The Physical Layer

COMP 30650: Networks and Internet Systems

Dr. Gavin McArdle
Email: gavin.mcardle@ucd.ie
Office: A1.09 Computer Science

RECAP

Protocols and Layers

- Advantages
- Disadvantages

Types of connections in a network

Services and Protocols

- Service Primitives

Guidelines for the designing the layers and functionality

- OSI Model
- TCP/IP Model

TODAY'S PLAN

1. Properties of the physical layer
   - Message Latency
   - Bandwidth Delay Product
2. Types of of media
   - Wires, fiber optics, wireless
3. Simple modulation

METRIC UNITS

Prefix	Exp.	prefix	exp.
K(ilo)		m(illi)	
M(ega)		μ(micro)	
G(iga)		n(ano)	

METRIC UNITS

The main prefixes we use:

Prefix	Exp.	prefix	exp.
K(ilo)	10^3	m(illi)	10^{-3}
M(ega)	10^6	μ(micro)	10^{-6}
G(iga)	10^9	n(ano)	10^{-9}

Use powers of 10 for rates, powers of 2 for storage

E.g., KB = 1024 bytes (2^10)

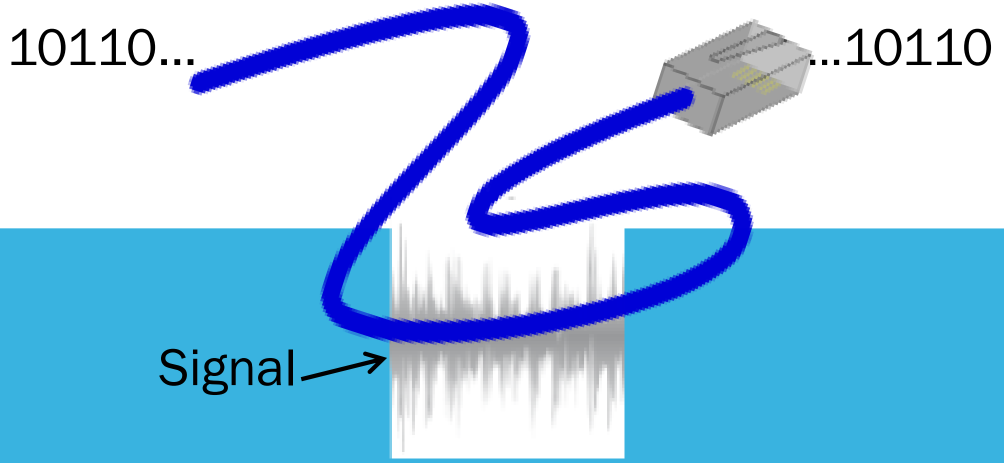
E.g., MB = 1,048,576 bytes (2^20)

"B" is for bytes, "b" is for bits: 1 Mbps = ? bps,

SCOPE OF THE PHYSICAL LAYER

Concerns how signals are used to transfer message bits over a link

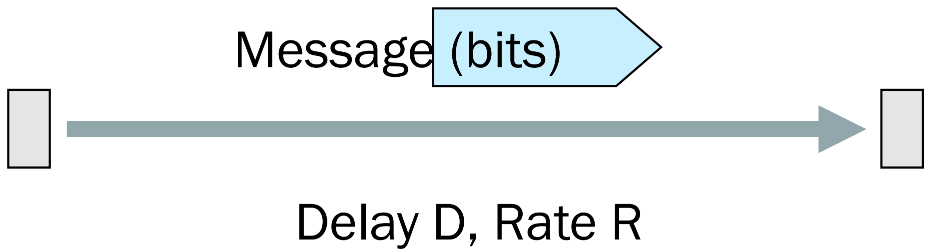
- Wires etc. carry analog signals
- We want to send digital bits (how computers communicate 1s and 0s)



SIMPLE LINK MODEL

We'll look at an abstraction of a physical channel

- Rate (or **bandwidth**, capacity, speed) in bits/second
- Delay in seconds, related to length



Other important properties:

- Whether the channel is broadcast, and its error rate

MESSAGE LATENCY

Latency is the delay to send a message over a link

- Transmission delay: time to put M-bit message "on the wire"
  - The time from the first bit until the last bit of a message has left the transmitting node.

- Propagation delay: time for bits to propagate across the wire

MESSAGE LATENCY (2)

<u>Latency</u> is the delay to send a message over a link

- <u>Transmission delay</u>: time to put M-bit message "on the wire"

  T-delay = M (bits) / Rate (bits/sec) = M/R seconds

- <u>Propagation delay</u>: time for bits to propagate across the wire

  P-delay = Length / speed of signals = Length / ⅔c = D seconds

- Combining the two terms we have: $\boxed{L = M/R + D}$

c refers to the speed of light in a vacuum, or 300,000 kilometers per second

LATENCY EXAMPLES

“Dialup” with a telephone modem:

- D = 5 ms, R = 56 kbps, M = 1250 Bytes

Broadband cross-country link:

- D = 50 ms, R = 10 Mbps, M = 1250 Bytes

LATENCY EXAMPLES

"Dialup" with a telephone modem:

D = 5 ms, R = 56 kbps, M = 1250 Bytes

L = 5 ms + (1250x8)/(56 x 10^3) **sec** =

L = 5 ms + 0.179 **sec =**

L = 5 ms + 179 **ms** = 184 ms

Broadband cross-country link:

D = 50 ms, R = 10 Mbps, M = 1250 Bytes

L = 50 ms + (1250x8) / (10 x 10^6) **sec** =

L=50 ms + .001 **sec** =

L = 50 ms + 1 **ms** = 51 ms

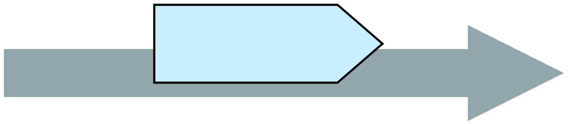
A long link or a slow rate means high latency

Often, one delay component dominates

1 byte = 8 bits for data size

BANDWIDTH-DELAY PRODUCT

Messages take space on the wire!



The amount of data in flight is the <u>bandwidth-delay (BD) product</u>

$$BD = R \times D$$

- Measure in bits, or in messages
- Small for LANs, big for “long fat” pipes

BANDWIDTH-DELAY EXAMPLE

Fiber at home, cross-country

R=40 Mbps, D=50 ms

BANDWIDTH-DELAY EXAMPLE

Fiber at home, cross-country

R=40 Mbps, D=50 ms (0.050 seconds)

R = 40 x 10^6 **bps** = 40000000**bps**

D = 50 * 10^{-3} = 50 * .001 = 0.05 **seconds**

BD = 40000000**bps** * 0.05 **seconds**

BD = 2000000 **bits**

= 2000 **Kbit** (8 bits in a Byte)

= 250 **KB**

BANDWIDTH VERSUS PROPAGATION DELAY/SPEED

The bandwidth: the number of bits per second.

The propagation speed: the time until the first bit arrives.

If you have an endless supply of turtles to carry 100GB hard drives any distance for you, their **propagation speed is very slow**, so it takes a long time until a turtle arrives after you send it. However, you can send a turtle every second, so that after the initial delay your turtles deliver a harddrive full of data every second – That equates to **high bandwidth.**

TYPES OF MEDIA

Media propagate signals that carry bits of information

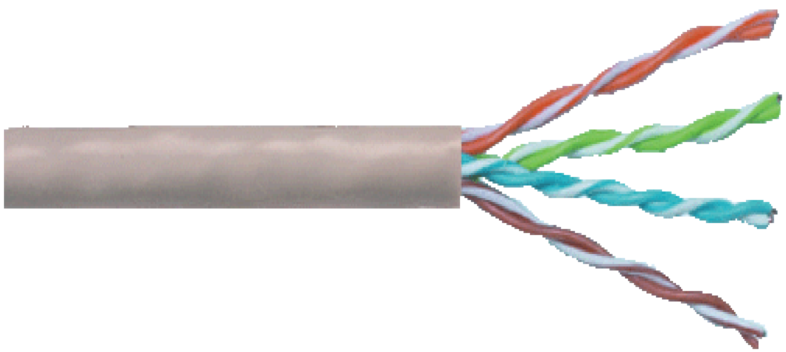
We'll look at some common types:

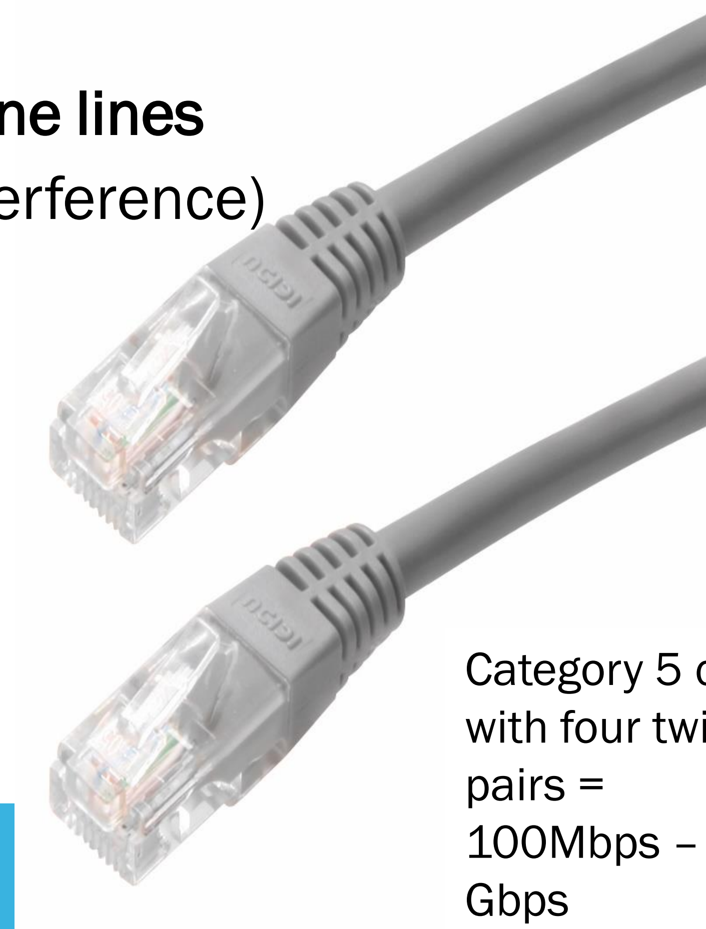
- Wires
- Fiber (fiber optic cables)
- Wireless
- Satellite

WIRES – TWISTED PAIR

Very common; used in LANs, telephone lines

Twists reduce radiated signal (interference)

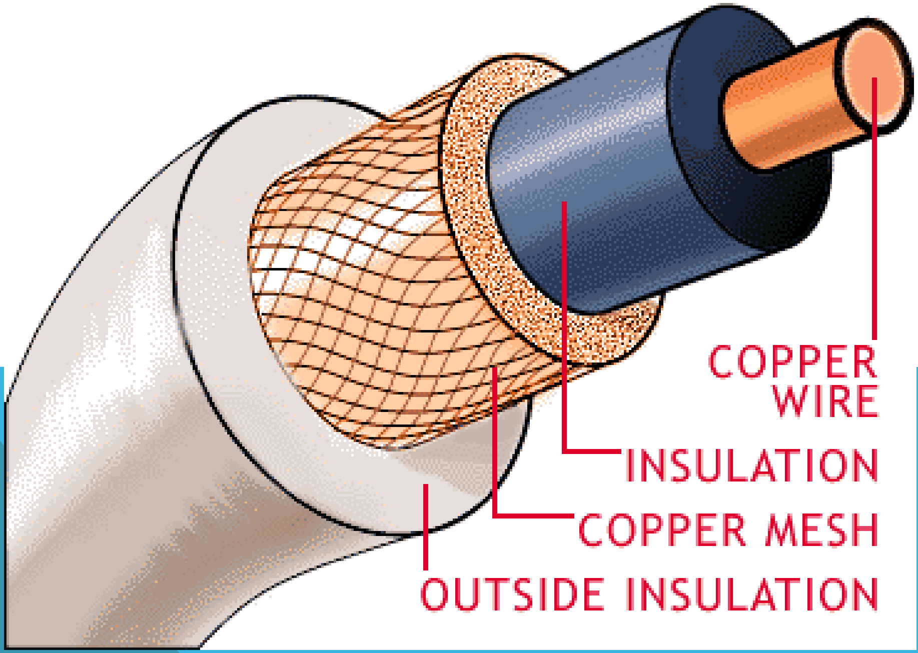




Category 5 cable with four twisted pairs = 100Mbps – 1 Gbps

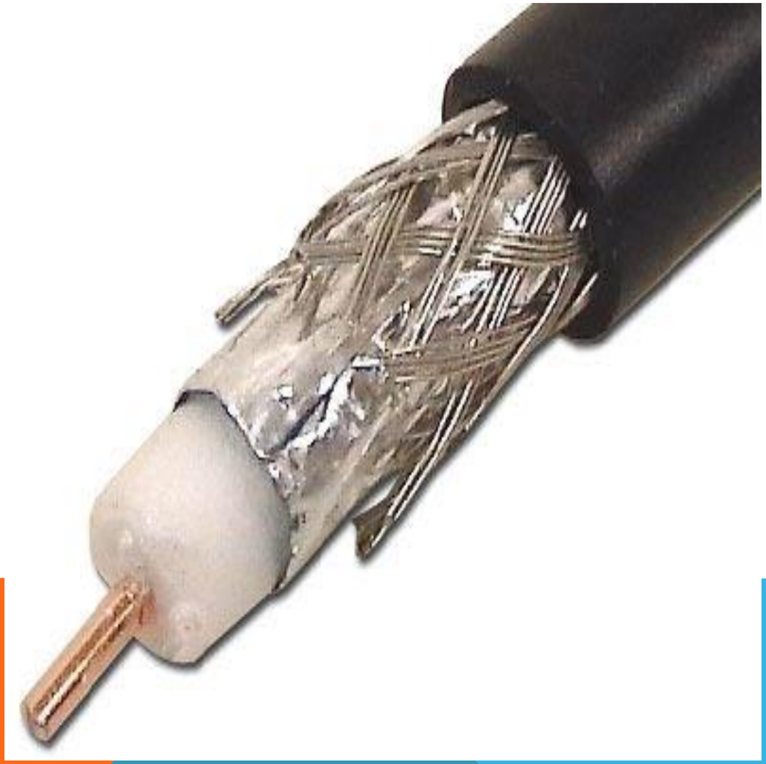
WIRES – COAXIAL CABLE ("CO-AX")

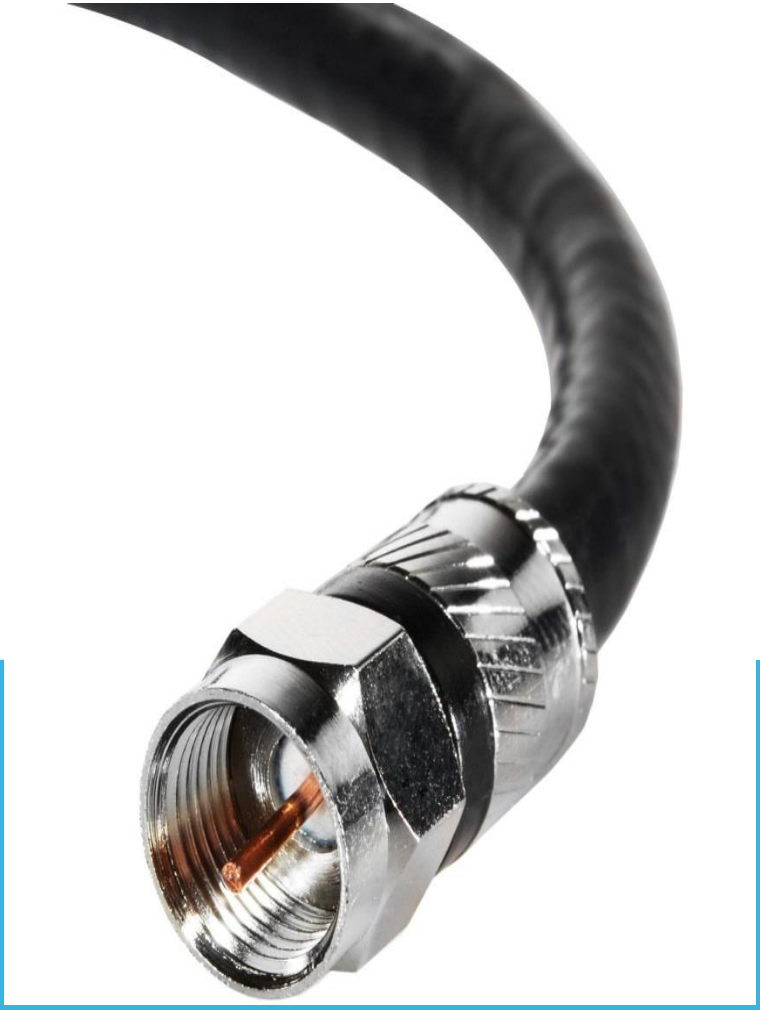
Also common. Better shielding for longer distances and higher rates than twisted pair due to higher excellent noise immunity.



~100Mbps

COAXIAL CABLE

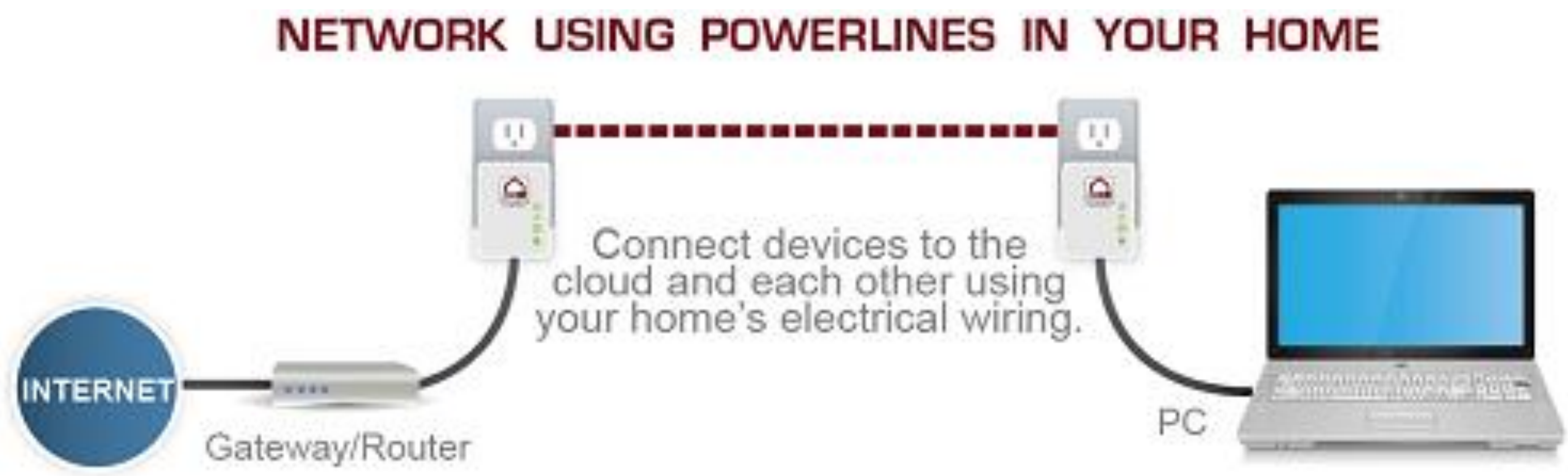




WIRES – POWER LINES

Household electrical wiring is another example of wires

Convenient to use, but not great for sending data



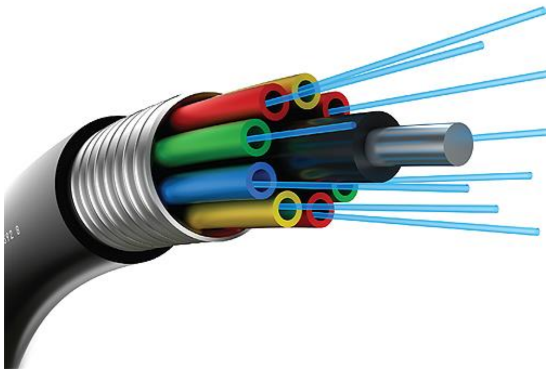
FIBER CABLES

<u>Single-mode</u>

- Core so narrow (10um) light can't even bounce around
- Used with lasers for long distances, e.g., 100km

<u>Multi-mode</u>

- Other main type of fiber
- Light can bounce (50um core)
- Used with LEDs for cheaper, shorter distance links

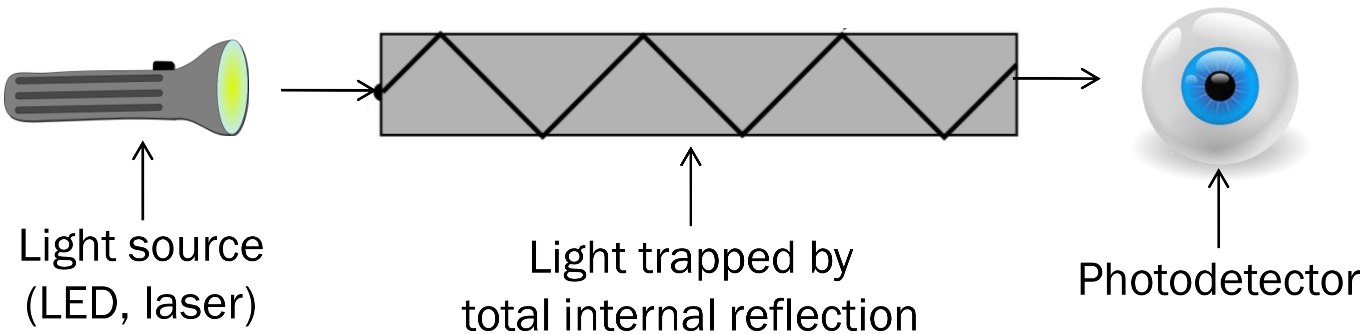


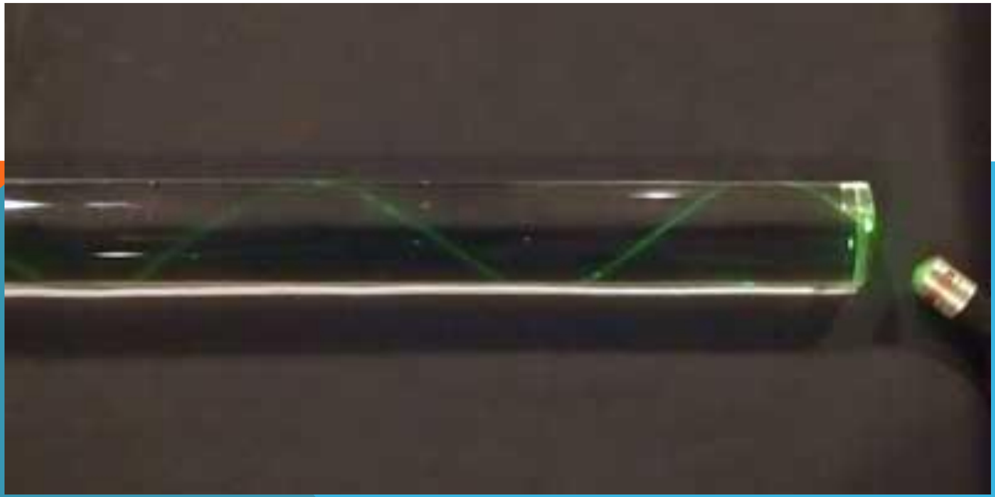
Fibers in a cable

FIBER CABLES

Common for high rates and long distances

- Long distance ISP links, Fiber-to-the-Home
- Light carried in very long, thin strand of glass





100-Gbps

FIBER CABLES

Comparison of the properties of wires and fiber:

Property	Wires	Fiber
Distance	Short (100s of m)	Long (tens of km)
Bandwidth	Moderate	Very High
Cost	Inexpensive	Less cheap
Convenience	Easy to use	Less easy
Security	Easy to tap	Hard to tap

Fiber gives you very high rates over long runs; wires score less highly on these properties and support high rates over much shorter runs. Wires are usually the inexpensive solution when the transmission/reception hardware is included. Wires are also easier to work with; fiber requires greater care with connections. Fiber has the advantage that it is very hard to tap as the light is confined only to the fiber or the fiber is broken. Wires are usually easy to tap because they radiate the signal well

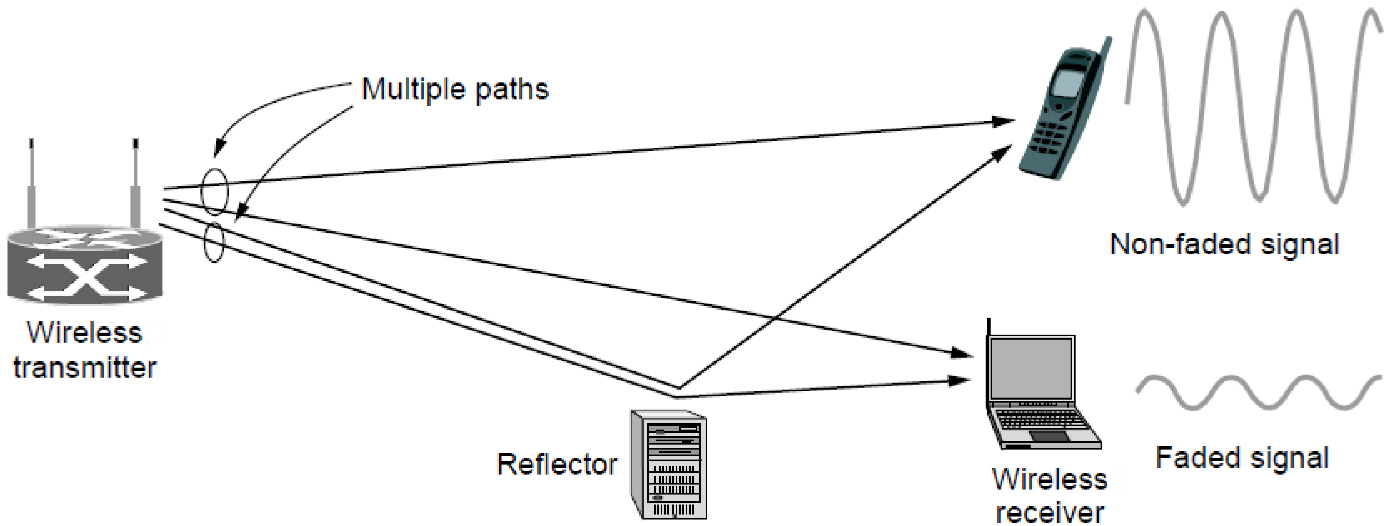
REALITY CHECK: STORAGE MEDIA

- Send data on tape / disk / DVD for a high bandwidth link
  - Mail one box with 1000 800GB drives (6400 Tbit)
  - Takes one day to send (86,400 secs)
  - Data rate is 70 Gbps.
- Data rate is faster than long-distance networks!

MICROWAVE TRANSMISSION

Microwaves have much bandwidth and are widely used indoors (WiFi) and outdoors (3G, satellites)

- Signal is attenuated/reflected by everyday objects
- Strength varies with mobility due multipath fading, etc.



WIRELESS VS. WIRES/FIBER

Wireless:

+Transmissions is easy and inexpensive to deploy

+Naturally supports mobility

+Naturally supports broadcast

- Interference and must be managed
- Signal strengths vary hence data rates vary greatly

Wires/Fiber:

+Easy to engineer a fixed data rate over point-to-point links

- Can be expensive to deploy, esp. over distances
- Doesn't readily support mobility or broadcast

SCOPE OF THE PHYSICAL LAYER

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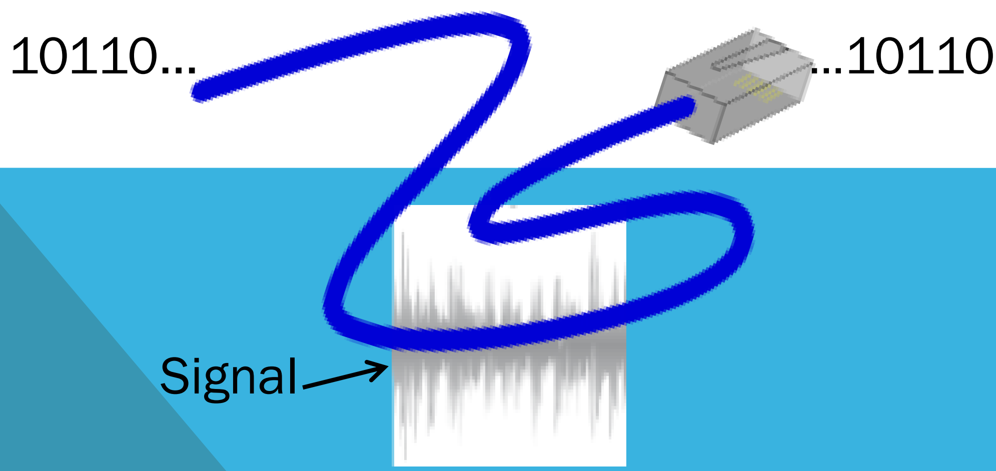
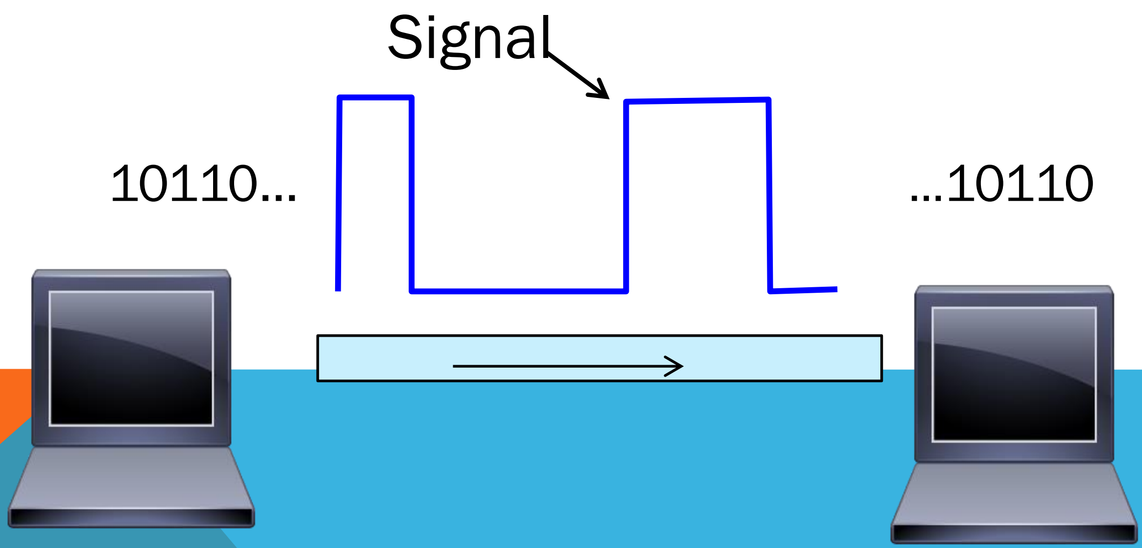
- Wires etc. carry <u>analog signals</u>
- We want to send <u>digital bits </u>(how computers communicate 1s and 0s)



TRANSMITTING DATA OVER MEDIA

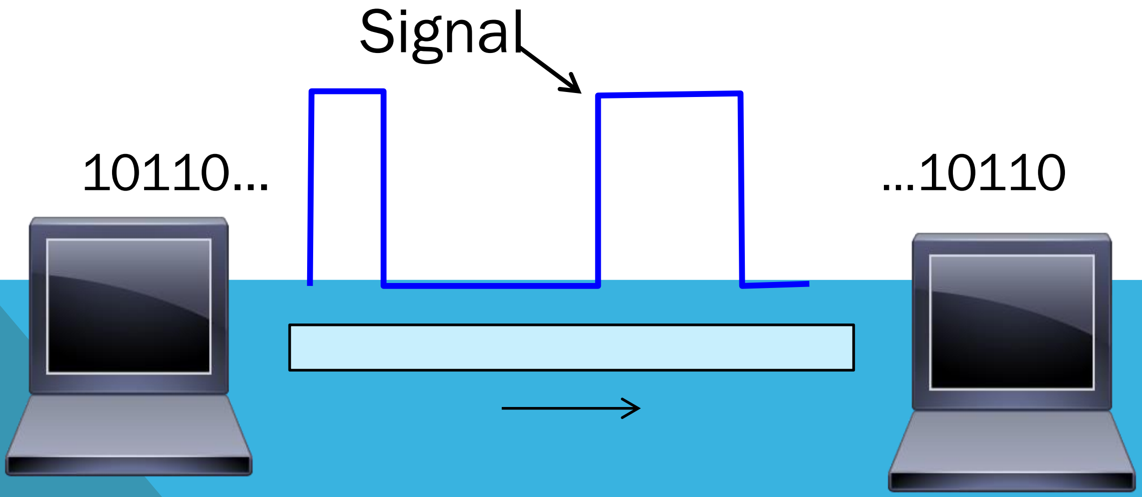
Analog signals encode digital bits. We want to know how this occurs – different techniques



MODULATION

We've talked about signals representing bits. How, exactly does this work?

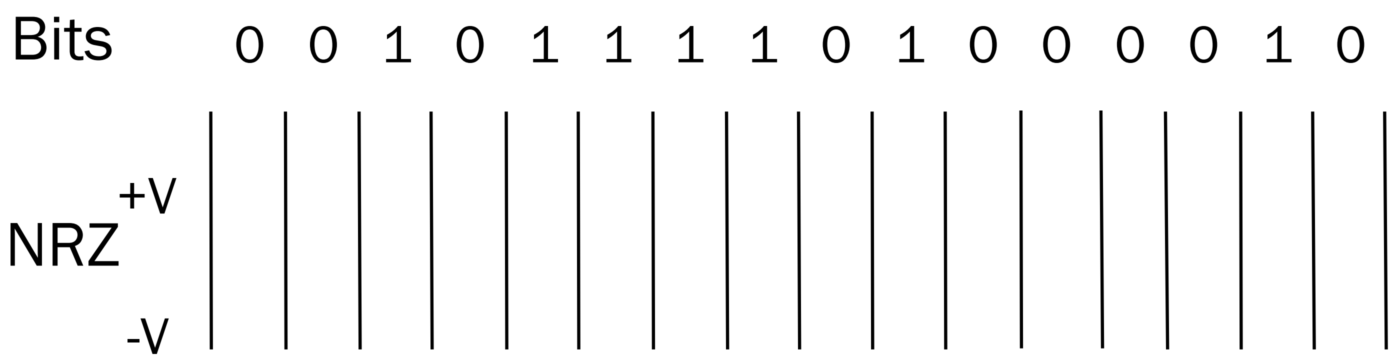
- This is the topic of <u>modulation</u>



A SIMPLE MODULATION

Let a high voltage (+V) represent a 1, and low voltage (-V) represent a 0

- This is called NRZ (Non-Return to Zero)



A SIMPLE MODULATION (2)

Let a high voltage (+V) represent a 1, and low voltage (-V) represent a 0

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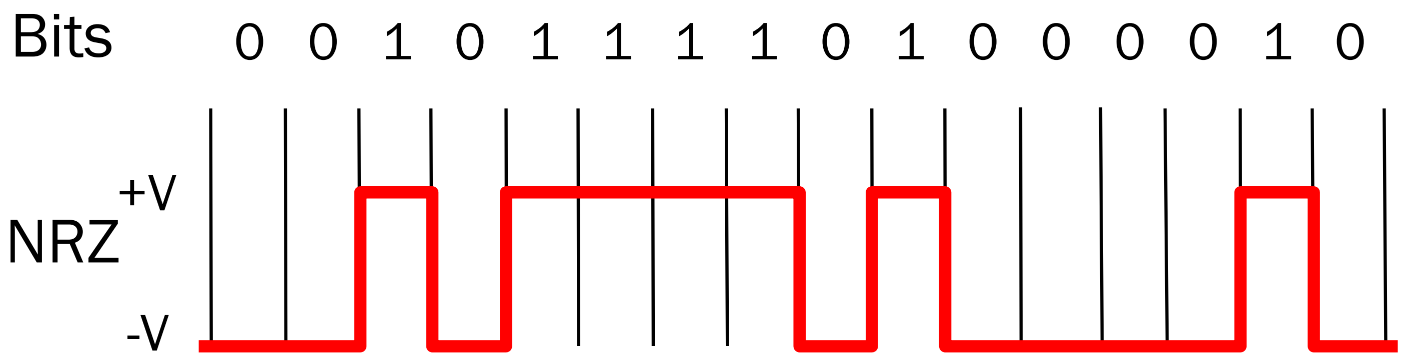

MANY OTHER SCHEMES

Can use more signal levels, e.g., 4 levels is 2 bits per symbol

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Level 1: 11
Level 2: 10
Level 3: 01
Level 4: 00

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Bits 0 0 1 0 1 1 1 1 0 1 0 0 0 0 1 0

Level 1: 11
Level 2: 10
Level 3: 01
Level 4: 00

NRZ

MANY OTHER SCHEMES

Can use more signal levels, e.g., 4 levels is 2 bits per <u>symbol</u>