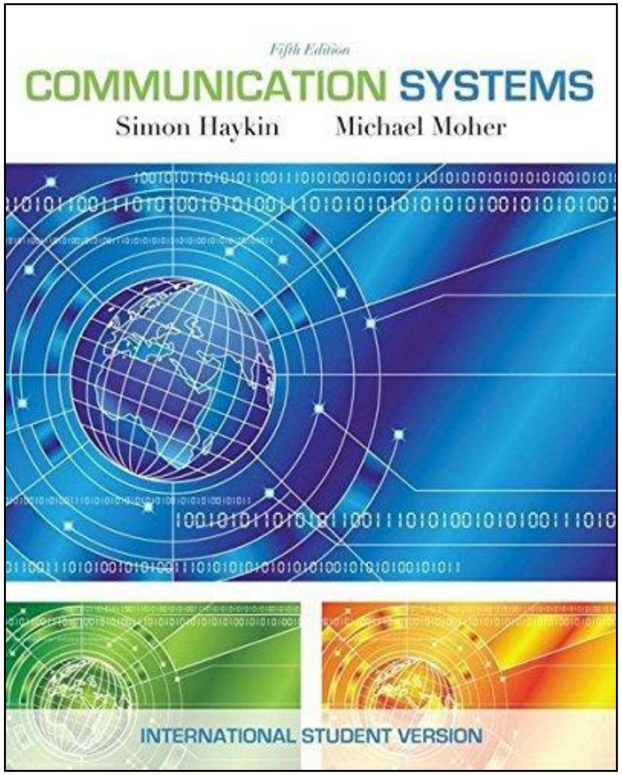
EE 364000 – Comm. Systems I

Lecture 1 – Introduction

Course Information I

- **Goal and Overview:**
  - Introductory course to communications.
  - Basic concepts of:
    - Signal Representation
    - Modulation (analog vs digital)
    - Random Processes
    - Channel and Noise
    - Signal Detection
- **Required background:**

  Probability; Signals and Systems.



- **Textbook Book:**

  Simon Haykin and Michael Moher, *Communication Systems*, 5th Edition, John Wiley & Sons, 2010

  (➔ Please read the book! Do not rely entirely on notes in class.)

Course Information II

- **Lecture Time:** M5M6 (13:00—15:10), RnR5 (13:00—14:10)
- **Lecture Location:** EECS Building 207
- **Instructor:** 翁詠祿 (Yeong-Luh Ueng)
- **Email:** ylueng.ee@gmail.com
- **Office:** Delta Building 830
- **Office Hour:** Monday 15:10—16:10 and Thursday 14:10—15:10 (or by appointment)

- **TA1:** 戴雅炘 (yaxin.dai19@gmail.com)
- **TA2:** 梁富翔 (868503@gmail.com)
- **TA3:** 李昌鴻 (ccc199786@gmail.com)
- **Location:** Delta Building 831

Course Information III

- **Grades:** Homework 15%; Midterm I 30%; Midterm II 30%; Finals 25%

(Academic integrity is strictly enforced!! Any form of cheating in HW or exams will result in failure of the course. No Warnings!!)

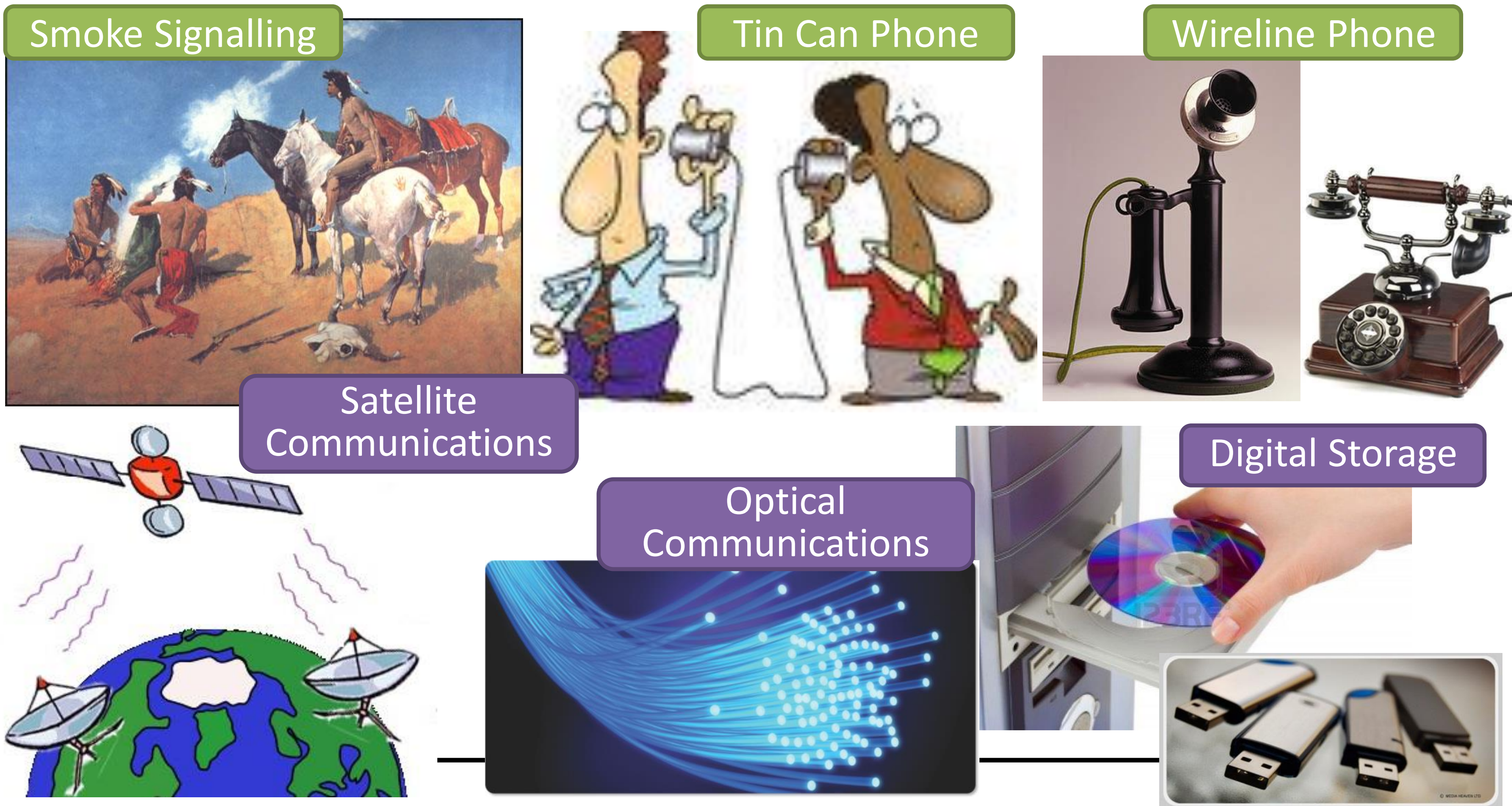
Important Dates:

- **Midterm I:** 5/4 Monday during class
- **Midterm II:** 6/1 Monday during class
- **Final Exam:** 6/22 Monday during class

- 作業鼓勵討論，禁止抄襲!!
- 除非有正式假單，期中考期末考不得補考!!

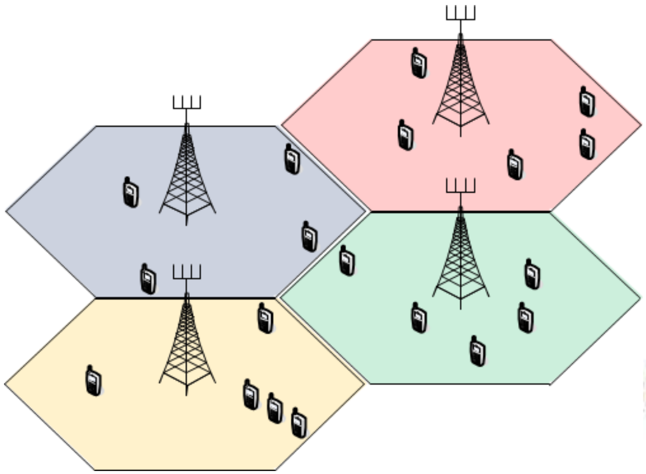
What is a communication system?

- Communication is referred to, in this course, as the *transmission of information from one end to another*.

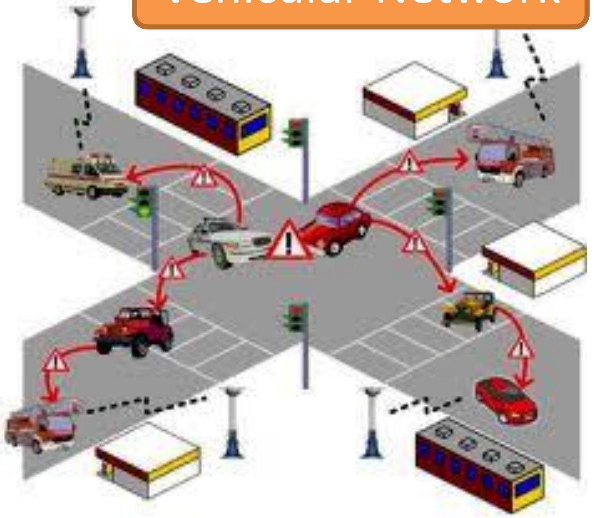


Communication Networks and Applications

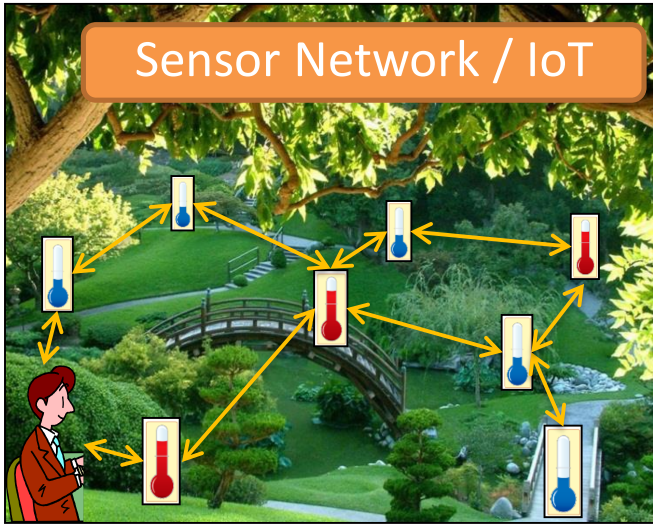
Mobile Cellular Network



Vehicular Network

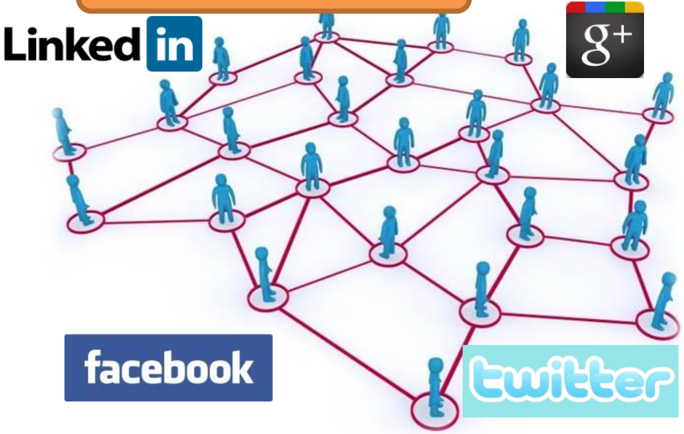


Sensor Network / IoT

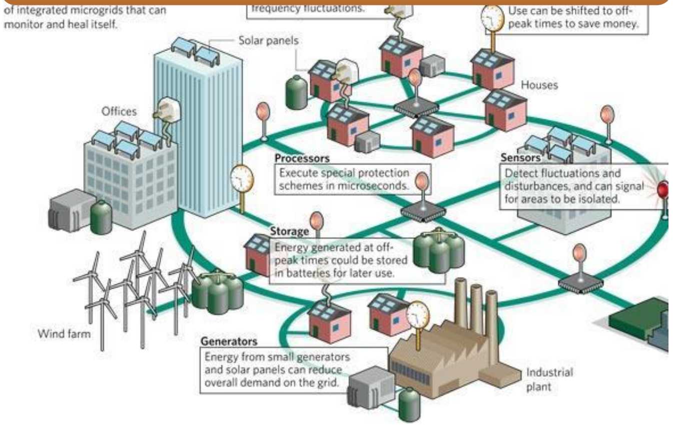


Local Area Network

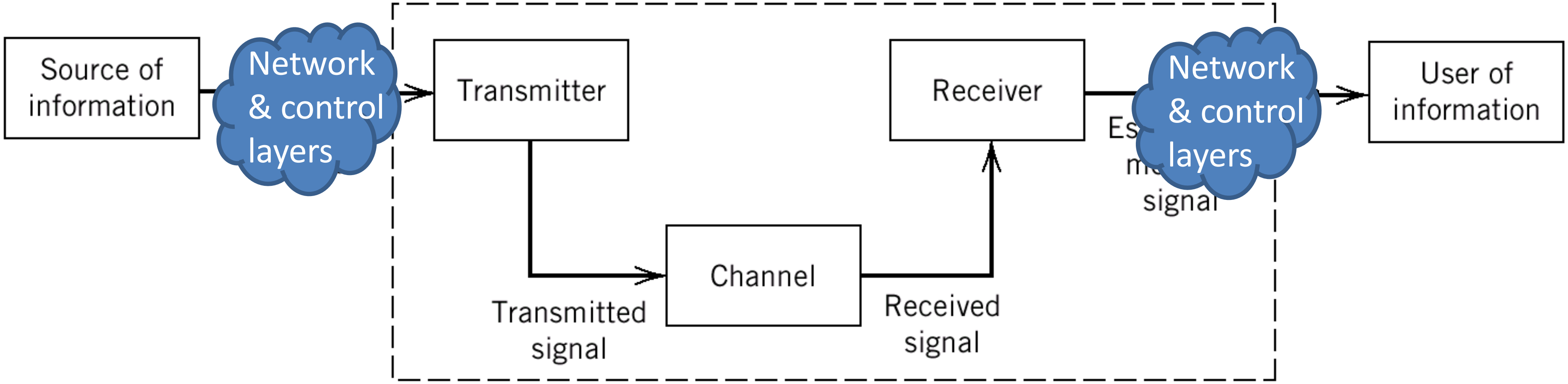
Social Network



Smart Grid Communications

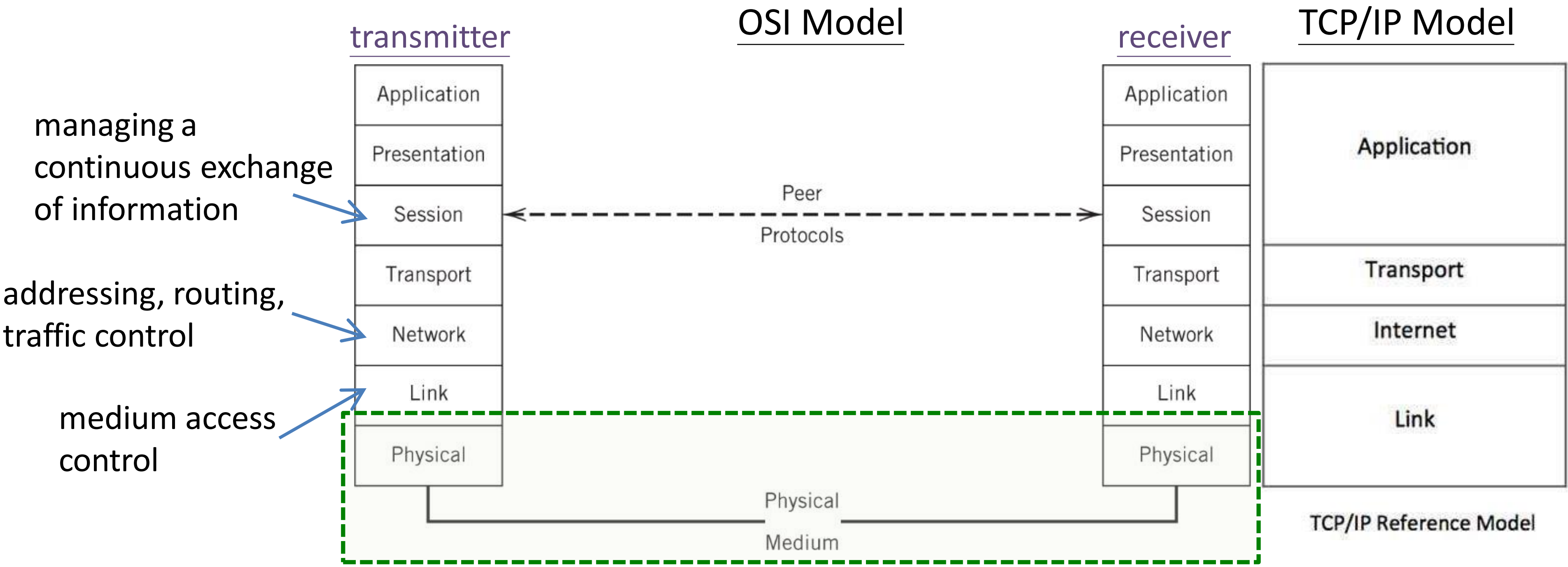


Point-to-Point Link



- Source or message signal: voice, music, picture, video computer data… etc.
- **Transmitter:** encoding and modulation
- **Channel:** transmission medium
- **Receiver:** decoding and demodulation
- User of information

Layered Approach

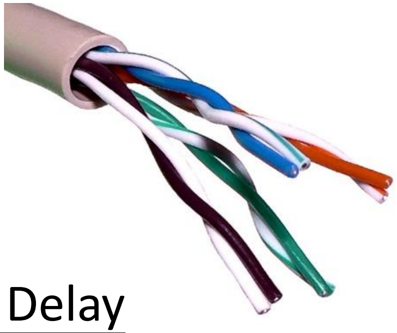


- The Open Systems Interconnect (OSI) model divides the system into 7 layers, each with different functionalities.
- Not closely followed in practice, but it
  - permits independent development of different functionalities;
  - simplifies the understanding and design of communication systems.

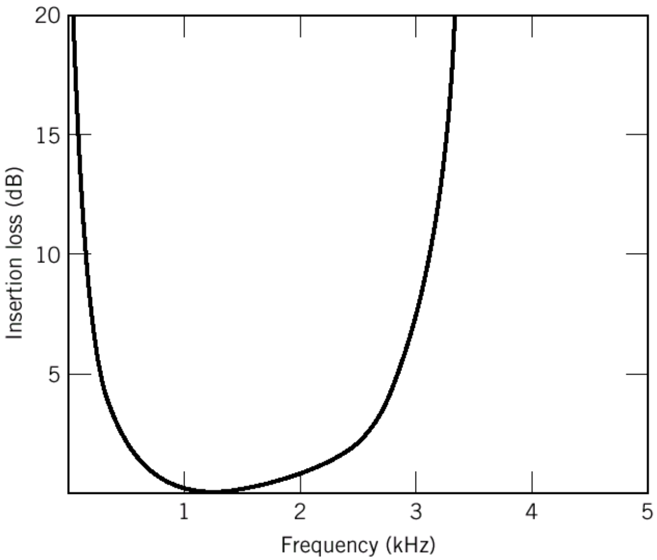
(➔ see course in Computer Networks)

Communication Channels (1)

- The best performance a communication system can achieve is often determined by its channel. (➔ see Information Theory)
- Channels based on guided propagation:
  - Telephone channel (twisted pair):
    - Human voice ~ 300-3100 Hz

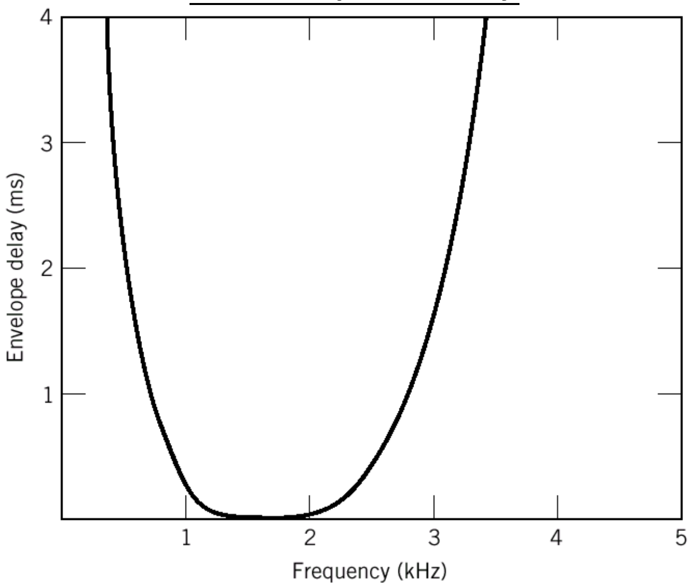


Insertion loss



(a)

Envelope Delay

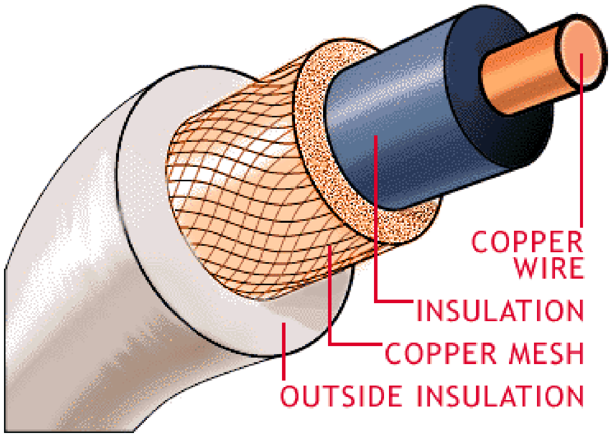


(b)

Communication Channels (2)

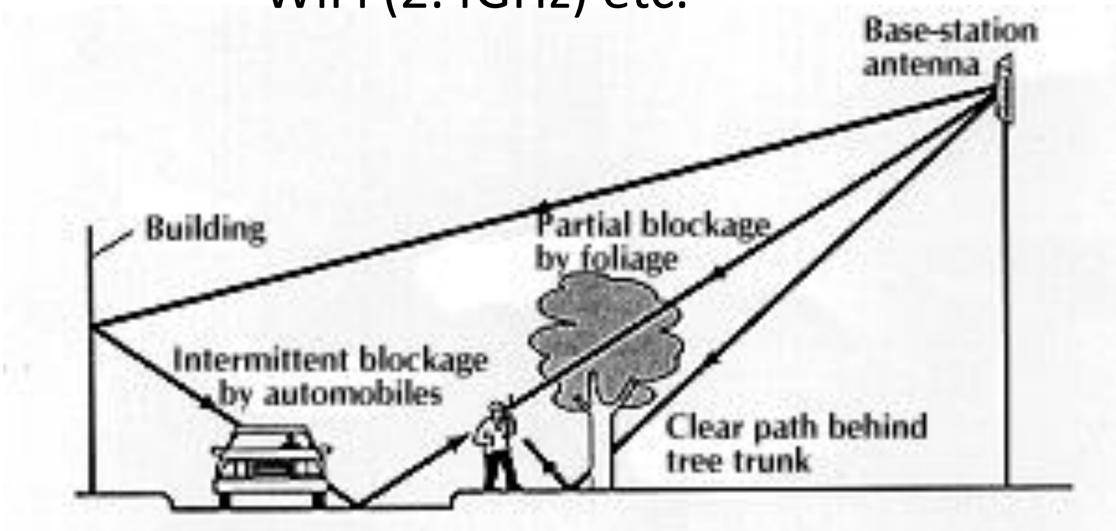
- Coaxial cable
  - Supports ~20Mbps
  - Also used for cable television
- Optical fiber
  - Dielectric waveguide for light
  - Extremely large bandwidth
    - Carrier frequency (~2×10^{14}Hz) if BW is 10% of carrier frequency

      ➔ (~2×10^{13} Hz bandwidth)
    - Small transmission loss 0.1dB/km (i.e., decay by half after 30km)
    - Immunity to EMI (electromagnetic interference)

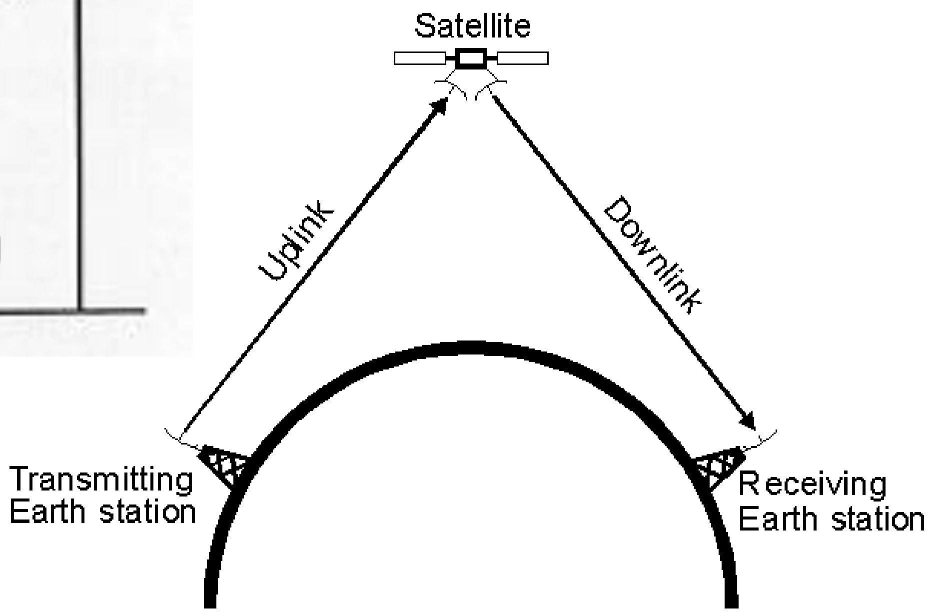


Communication Channels (3)

- Channels based on free propagation:
  - Wireless or mobile channels: e.g. AM radio (500-1600 kHz), FM radio (30-300MHz), mobile communication (700-1900 MHz), WiFi (2.4GHz) etc.



  - Satellite communications
    ➔requires line-of-sight



Communication Engineering

- **Goal:** Design transmitters and receivers that optimize the performance (e.g., data rate, error probability etc) given constraints or limitations of the system.

- **Communication Constraints:**
  - **Channel bandwidth**
  - **Channel distortion**
  - **Propagation loss**
  - **Noise**
  - **Transmit power**
  - Multi-user interference
  - Cross-talk
  - … etc.

Modulation & Demodulation

- **Modulation:** Modification of the message into a signal suitable for transmission over the channel.
- **Demodulation:** Reconstruction of the message with degraded version of the signal.

  (➔ **MODEM**)

ADSL modem

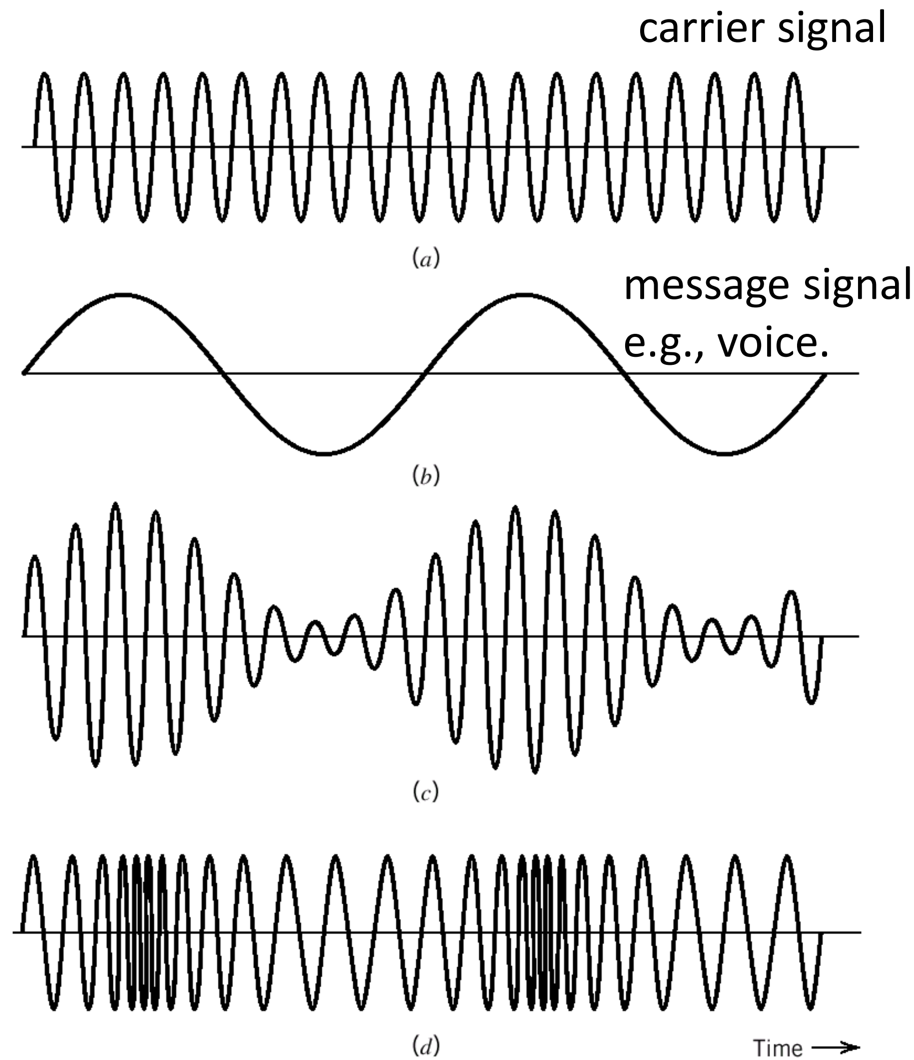
- **Covered in this course:**
  - Continuous-wave modulation:
    - Amplitude modulation (AM);
    - Frequency modulation (FM);
    - Phase modulation (PM).
  - Pulse modulation (analog vs digital)
    - Analog: Pulse Amplitude Modulation (PAM), Pulse Position Modulation (PPM)
    - Digital: Pulse Coded Modulation (PAM+Quantization)

Analog vs Digital Modulation

- **Analog Modulation**
  - Conceptually simple, and low power.
  - Still tolerable at low signal-to-noise ratio (SNR)

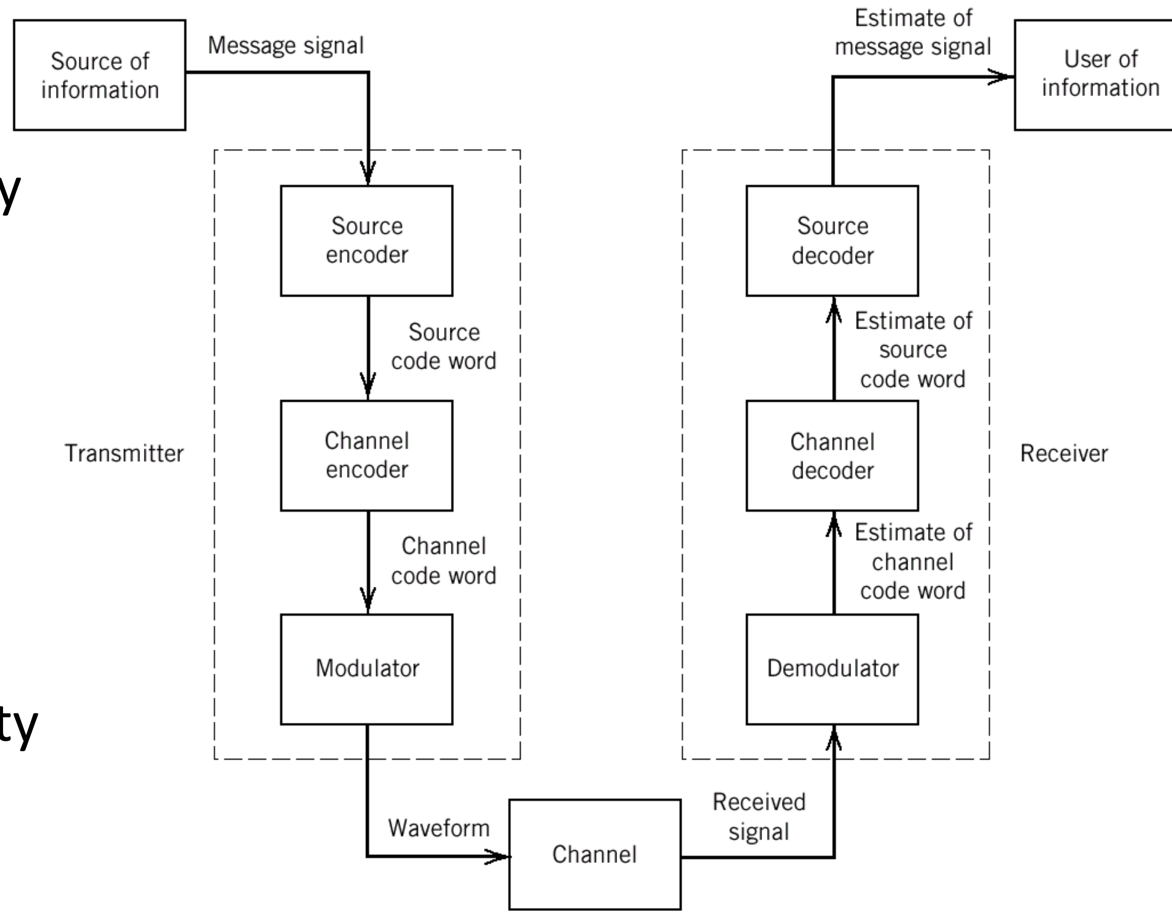
  But, ...
  - Strict linearity requirements
  - Does not adapt to the channel easily.

➔ E.g., AM and FM radios



Analog vs Digital Modulation (cont'd)

- **Digital Modulation**
  - Treats different sources the same way
  - Waveforms adapt optimally to the channel
  - Ability to perform channel coding
  - Ability to perform encryption for security
  - Ease of integrating different systems.



➔ E.g., mobile communications, WiFi, bluetooth

Source and Channel Coding

- **Source Coding:** Remove redundancy from the data. (E.g., JPEG, MPEG, MP3, ZIP etc)

```
010100001011111010
001011110010100000
101111110101010110
001100001111001010
101101010101010101
010111010101010101
010101010101010101
010101000001111101
011110100100001101
010101010100001111
101010101011010101
010101010101010001
```

```
010101101010101001
010101011100011001
110010010
```

- **Channel Coding:** Insert controlled redundancy to combat channel errors.

```
010101101010101001
010101011100011001
110010010
```

e.g. repetition code

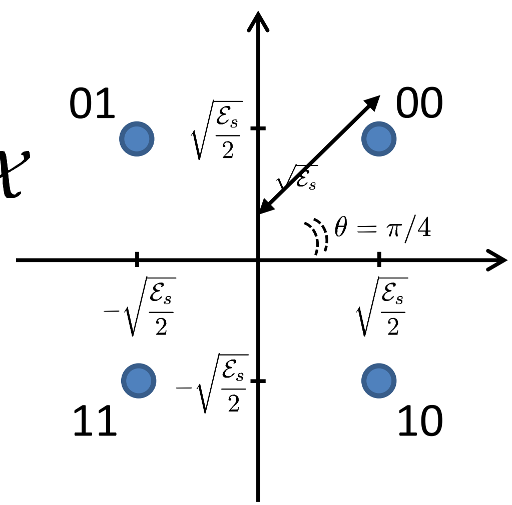
```
000111000111000011
111100011100011110
001110001110000000
111000111000111000
011100011111111110
000000000111111000
000111111111100000
011100000011100
```

(Baseband) Digital Modulation

- **Digital Modulation:** Conversion of digital data streams into continuous-time signals.
  - Binary to M-ary Conversion (e.g. QPSK)

Binary Data	Modulated Symbol
00	$\left(\sqrt{\frac{\mathcal{E}_s}{2}}, \sqrt{\frac{\mathcal{E}_s}{2}}\right)$ or $\left(\sqrt{\frac{\mathcal{E}_s}{2}} + j\sqrt{\frac{\mathcal{E}_s}{2}}\right)$
01	$\left(-\sqrt{\frac{\mathcal{E}_s}{2}}, \sqrt{\frac{\mathcal{E}_s}{2}}\right)$ or $\left(-\sqrt{\frac{\mathcal{E}_s}{2}} + j\sqrt{\frac{\mathcal{E}_s}{2}}\right)$
11	$\left(-\sqrt{\frac{\mathcal{E}_s}{2}}, -\sqrt{\frac{\mathcal{E}_s}{2}}\right)$ or $\left(-\sqrt{\frac{\mathcal{E}_s}{2}} - j\sqrt{\frac{\mathcal{E}_s}{2}}\right)$
10	$\left(\sqrt{\frac{\mathcal{E}_s}{2}}, -\sqrt{\frac{\mathcal{E}_s}{2}}\right)$ or $\left(\sqrt{\frac{\mathcal{E}_s}{2}} - j\sqrt{\frac{\mathcal{E}_s}{2}}\right)$

$\triangleq \mathcal{X}$



  - Discrete to Continuous Time Signal

$$x(t) = \sum_{n=-\infty}^{\infty} x[n] \cdot p(t - nT_s) \triangleq x_r(t) + jx_i(t)$$

where $x[n] = x_r[n] + jx_i[n] \in \mathcal{X}$ and T_s is the symbol period.

(➔ Modulate onto different carriers (frequencies) to obtain OFDM symbols.)

Contents to Cover

- Chapter 1 - Introduction to Communication Systems
- Chapter 2 - Fourier Theory and Communication Signals
- Chapter 3 - Amplitude Modulation
- Chapter 4 - Phase and Frequency Modulation
- Chapter 5 - Random Variables and Processes
- Chapter 6 - Noise in Analog Modulation
- Chapter 7 - Digital Representation of Analog Signals
  - Sampling, Quantization, Pulse Modulation
- Chapter 8 - Baseband Transmission of Digital Signals
  - Matched Filtering, Inter-symbol Interference (ISI), Equalization, etc.

Readings and Questions

- Readings: Chapters 1 and 2
- Questions:
  - What is a communication system?
  - What are its basic components?
  - How do I represent a signal in time and frequency?
  - What is the representation when passed through a linear time-invariant system?
  - What is bandwidth?
  - What is the difference between baseband and bandpass systems?
  - How do you convert a baseband signal to a bandpass signal?