CS120: Computer Networks

Lecture 3. Physical Links

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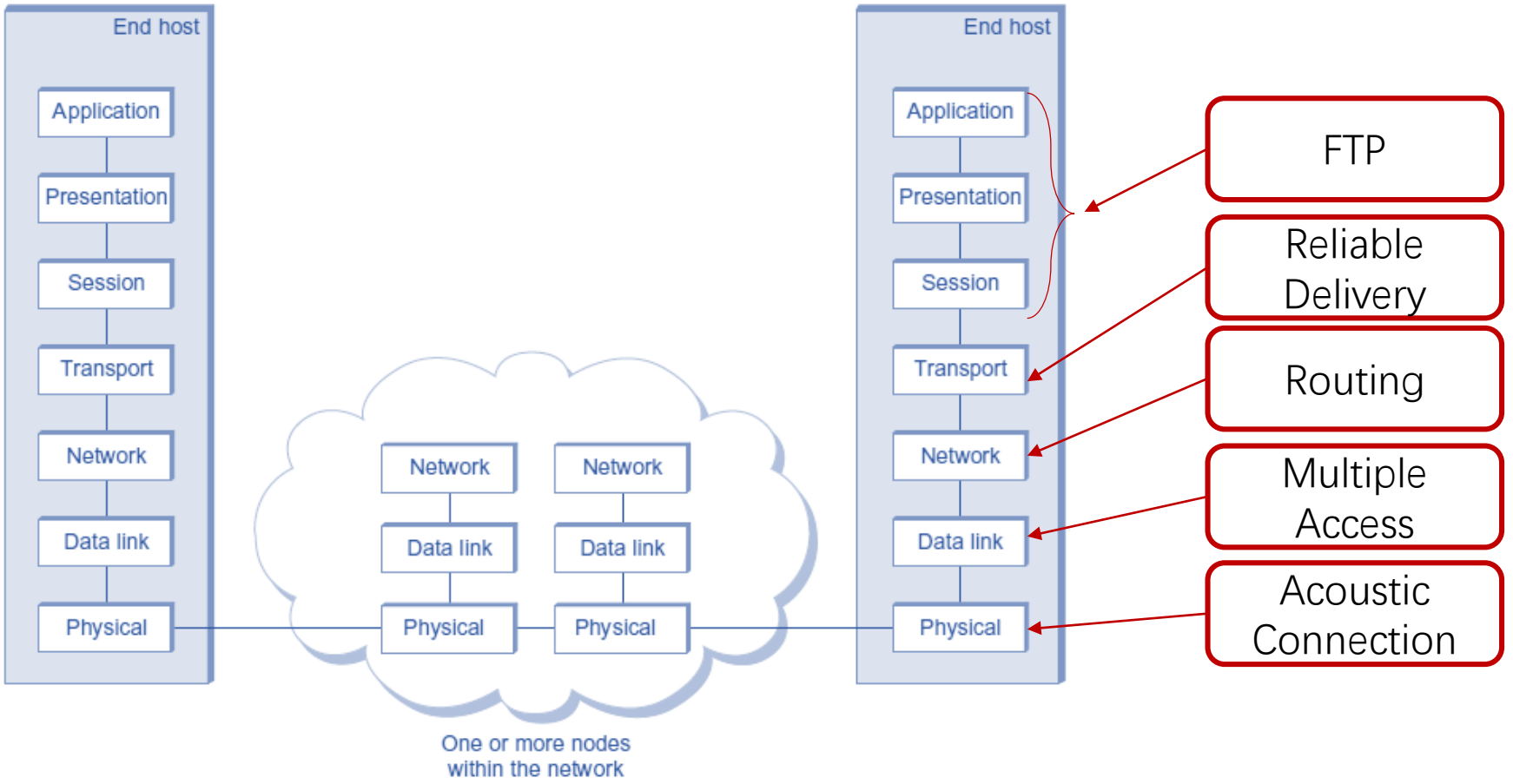
Network Layers



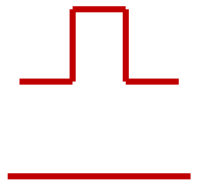
Outline

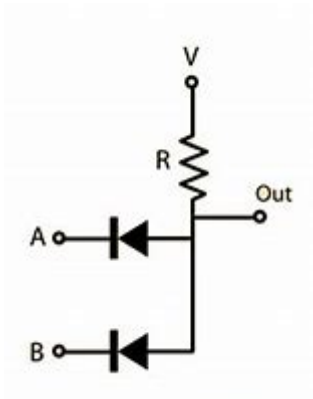
- Communication Basics
  - Communication Medium
    - Carrier
  - Modulation
- Upper Bound of Throughput
- Modulation Method

How to Transmit a Bit in Physical World ?

- Bits in the physical world

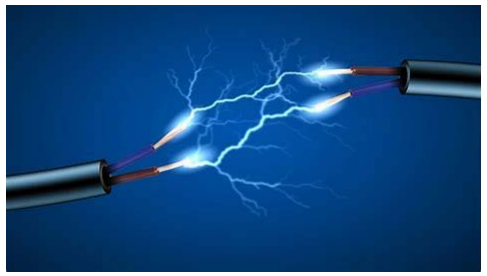
```
a = 1 & 0;
```



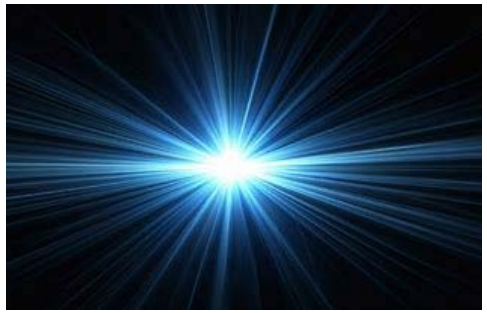


Bits are conveyed by physical medium (eg. electrical signal)

Basic Components of Communication



Electrical Signal



Light

Sound

Medium + Modulation

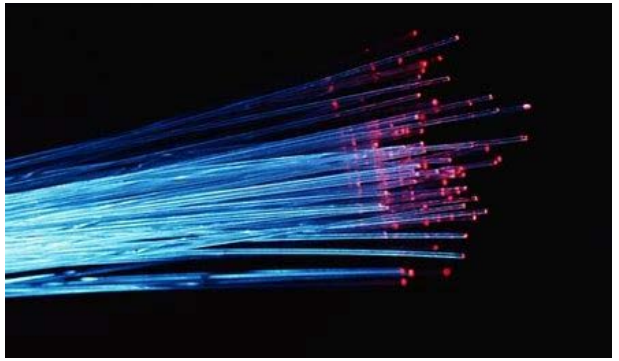
Change/Manipulate the Physical Medium

Communication Medium

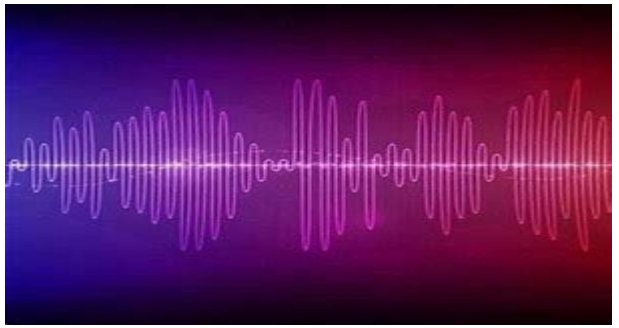
Communication Medium

- How to propagate in the other medium

?



Fiber

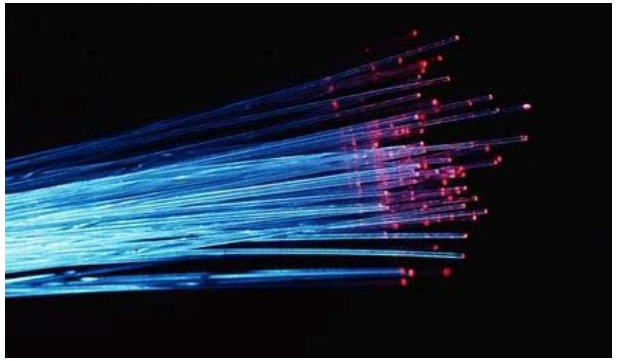


Free Space

Communication Medium

- How to propagate in the other medium

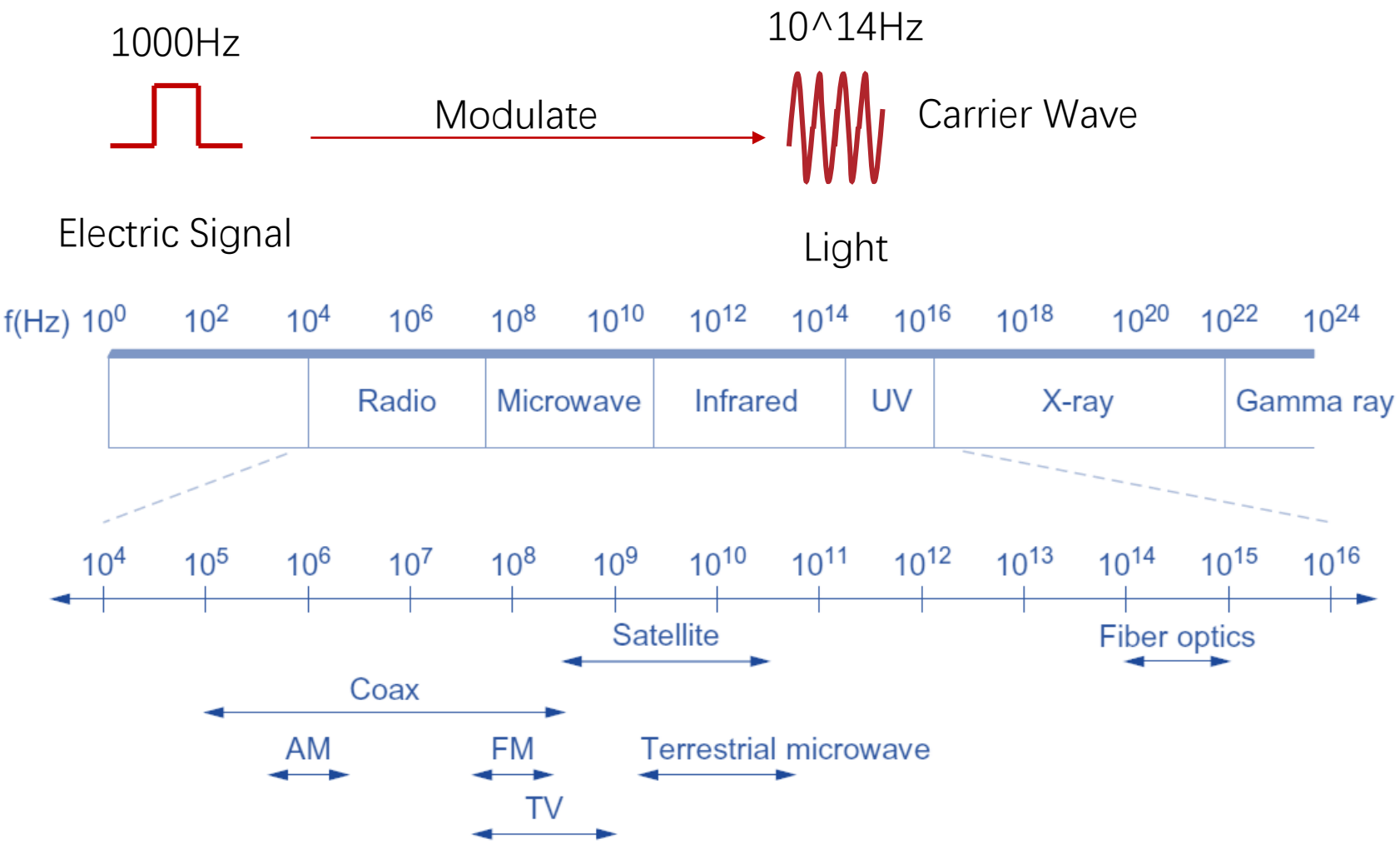
?



Fiber:
Light Wave

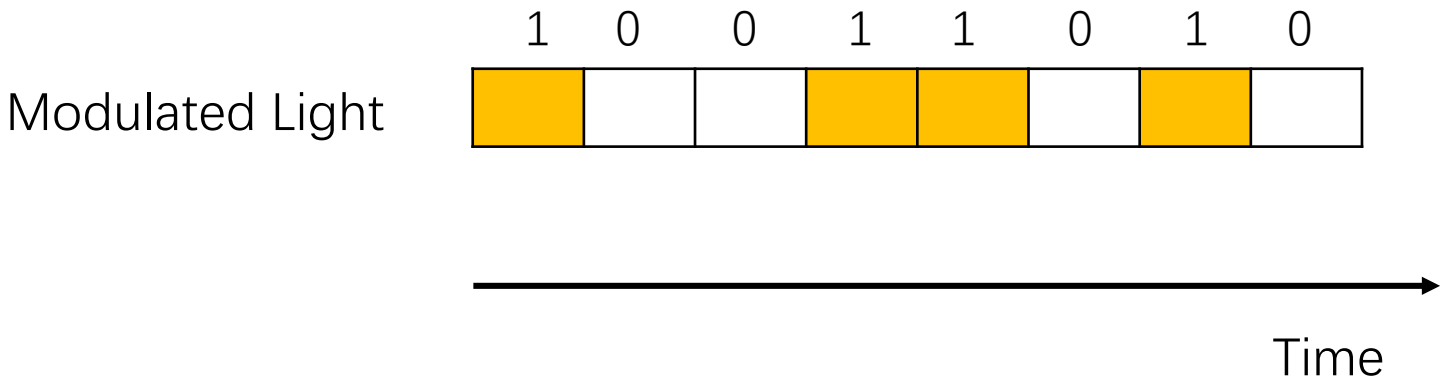
Free Space:
Radio Wave,
Acoustic Wave,
etc.

The Carrier Wave



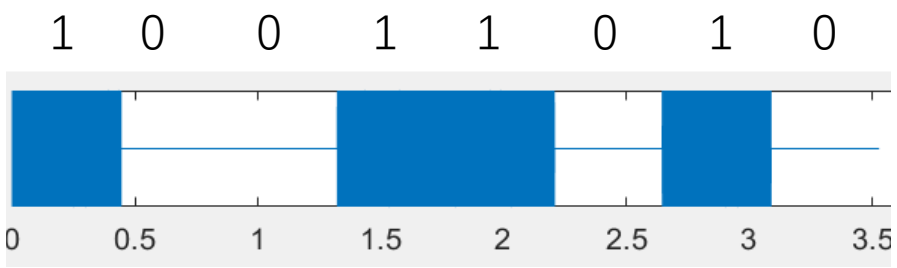
Modulation

- Modulation: the process of varying one or more properties of the carrier wave to transmit the information
  - Signal containing information is called modulating signal
- Example: On-Off Modulation



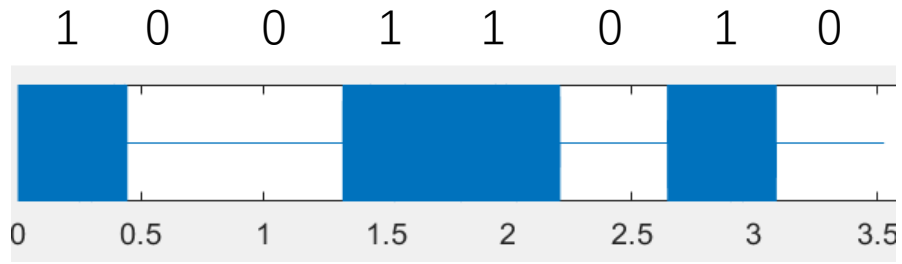
Demo: On-Off Modulation

```
%%
clear all;
t=linspace(0,1,44100);
one=sin(2*pi*1000*t);
zero=zeros(1,length(one));
transmit=([one,zero,zero,one,one,zero,one,zero]);
figure;
plot(transmit);
sound(transmit,44100);
```

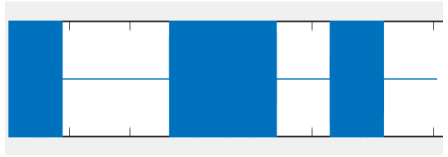


How Fast can We Achieve ?

1bps



2bps



Shannon-Hartley Theorem

- The theoretical throughput upper bound:

Bandwidth

Signal Power

$$C = B\log_2(1 + \frac{S}{N})$$

Channel Capacity

Noise Power

“Bandwidth” v.s. Bandwidth

- The term “Bandwidth” is often used with two different meanings.
  - Rate: throughput (bps)
  - Spectrum: the width of the occupied the spectrum (Hz)

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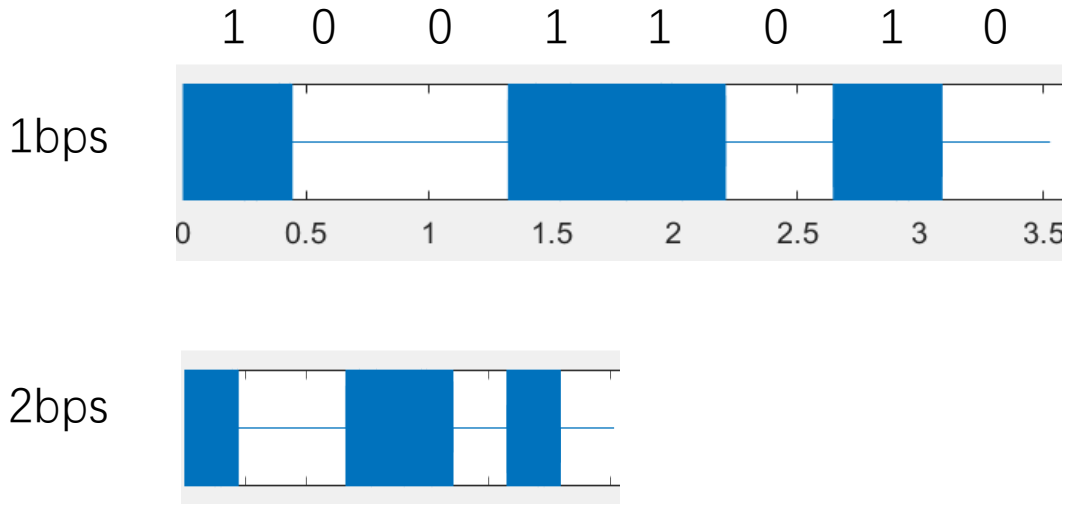
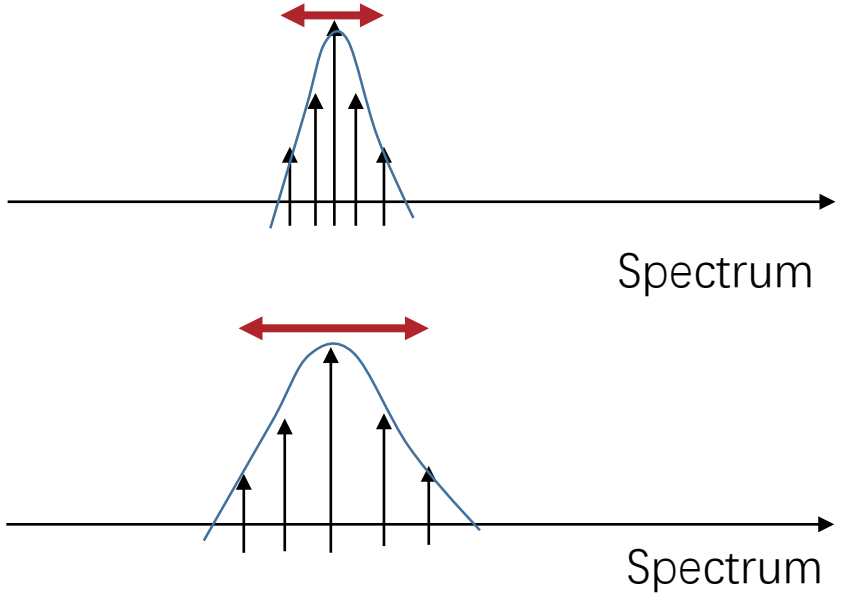
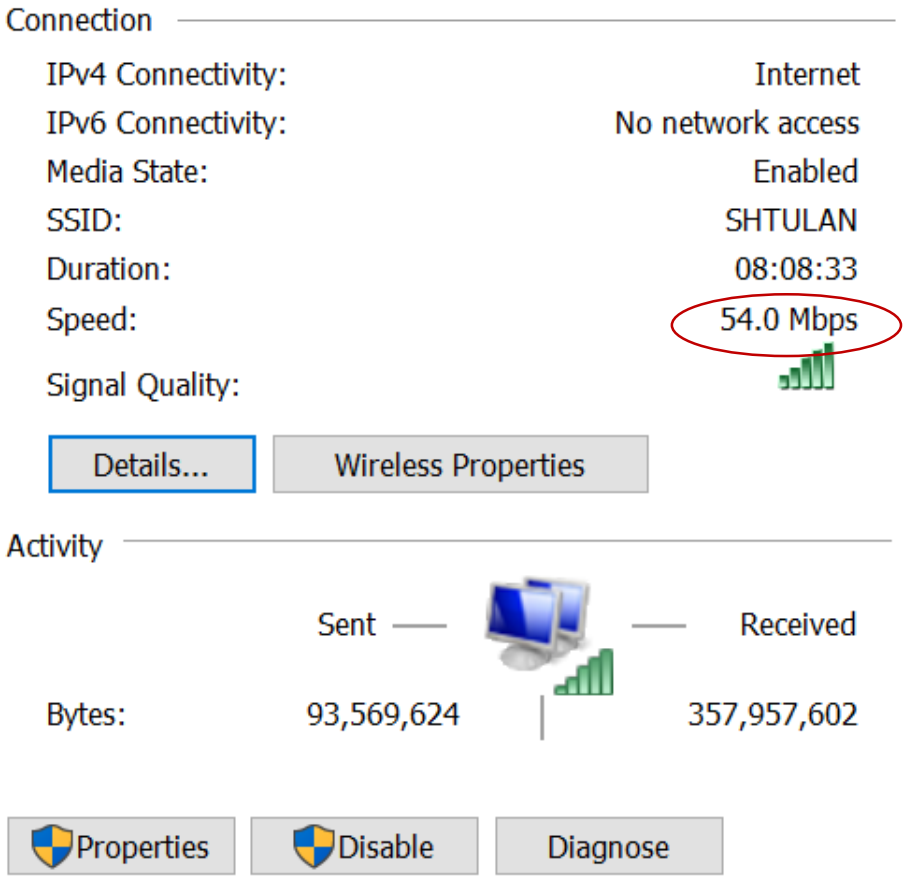




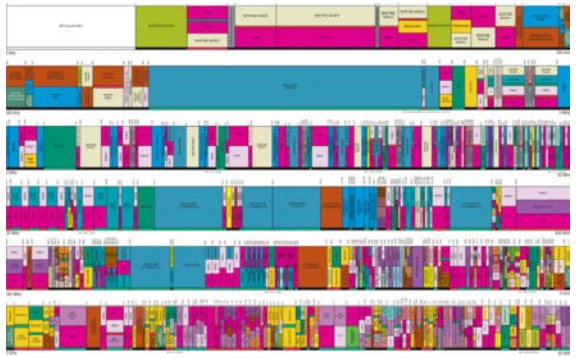
“Bandwidth” v.s. Bandwidth

- Be careful about the confusion



This is the rate bandwidth
The spectrum bandwidth is 20MHz !

How Fast can We Achieve ?



Limited by ADC DAC rate,
Available Spectrum

Bandwidth

Limited by Power and
Safety Concern

Signal Power

$$C = B\log_2(1 + \frac{S}{N})$$

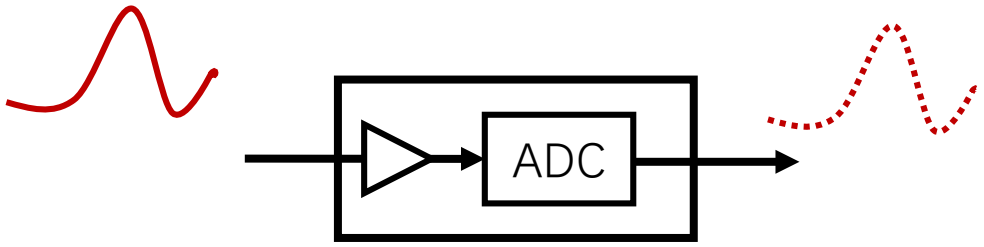
Channel Capacity

Noise Power

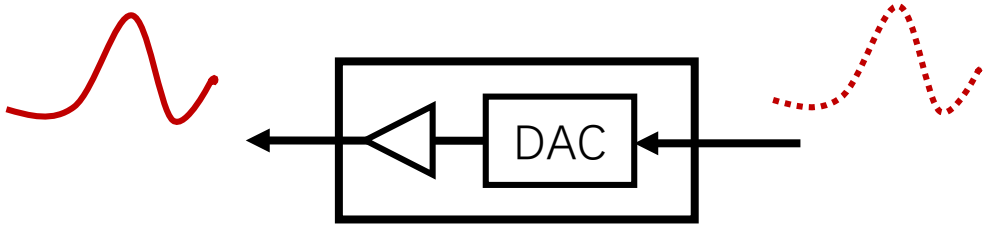
Limited by Thermal Noise
and Manufacturing

A/D and D/A Converter

- A/D Converter



- D/A Converter



(1/the space of the samples) is defined as the rate of the ADC or DAC

The rate of the ADC or DAC must 2 times of the bandwidth of the analog signal (Sampling Theorem) to avoid aliasing

Reference

- Textbook 2.1