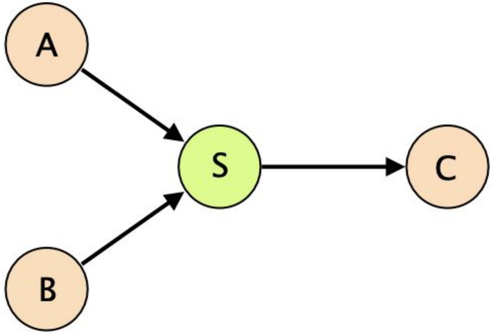
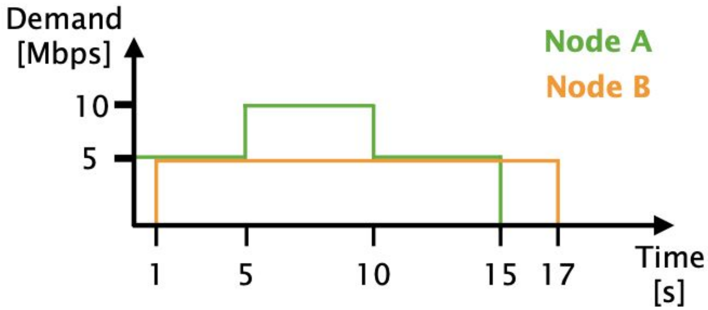
Circuit Switching vs Packet Switching

Assume that A and B have to send data with a demand according to the diagram on the right.

- How long does it take to send all data if A and B use circuit switching (reserving for the peak demand)?
  Answer: First, node A reserves 10Mbps bandwidth. During this time, node B cannot establish its circuit.
  0.05 + 15 + 0.05 + 0.05 + 16 + 0.05 = 31.2 s

- How long does it take to send all data if A and B use packet switching (you can assume an unlimited buffer size on S)?
  Answer: Both nodes start to send packets immediately. From 5 to 10 s, packets are buffered. Assuming the switch always uses the full link bandwidth towards C:
  1 + 14 + 2 + 1.5 = 18.5 s

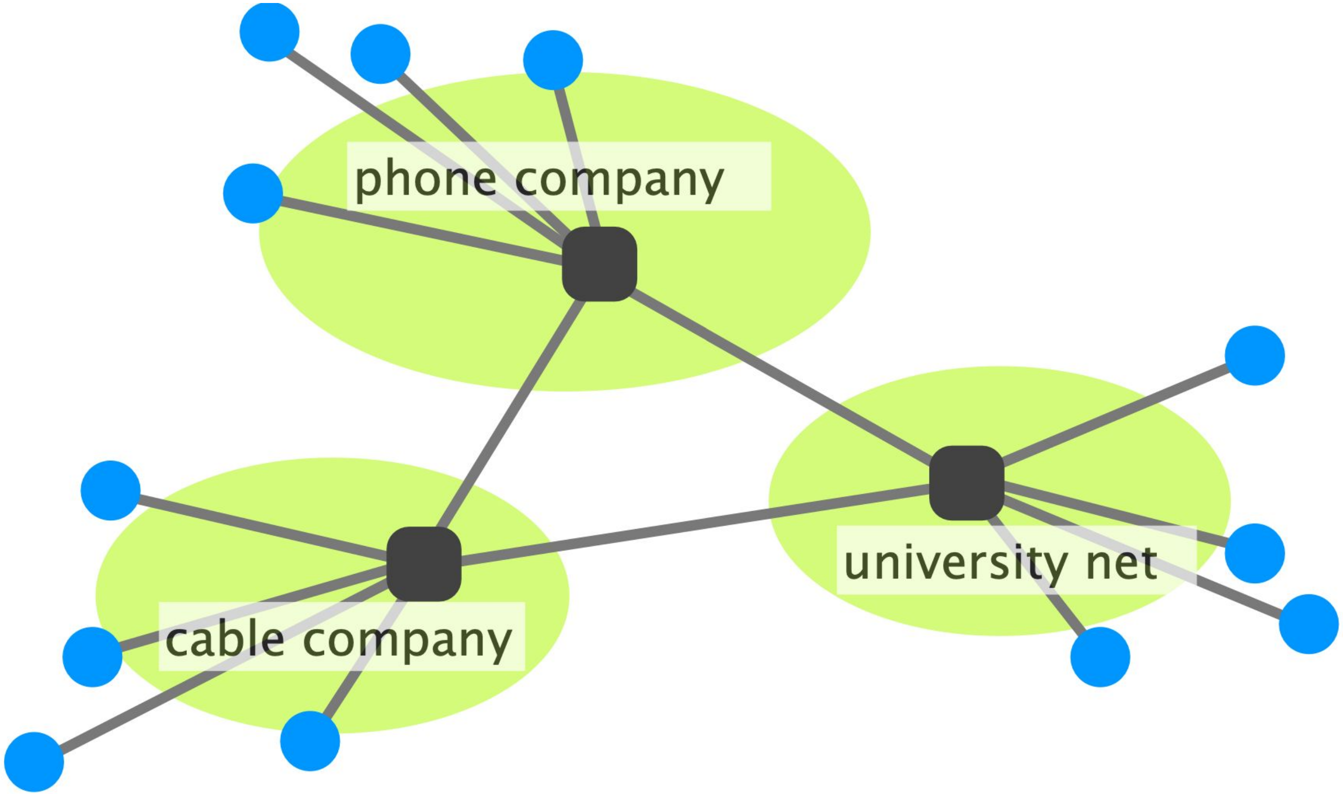




Demand distributions for node A and B.

Internet Organization

The Internet is a Network of Networks



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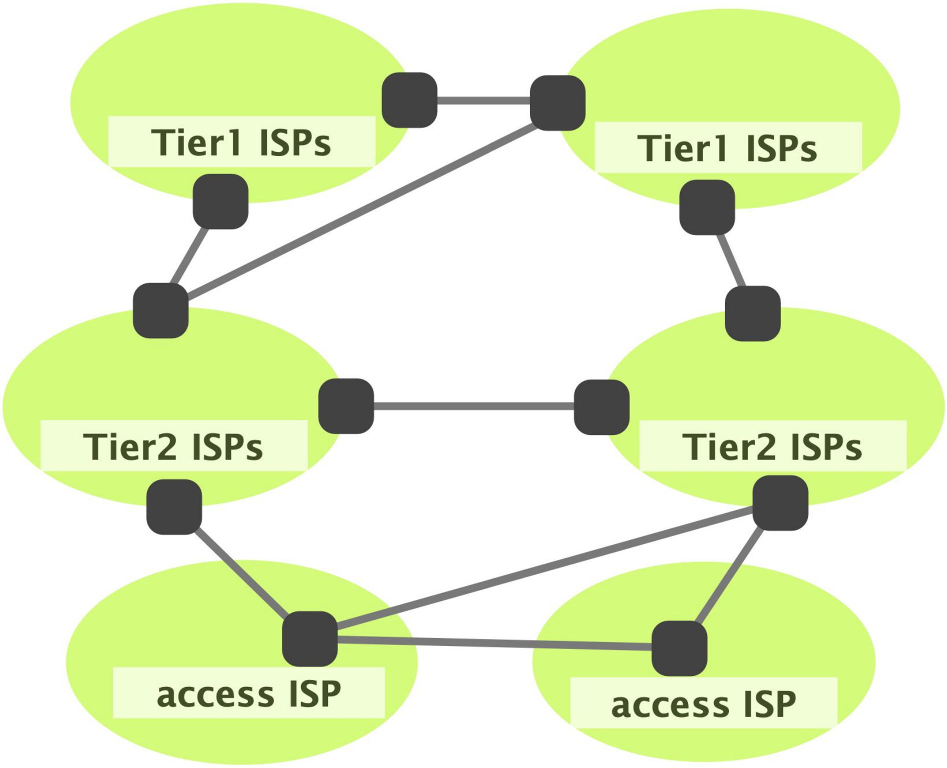
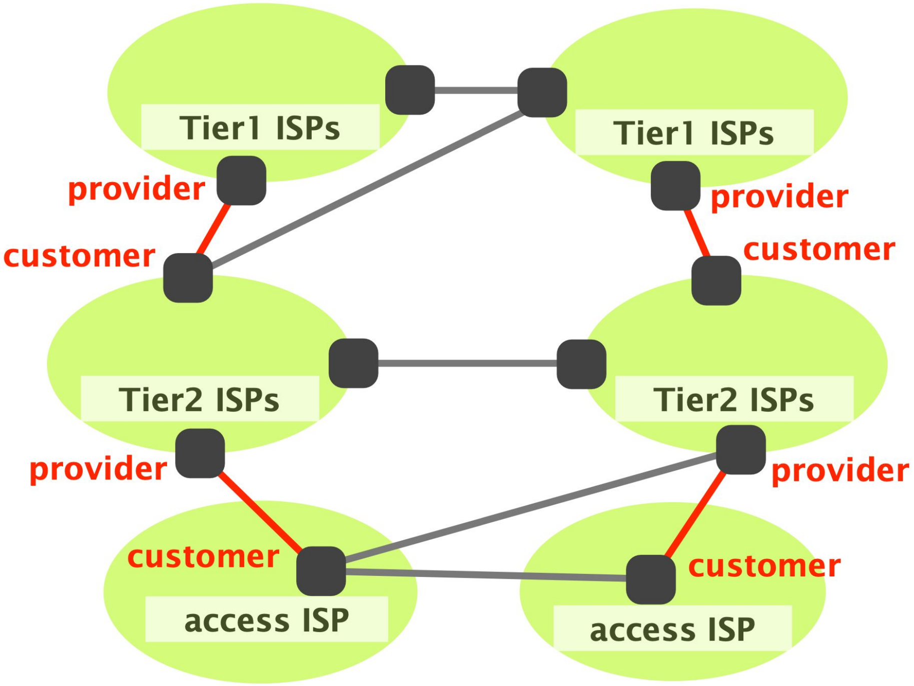
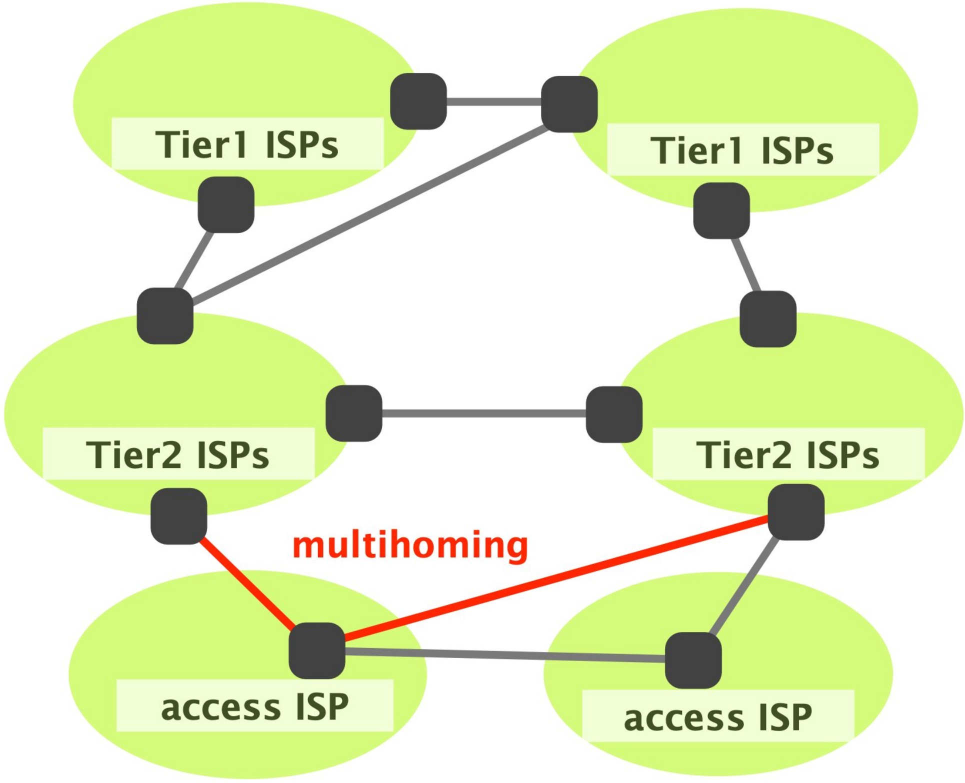


The Internet Hierarchy

- Tier-1 (international)
  - Have no provider
- Tier-2 (national)
  - Provide transit to tier-3s
  - Have at least one provider
- Tier-3 (local)
  - Do not provide any transit
  - Have at least one provider



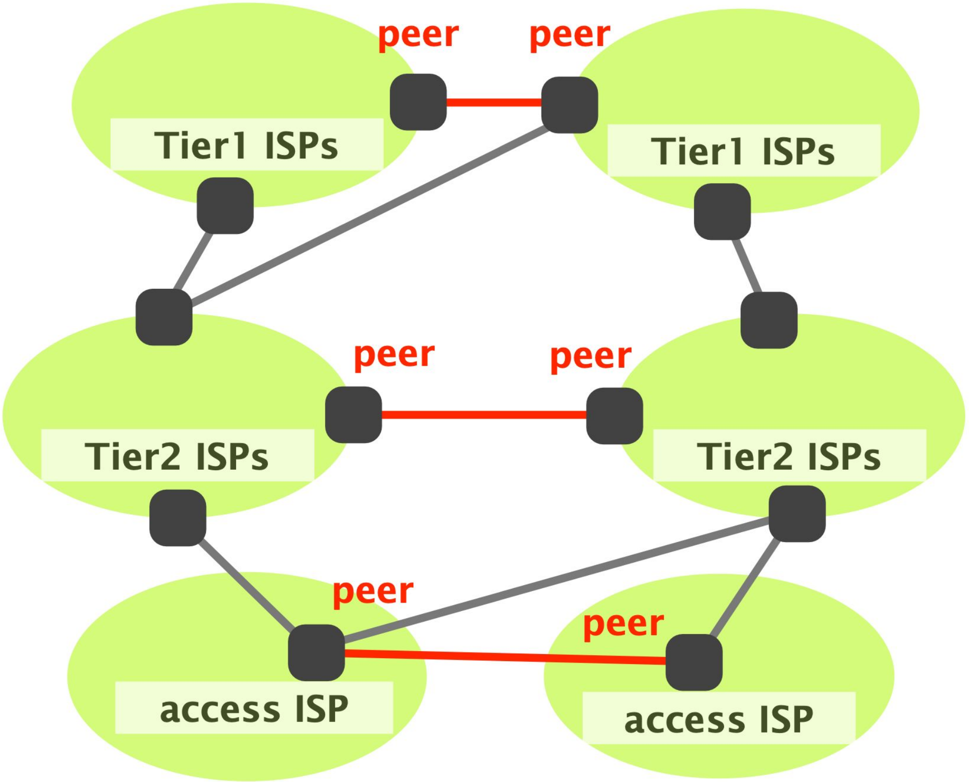
The Internet is a Network of Networks



Some Networks Connect Directly to One Another to Save $$$

Known as “peering”

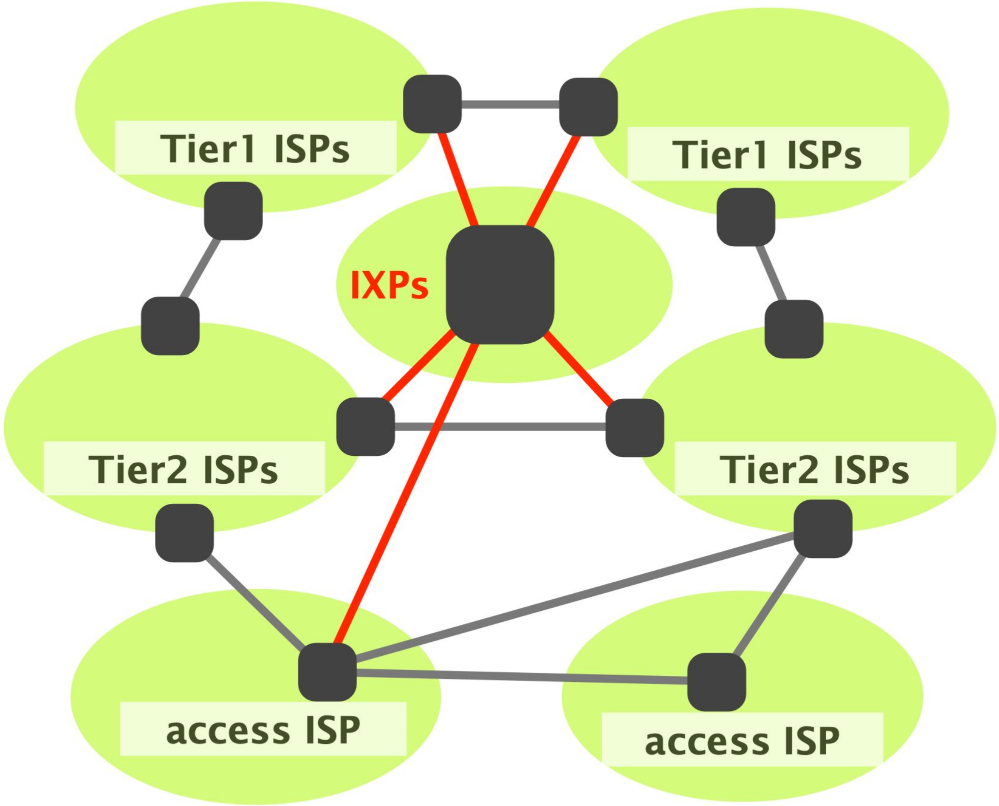
Some Networks Connect Directly to One Another to Save $$$



Interconnecting One-by-One is not Efficient / Cost Effective

- Physical costs
  - Provisioning or renting links
- Bandwidth costs
  - Many links underutilized
- Human costs
  - Management of each connection
- Answer? Internet Exchange Points (IXPs)

Interconnecting One-by-One is not Efficient / Cost Effective

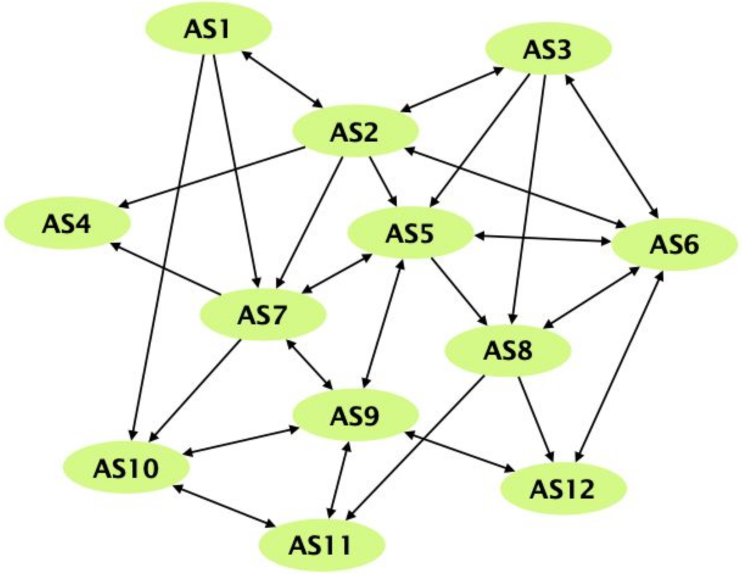


Internet Hierarchy

The network on the left consists of multiple autonomous systems (AS). Single-headed arrows point from providers to their customers. Double-headed arrows represent peer connections.

- For each AS, identify if it is a Tier-1, Tier-2 or Tier-3 network or an IXP.

- AS7 has two different providers (AS1 and AS2). How is this type of interconnection called? What are the advantages of multiple different providers for AS7? Can you see any disadvantages?



Internet Hierarchy

The network on the left consists of multiple autonomous systems (AS). Single-headed arrows point from providers to their customers. Double-headed arrows represent peer connections.

- For each AS, identify if it is a Tier-1, Tier-2 or Tier-3 network or an IXP.

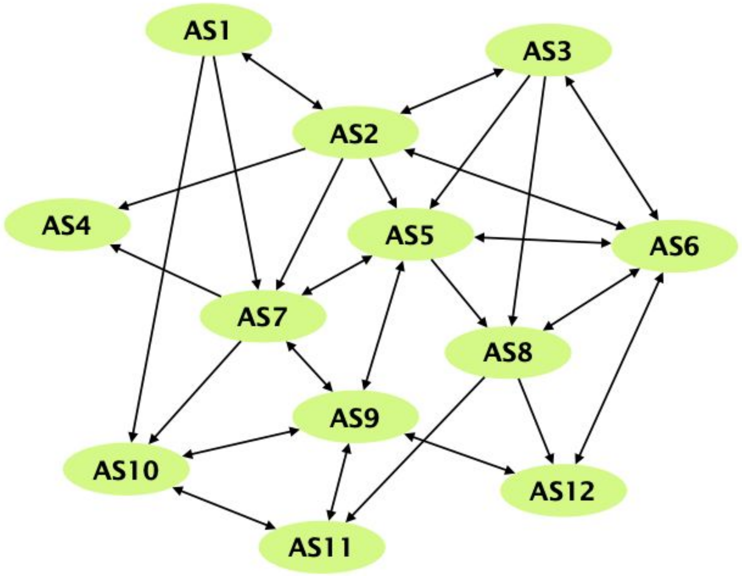
  Solution: Tier-1 ISPs: AS1, AS2, AS3. Tier-2 ISPs: AS5, AS7, AS8. Tier-3 ISPs: AS4, AS10, AS11, AS12. IXPs: AS6, AS9.

- AS7 has two different providers (AS1 and AS2). How is this type of interconnection called? What are the advantages of multiple different providers for AS7? Can you see any disadvantages?

  Solution: Multihoming.

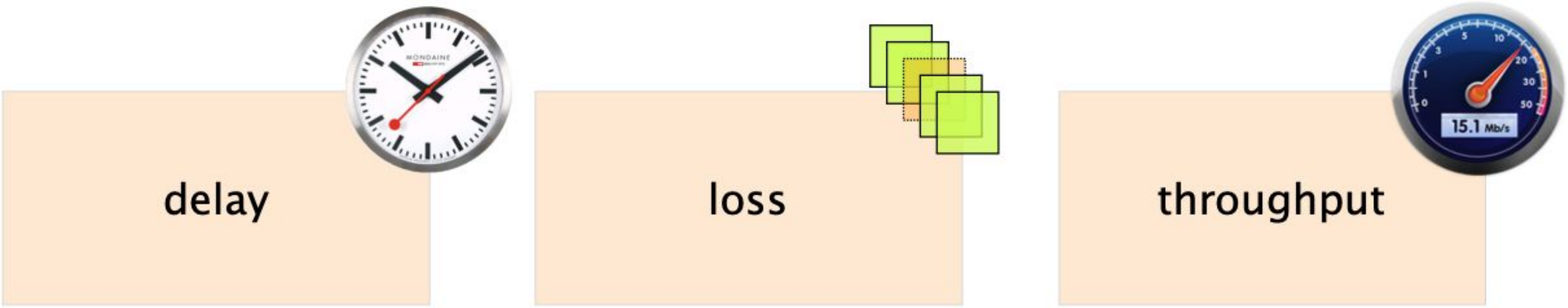
  Advantages: Still connected if one of the provider fails. For destinations (IP prefixes) which can be reached over both providers, AS7 can choose the better one based on cost, trust, ...

  Disadvantages: network configuration is slightly more difficult. The total cost could be higher compared to an ISP with only one provider.



Delay, Loss, and Throughput

A Network Connection is Characterized by Three Metrics



How long does it take for a packet to reach the destination

What fraction of packets sent to a destination are dropped?

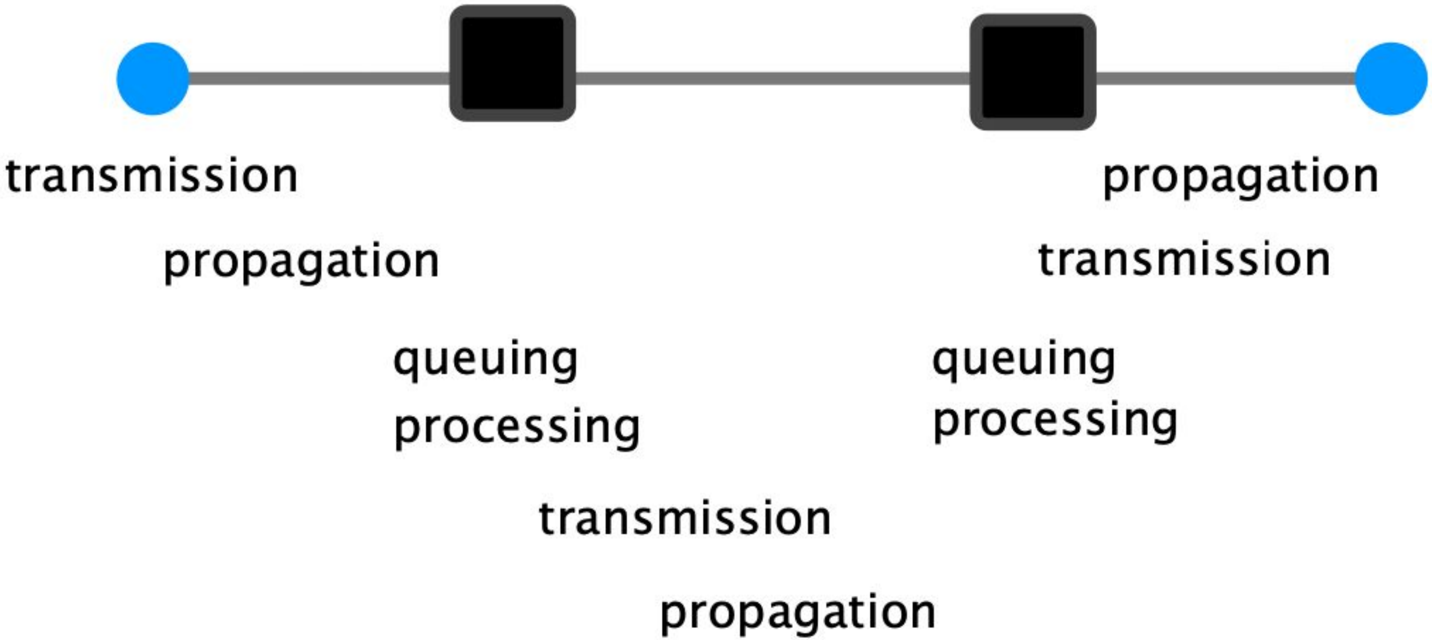
At what rate is the destination receiving data from the source?

Every Packet Suffers from Several Types of Delay *at Each Node*

	transmission	delay	due to link properties
⊕	propagation	delay	
⊕	processing	delay	due to traffic mix & switch internals
⊕	queuing	delay	
=	total	delay	

The Main Culprits for Overall Delay are Transmission, Propagation, and Queuing

	transmission	delay	
⊕	propagation	delay	
⊕	processing	delay	*tend to be tiny*
⊕	queuing	delay	
=	total	delay	


transmission
propagation
queuing
processing
transmission
propagation
propagation
transmission
queuing
processing

Transmission Delay is the Time Required to Push all Bits onto the Link

$$\text{Transmission delay [sec]} = \frac{\text{packet size [\#bits]}}{\text{link bandwidth [\#bits/sec]}}$$

$$\text{Example} \quad \frac{\text{1000 bits}}{\text{100 Gbps}} \quad \text{10 ns}$$

Propagation Delay is the Time Required a Bit to Travel to the End of the Link

$$\text{Propagation delay [sec]} = \frac{\text{link length [m]}}{\text{propagation speed [m/sec]}}$$

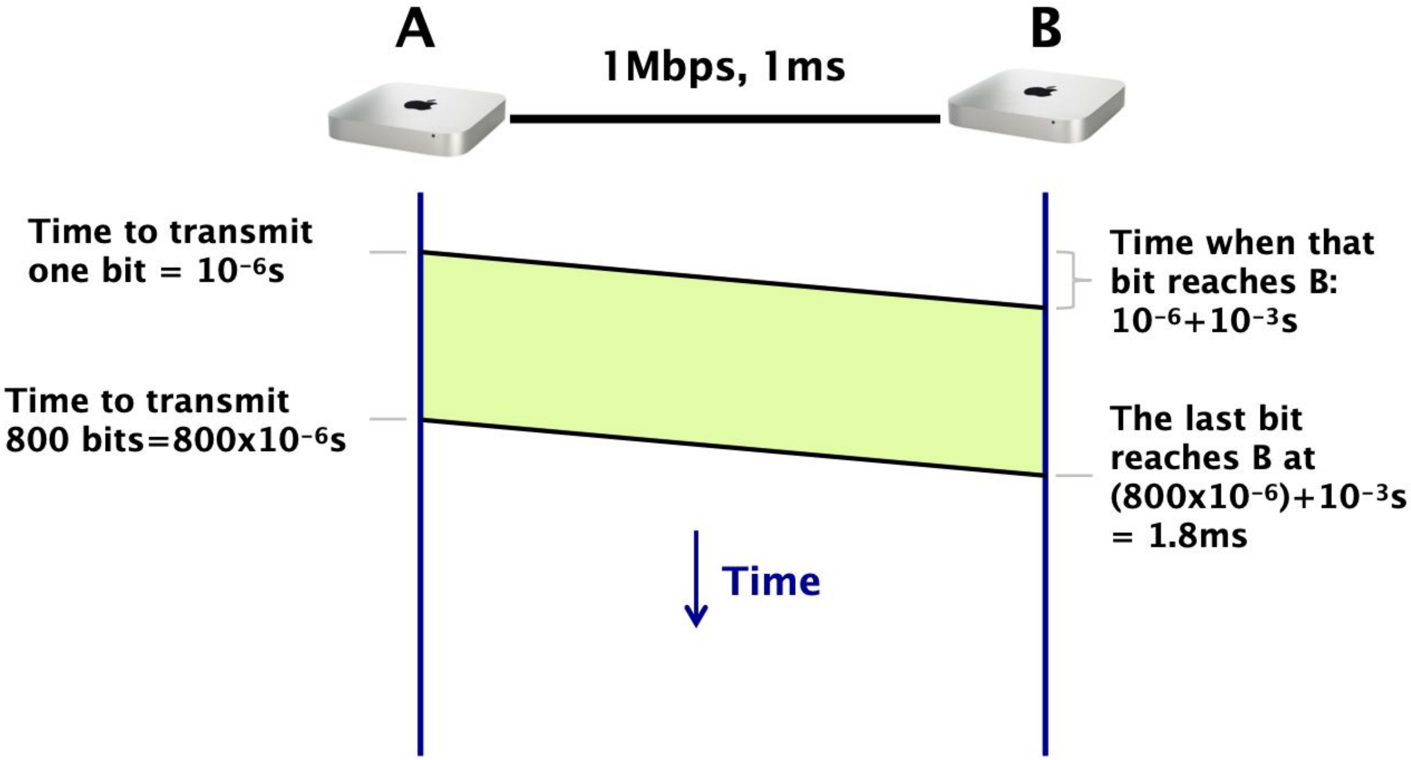
(fraction of speed of light)

Example

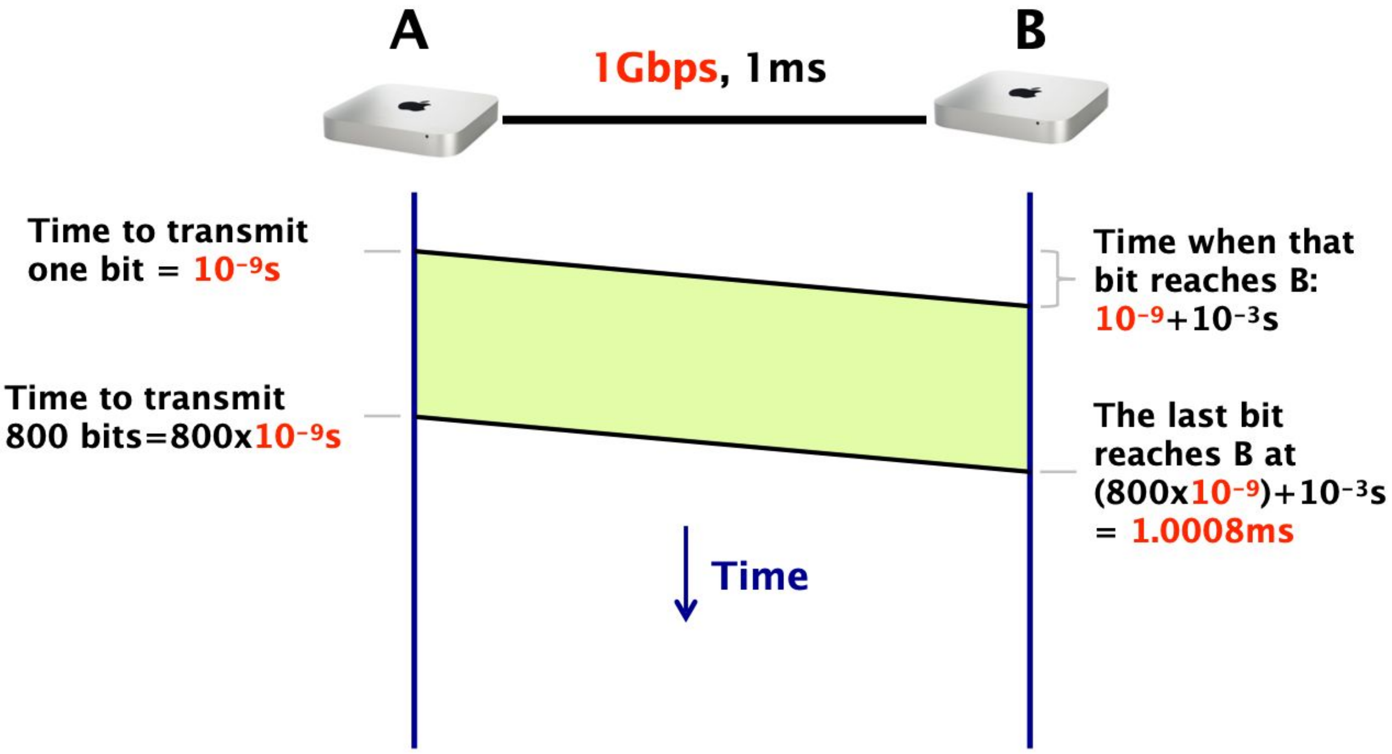
$$\frac{30\,000 \text{ m}}{2\text{x}10^8 \text{ m/sec}} \quad 150\ \mu\text{sec}$$

(speed of light in fiber)

How Long Does it Take to Send a 100 Byte (800 bits) Packet?



If We Have a 1Gbps Link

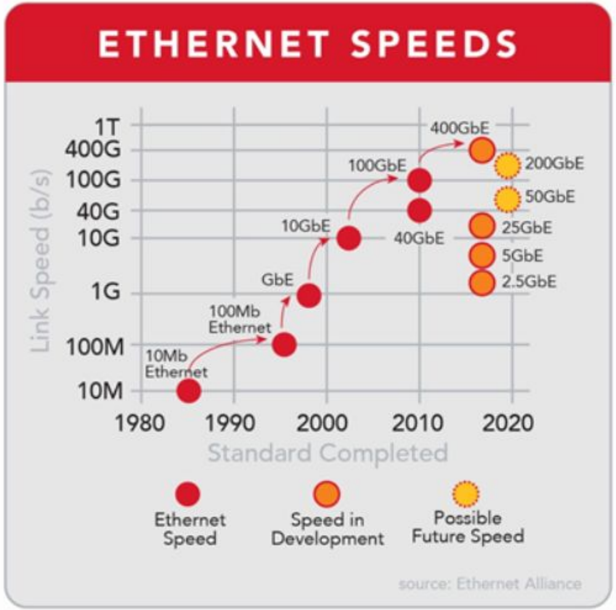


Different Transmission Characteristics Imply Different Tradeoffs in Terms of Which Delay Dominates

10^7x100B pkt	1Gbps link	transmission delay dominates
1x100B pkt	1Gbps link	propagation delay dominates
1x100B pkt	1Mbps link	both matter

In the Internet, we **can't know** in advance which one matters!

As Technology Improves, Throughputs Increase and Delays Decrease (except for propagation)



source: ciena.com

What To Do About Propagation Delays?