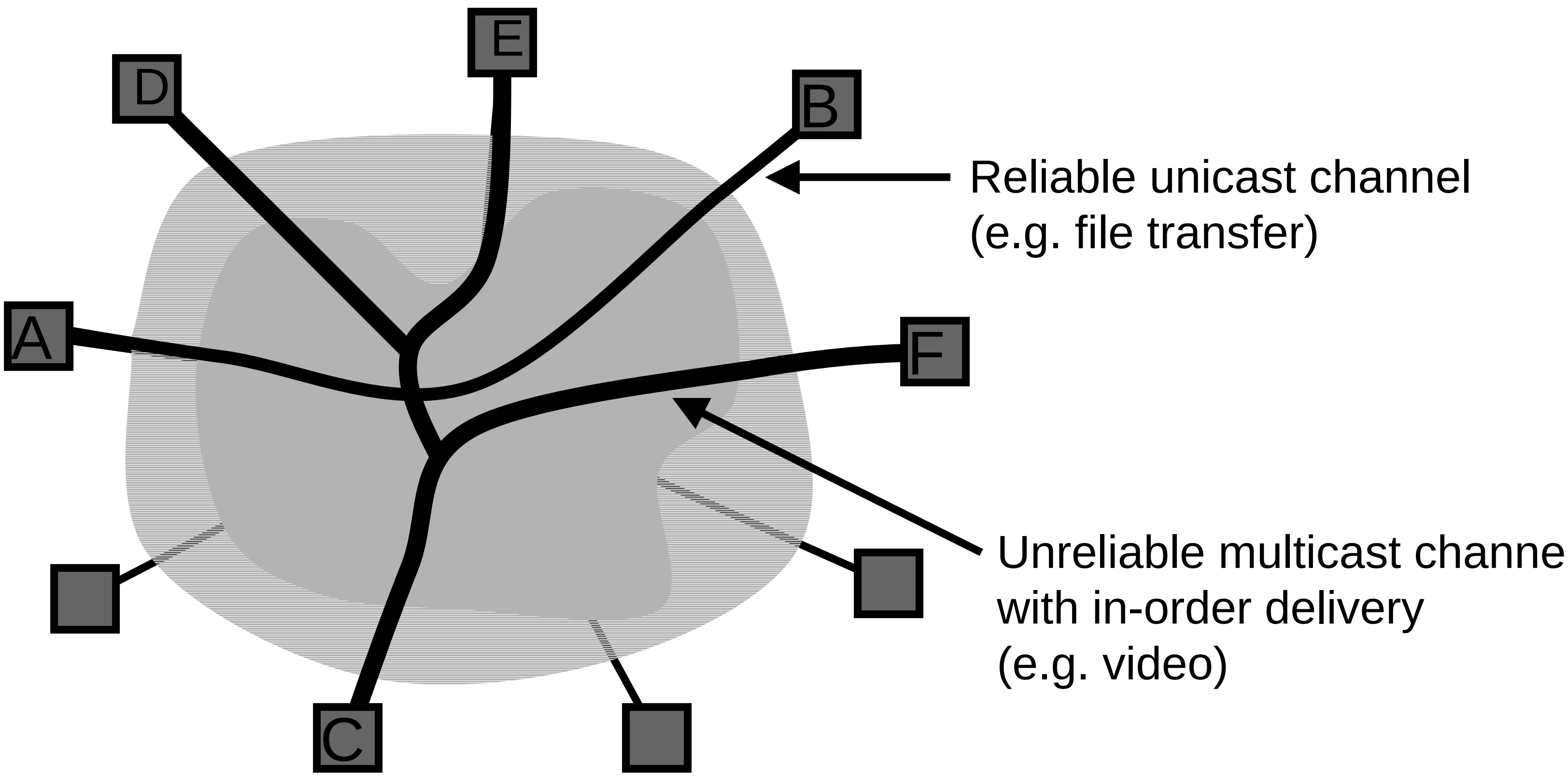
Statistical Multiplexing

- Data is partitioned into *packets*
- Routing decision is made per packet
- Better resource usage than STDM
- Fairness? Congestion?



Functionality

- Different applications require different services



Functionality & Dealing with Failure

- Fairness
- Congestion
- Quality of Service
- Bit or burst errors
- Link or node outages

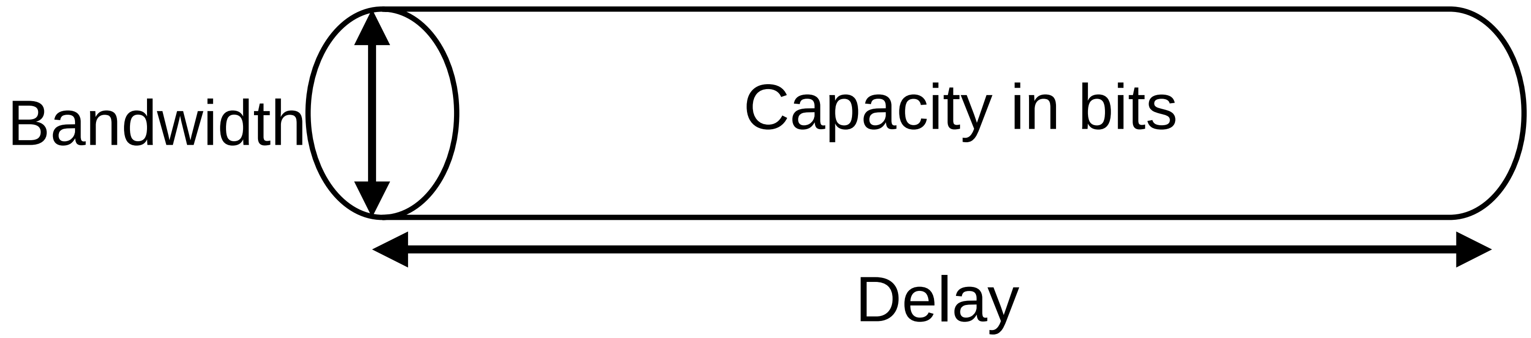
Performance

- *Bandwidth* (throughput)
  – The number of bits that can be transmitted over the network in a certain period of time.
  – Measured in bits/sec
- *Latency* (delay)
  – How long it takes a single bit to propagate from one end of the network to the other.
  – Measured in seconds
- Round Trip Time (RTT)
  – How long it takes for a bit to get from one end of the network to the other *and back*.

Connectivity: Direct Link Technologies

Wired Ethernet	10, 100 Mbps, 1, 10 Gbps
SONET fiber Synchronous Optical Network	up to 9.6 Gbps
CATV Cable TV	1-6 Mbps, asymmetric
ADSL Asymmetric Digital Subscriber Line	Downstream: 1.5-55.2 Mbps Upstream: 16-640 Kbps
ISDN Integrated Services Digital Network	64 Kbps*n with bonding
POTS Plane Old Telephone Service	56 Kbps
Wireless Ethernet	2, 11, …, Mbps
Infrared IrDA	115 Kbps to 4 Mbps
CDPD Cellular Digital Packet Data	19.2 Kbps

Performance: Delay x Bandwidth



Delay x Bandwidth determines the number of bits that can be "in flight".

For efficient resource usage: keep the pipe full.

Key Equations

Latency = Propagation + Transmit + Queue

Propagation = Distance / SpeedOfLight

Transmit = Size / Bandwidth

Total Latency: Direct Link

Data moves through the link at the speed of light.

Time

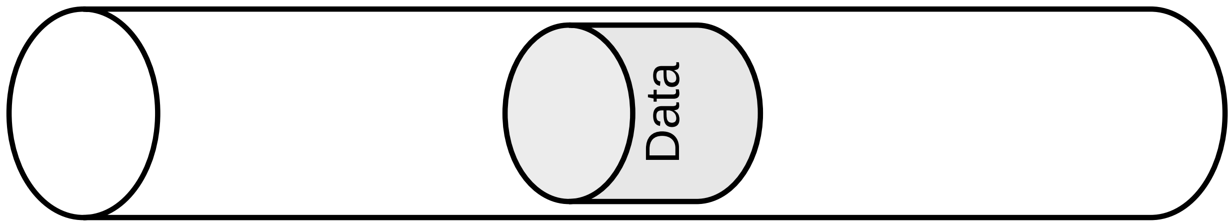
0 Data ready to be sent

Total Latency: Direct Link

Data moves through the link at the speed of light.

Time	
0	Data ready to be sent
t = Size/Bandwidth	Data in the link

Total Latency: Direct Link



Data moves through the link at the speed of light.

Time	
0	Data ready to be sent
t = Size/Bandwidth	Data in the link
t+k	Data traveling through the link

Total Latency: Direct Link

Data moves through the link at the speed of light.

Time	
0	Data ready to be sent
t = Size/Bandwidth	Data in the link
t+k	Data traveling through the link
prop = Distance/LightSpeed	First bit arrives at destination

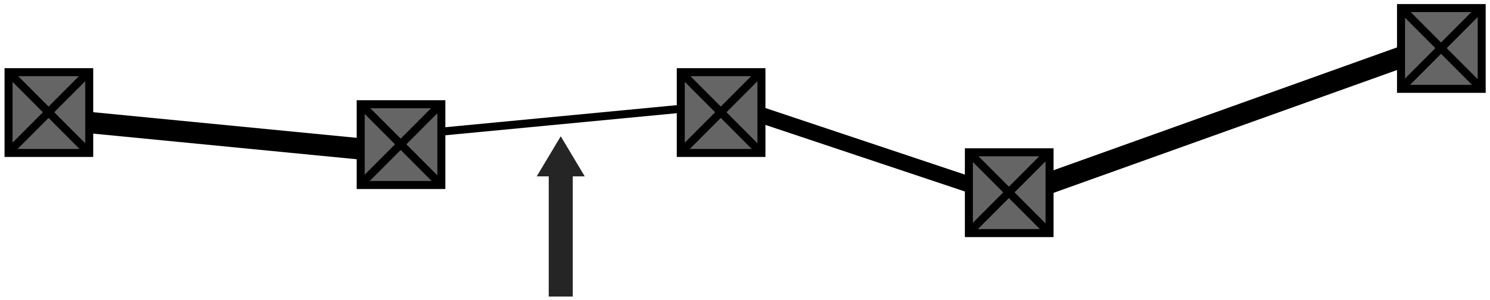
Total Latency: Direct Link

Data moves through the link at the speed of light.

Time	
0	Data ready to be sent
t = Size/Bandwidth	Data in the link
t+k	Data traveling through the link
prop = Distance/LightSpeed	First bit arrives at destination
prop + t	Last bit arrives at destination

Paths Are Made of *Links*

- Links are interconnected by zero or more *network elements*, e.g., switches, routers, hubs, bridges, etc.
- Path delay is sum of link delays plus queuing (switching) delays
- Path throughput = *bottleneck link* t'put



Tradeoffs

- RTT from Penn to Stanford is approx. 100ms
- 1.4 GHz workstation
  - 140 million cycles elapsed in that time
- Data compression
  - Trades machine cycles for bandwidth
- (Question: Why is RTT important?)

Bandwidth vs. Latency

- Which is the better deal:
  - Improve your *bandwidth* from 1 Mbps to 100 Mbps, or
  - Improve your *RTT* from 100 ms to 1 ms?
- The answer depends on what you need to send.

Latency Bound

- Send 1 byte

Transmit Time	
1 Mbps	8 μs
100 Mbps	.08 μs

Perceived Latency	100 ms	1 ms	
1 Mbps	100.008 ms	1.008 ms	99%
100 Mbps	100.00008 ms	1.00008 ms	99%
	.008%	.8%	

Bandwidth Bound

- Send 25 MB

Transmit Time	
1 Mbps	3.5 min
100 Mbps	21 sec

Perceived Latency	100 ms	1 ms	
1 Mbps	210.1 sec	210.001 sec	.05%
100 Mbps	21.1 sec	21.001 sec	.5%
	90%	90%	

Some Units and Measurements

- Mbps = 10^6 bits/sec
- byte = 8 bits
- KB = 2^{10} bytes (= 8,192 bits)
- MB = 2^{20} bytes (= 8,388,608 bits)
- ms = 10^{-3} seconds
- μs = 10^{-6} seconds

- Speed of light:
  – Vacuum : 3×10^8 m/sec
  – Copper or Fiber: 2×10^8 m/sec