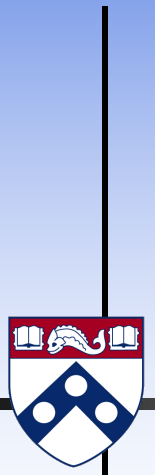


CIS 553: Networked Systems

Physical Layer

February 1, 2021

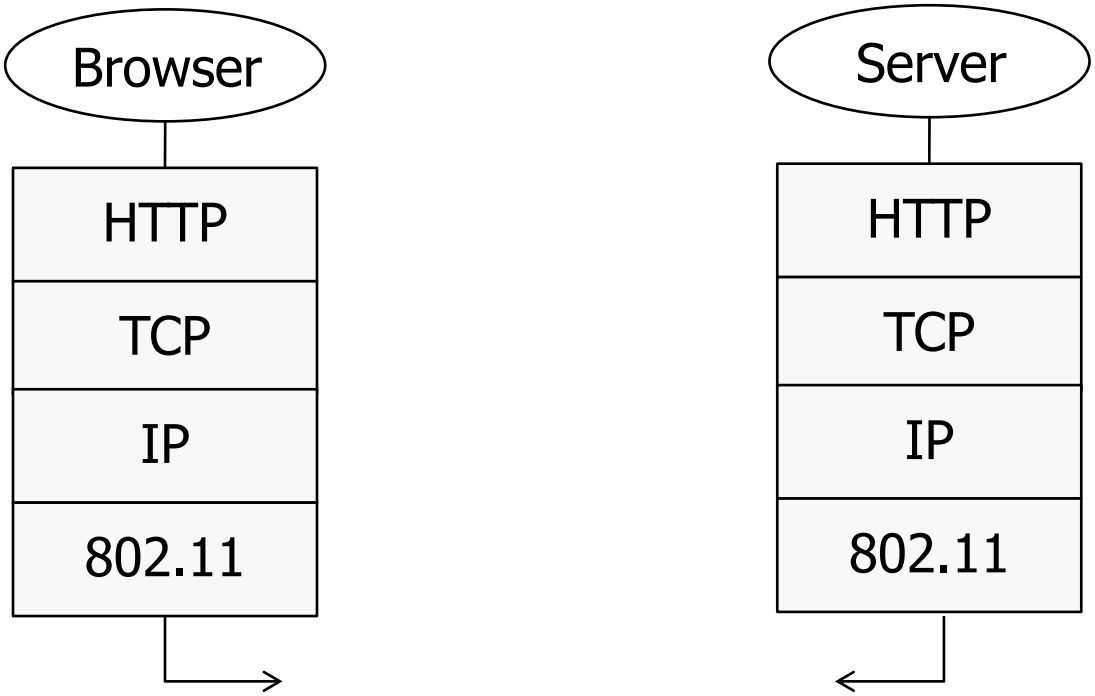
Agenda

- Design goals of the Internet 
  - Taxonomy of networks 
  - Design goals (Clark '88) 
  - Layering and the end-to-end principle 

- Physical Layer
  - Media types
  - Performance Metrics

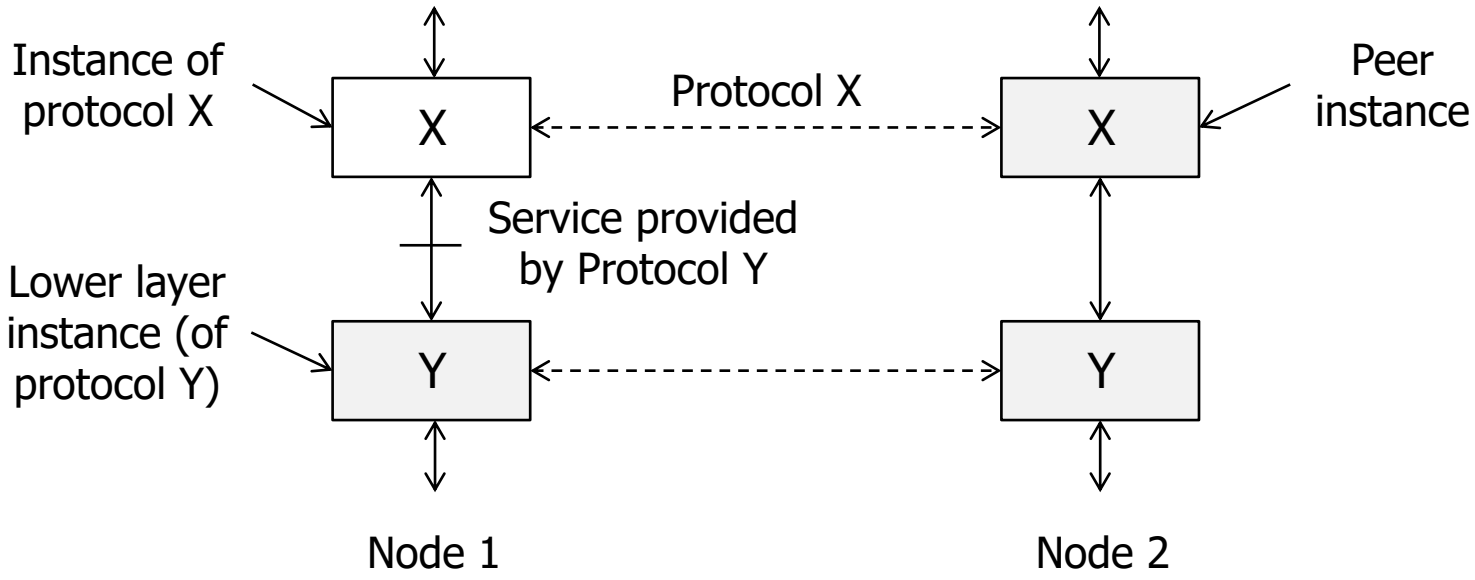
Layering

- The ability to mix and match protocols
- Set of protocols in use is called a protocol stack
- Ex:



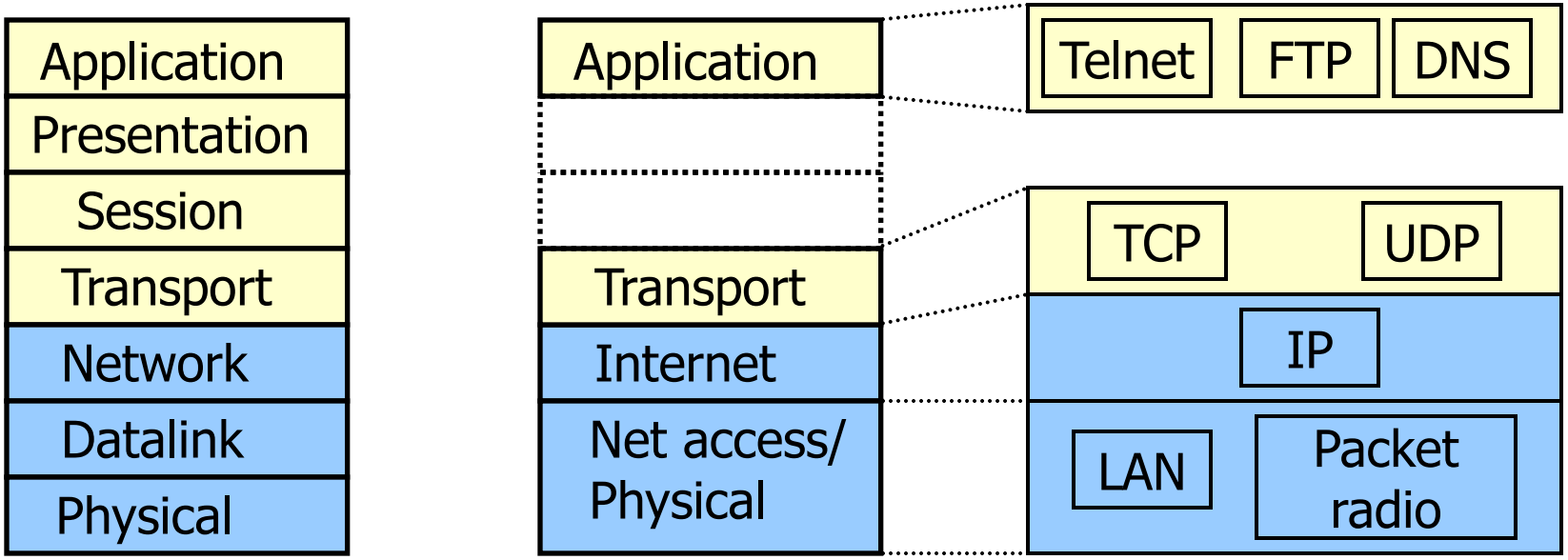
Protocols and Layers

- Protocols are horizontal, layers are vertical



OSI vs. Internet

- OSI: conceptually define services, interfaces, protocols
- Internet: provide a successful implementation



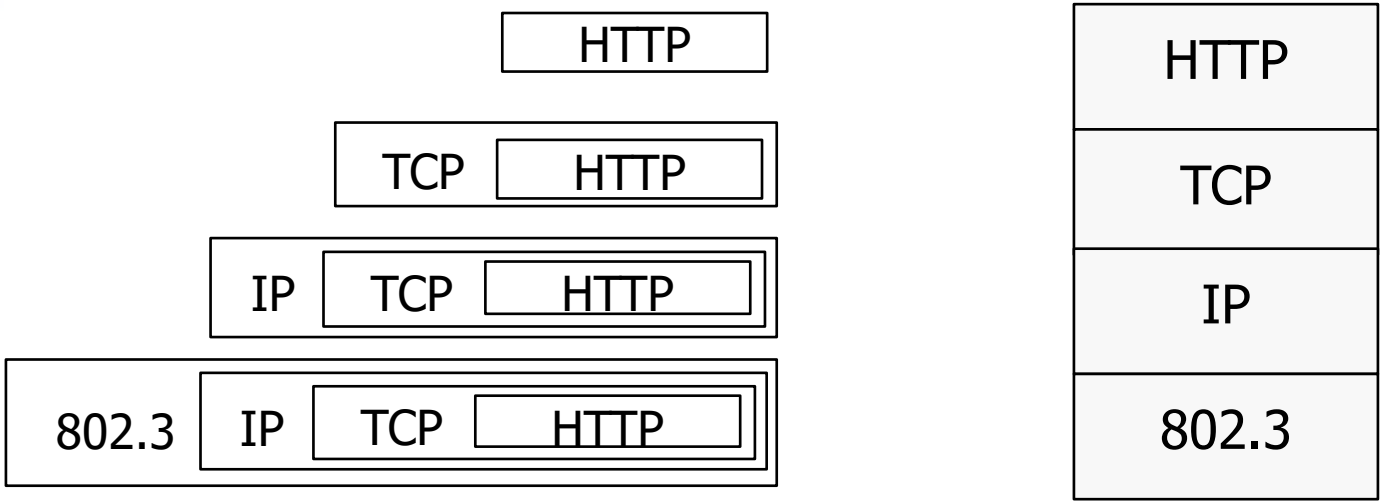
OSI (formal)

Internet (informal)

Encapsulation and (decapsulation)

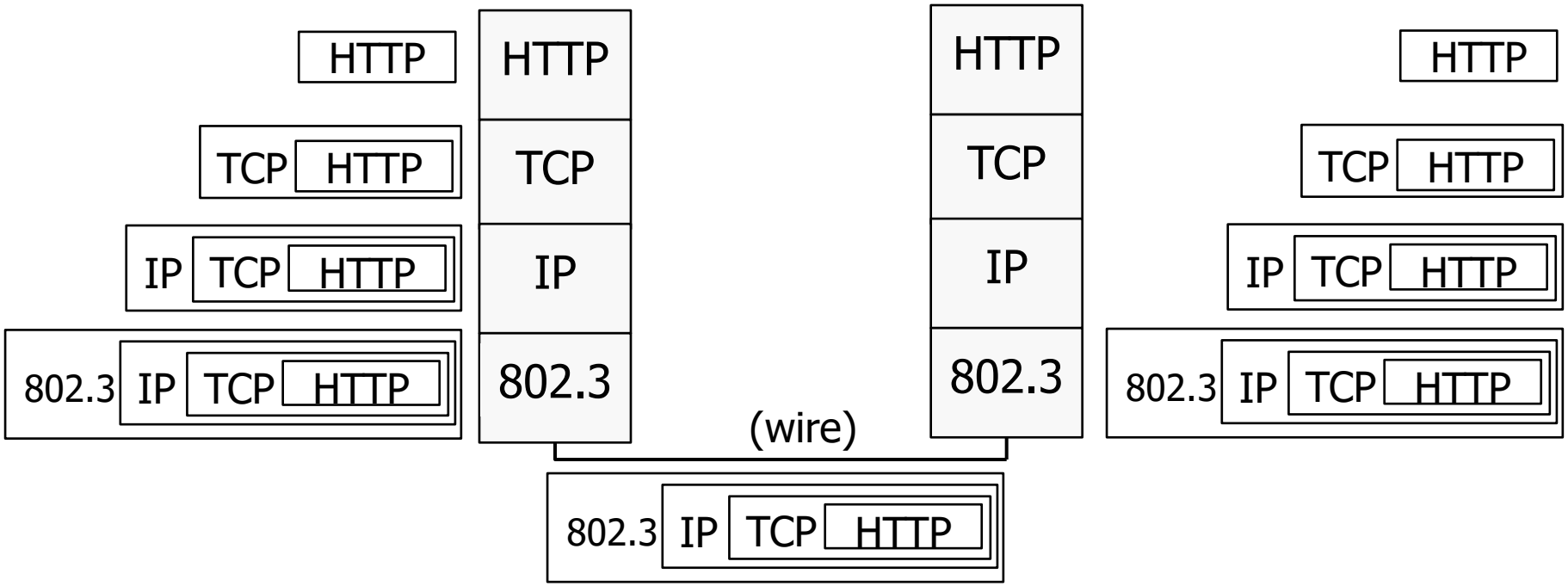
- Encapsulation is the mechanism used to effect protocol layering
  - Lower layer wraps higher layer content, adding its own information to make a new message for delivery
  - Like sending a letter in an envelope; postal service doesn't look inside

Encapsulation (Cont.)



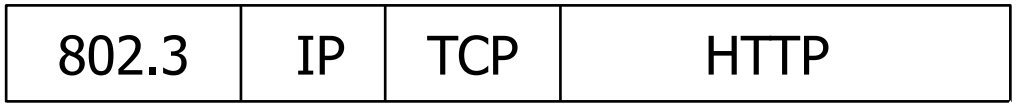
- Message "on the wire" begins to look like an onion
  - Lower layers are outermost

Encapsulation (Cont.)



Encapsulation (Cont.)

- Normally draw message like this:
  - Each layer adds its own header



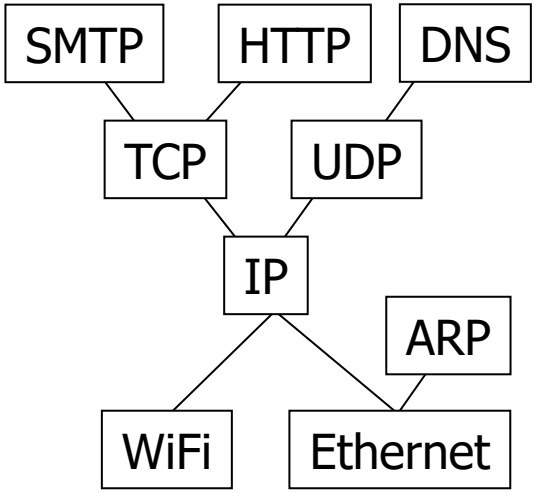
First bits on the wire

Last bits

- More involved in practice
  - Trailers as well as headers, encrypt/compress contents
  - Segmentation (divide long message) and reassembly

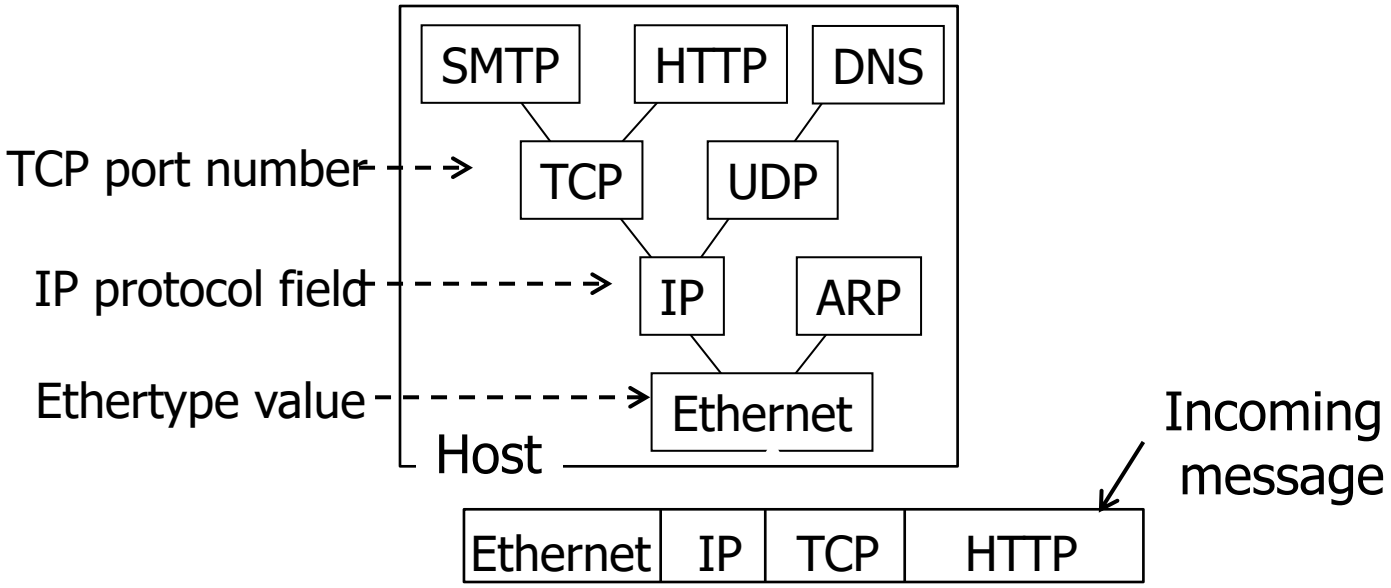
Multiplexing (and demultiplexing)

- Outgoing message must be encapsulated with the correct header
- Incoming message must be passed to the protocols that it uses



Demultiplexing (Cont.)

- Done with demultiplexing keys in the headers



Which Layer is Right for Me?

http://web.mit.edu/Saltzer/www/publications/endtoend/endtoend.txt

- Consider file transfer from A's hard drive to B's hard drive over the network
- Transient failures at many levels
  - Disk errors
  - Incorrect software (FS, FTP, network, …)
  - Hardware errors (CPU, memory, network, disk, system crash, …)
- Implementing reliability at lower layers is insufficient!
  - Don't over-engineer if end-to-end checks are still required
  - Not everyone will need it anyway
- Many exceptions and gray areas
  - Performance, cost, engineering, …

E2E rule of thumb in network design

- If hosts can implement functionality correctly, implement it a lower layer only as a performance enhancement
- But do so only if it does not impose burden on applications that do not require that functionality
- Other examples in the paper include encryption, duplicate suppression, etc.

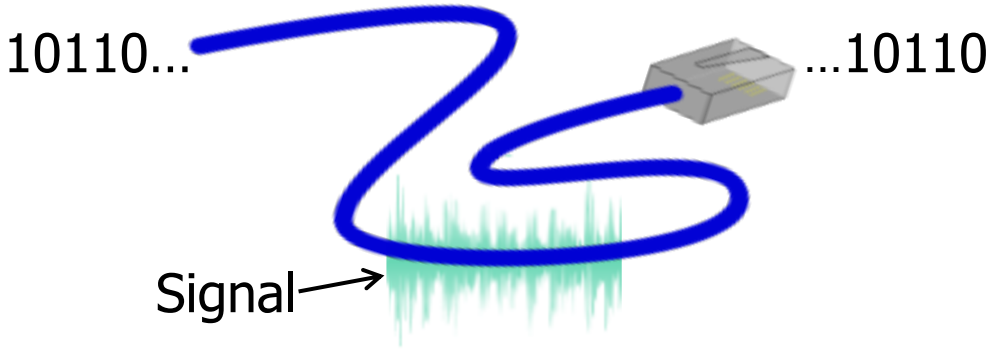
Agenda

- Design goals of the Internet 
  - Layering and the end-to-end principle 
- Physical Layer 

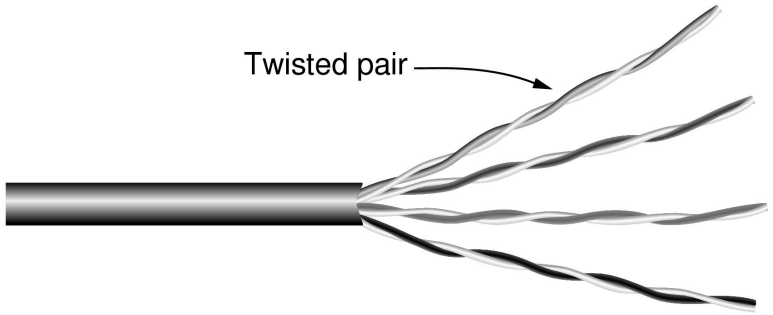
  - Media types
  - Performance Metrics

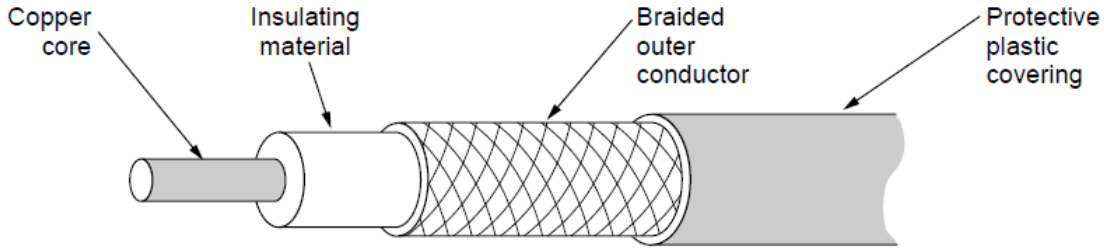
Scope of the Physical Layer

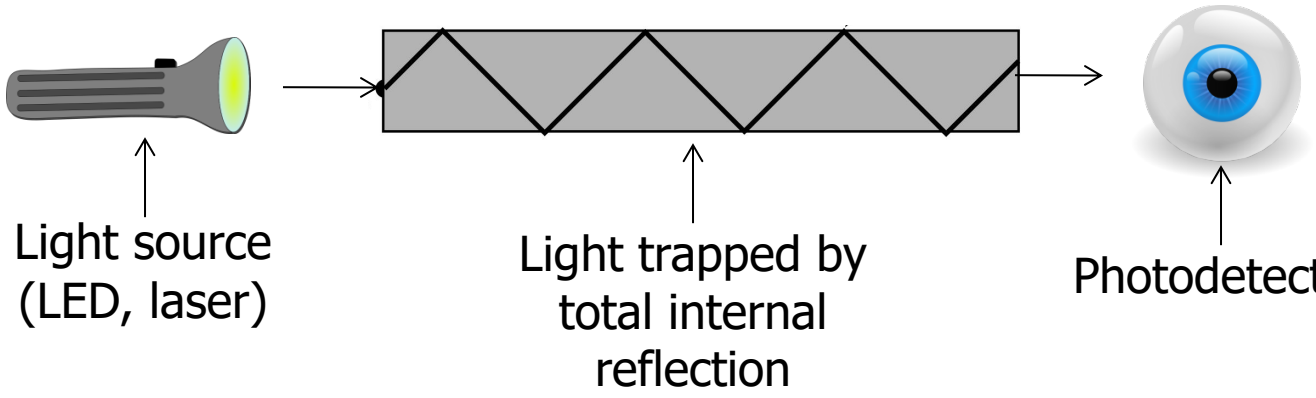
- Concerns how signals are used to transfer message bits over a link
  - Wires etc. carry analog signals
  - We want to send digital bits



Wires

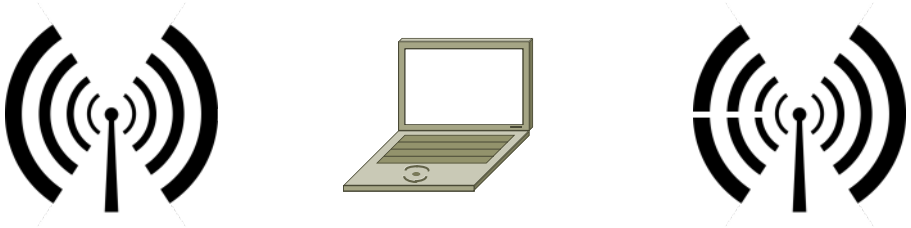

Twisted pair


Copper core
Insulating material
Braided outer conductor
Protective plastic covering


Light source (LED, laser)
Light trapped by total internal reflection
Photodetector

Wireless

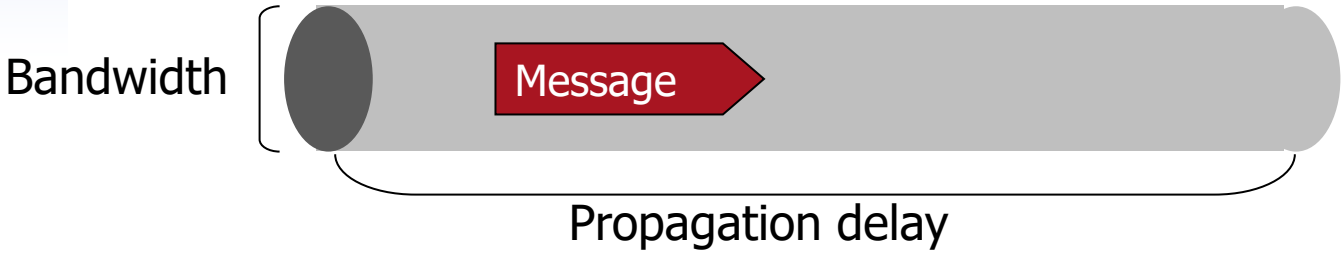
- Sender radiates signal over a region
  - In many directions, unlike a wire, to potentially many receivers
  - Nearby signals (same freq.) interfere at a receiver; need to coordinate use



Agenda

- Design goals of the Internet ✓
  - Layering and the end-to-end principle ✓
- Physical Layer ✓
  - Media types ✓
  - Performance Metrics NEXT

A Simple Model of a Link



Performance metrics:

- Delay (latency)
- Bandwidth (throughput, capacity, speed, etc.)
- Loss rate

- Also:
  - Broadcast vs Not
  - Full Duplex vs Half Duplex vs Simplex
  - SNR
  - etc.

Performance Metric: Latency

- Consists of four components
  - Transmission delay
  - Propagation delay
  - Queuing delay
  - Processing delay

due to link properties

due to traffic mix and switch internals

1. Transmission delay

- How long does it take to push all the bits of a message into a link?
- Message size / bandwidth of the link
  - e.g., 1000 bits / 100 Mbits per sec = 10 us

2. Propagation delay

- How long does it take to move one bit from one end of a link to the other?
- Link length / Propagation speed of link
  - E.g., 30 kilometers / $3*10^8$ meters per sec = 100 us