ECE 3770: Communication Systems

Lecture 1: Introduction

Mojtaba Vaezi

www.ece.villanova.edu/~mvaezi

Lecture 1
Introduction

- Course Information
- History of Communication
- Communication Process and OSI Model

Contents

Course Logistics

- **Instructors**

  Instructor: Mojtaba Vaezi
  E-mail: mvaezi@villanova.edu
  Office: Tolentine 433A
  Office Hours: TR from 11:15 am-12:30 pm, or by appointment

  Teaching Assistant: TBD (xxx@villanova.edu)
  Office Hours: xx from x am-x pm

- **Time and Location**

	Time	Location
Lectures	TR from 10:00 am to 11:15 am	Tolentine 309
Labs	T from 04:30 pm to 06:10pm	Tolentine 215

Objectives

This course provides broad knowledge of how communication systems work from a system engineering point of view and how to apply it to real-world problems.

Course Objectives

- Introduce the basic building blocks of communication systems
- Introduce communication channel and discuss how signals are shaped for transmission and reception over channel
- Develop and compare the performance of analog and digital modulation/demodulation schemes
- Introduce sampling, quantization and pulse code modulation
- Introduce and analyze the noise effect in communication systems

References

- **Textbook**

  Simon Haykin and Michael Moher, *Communication Systems*, 5th Edition, John Wiley & Sons, 2009. (ISBN: 978-0-471-69790-9)

- **References**
  - B. P. Lathi and Zhi Ding, *Modern Digital and Analog Communication Systems*, 4th Edition, Oxford University Press. (ISBN 978-0-19-533145-5)
  - Proakis and Salehi, *Fundamentals of Communication Systems*, (2nd Edition) Pearson, 2013.

Outline

- **Part I: Introduction/Math Foundational** (Chapters 1 & 2)
  - An overview of early and current communication systems/history
  - Review of frequency domain analysis of signals and systems
  - Review of signal classification and operations
- **Part II: Analog Communications** (Chapters 3, 4 & 6)
  - Amplitude modulation schemes
  - Angle (frequency and phase) modulation schemes
  - Frequency and time division multiplexing
- **Part III: Digital Communications** (Chapters 7 & 8)
  - Sampling theorem and the basis for digital communications
  - Quantization, PCM, and line coding
  - Digital transmission, matched filter decoding, and bit error rate

Assessment

Item	Weight	Remarks
Homework	16%	8 homework; each due in 1 week
Practicums	24%	A total of 8 practicum assignments
Test 1	15%	AM Modulation, Tuesday, Feb. 27, 2024
Test 2	15%	FM Modulation, Thursday, Mar. 28, 2024
Final	20%	8:30 am - 11:00 am, May 9, 2024
Participation	10%	Attendance, participation, and Kahoot quizzes

Homework Policy

- Due in one week after assignment, upload to Blackboard
- 25% penalty for late assignments
- No assignment is accepted after posting solutions
- You could work in group but everyone should turn in their own write up

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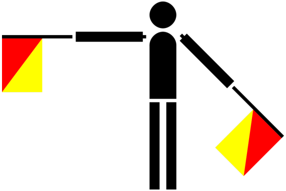
Early Communication Methods

(a) smoke signal

(b) carrier pigeon



(c) semaphore telegraph

Modern Communication Systems

- Telegraph
  - 1830, Joseph Henry
  - 1837, Samuel B. Morse, Morse code
- Telephone
  - 1876, Alexander G. Bell ("Watson come here; I need you")
  - 1915, US transcontinental service (requires amplifiers)
- Wireless telegraphy
  - 1895, Jagadish Chandra Bose builds radio transmitter
  - 1896, Marconi patents radio telegraphy
  - 1901, Marconi, first transatlantic transmission
- Radio
  - 1906, first broadcast (Reginald Fessendend)
  - 1920, first commercial AM radio station (Montreal XWA → CINW)
  - 1935, FM radio (Edwin Howard Armstrong)

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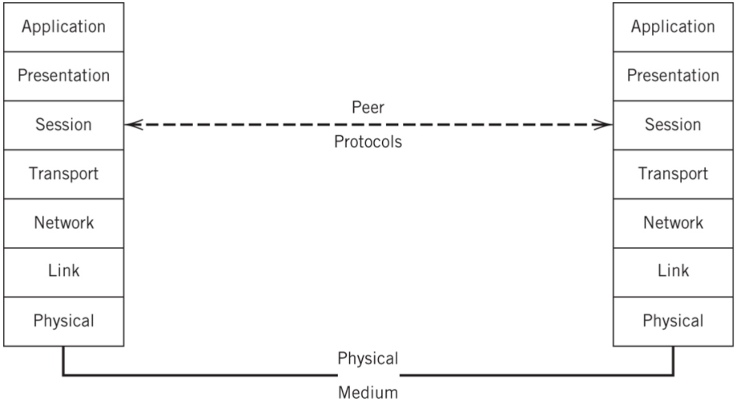
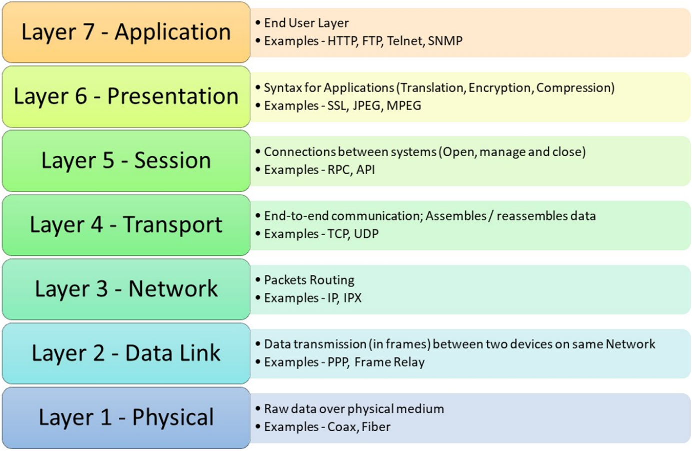
Open Standards Interconnection (OSI) Reference Model

- The OSI is a *conceptual model* created by international organization for standardization (ISO) to describe a stack of layers that enable communications between two systems.



The OSI Model

- The OSI model comprises *7 layers*, defining various functions involved in establishing an end-to-end communications.
- It simplifies the design and permits independent development of different functions.

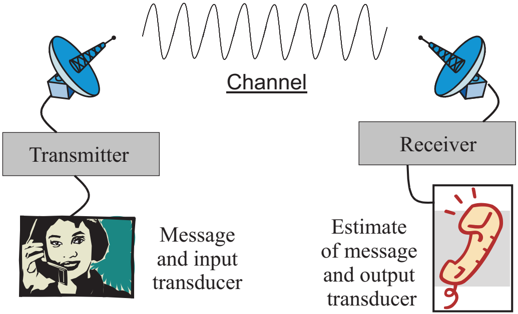


Example: Sending an Email

- **Layer 7 (Application)** what the system does for the user (enables sending emails, in this example)
- **Layer 6 (Presentation)** what app you could use to send an email, e.g., outlook, Gmail, etc.
- **Layer 5 (Session)** controls the session, checks username/passwords
- **Layer 4 (Transport)** which network to use to get the info from the source to destination (5G, GSM, telephony network, etc.)
- **Layer 3 (Network)** which way (route) to send the info
- **Layer 2 (Data Link)** controls the flow of info between the nodes and handles congestion and re-transmission
- **Layer 1 (Physical)** means of communication (voltage, frequency, transmission rate, medium (wire, radio, fiber), etc.)

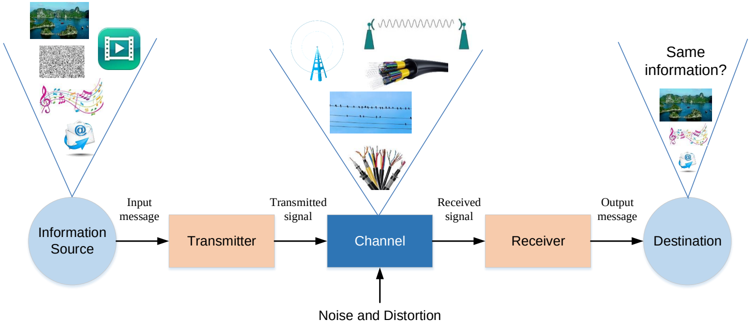
Electrical Communication System

- In its simplest form, a telecommunication system consists of a *transmitter*, a *channel*, and a *receiver*.



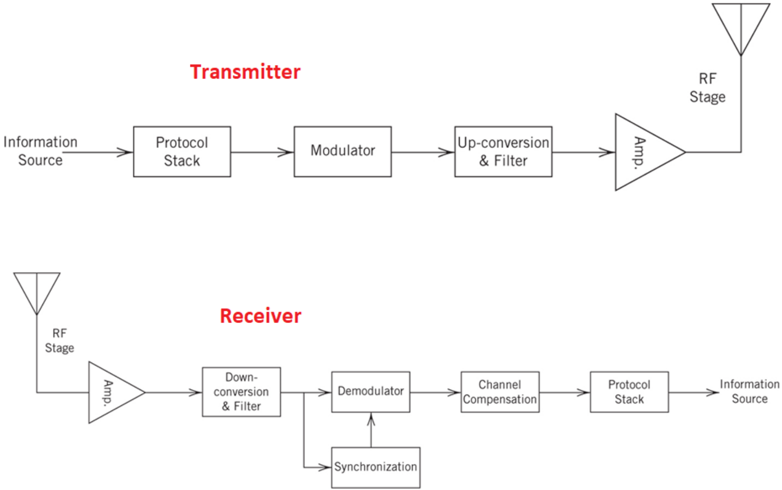
- Examples of channels
  - Wired (copper wire: 1 MHz, coaxial cable: 100 MHz)
  - Wireless (microwave: GHz)
  - Optical fibre (uses light as the signal carrier, THz)

Elements of Communication System



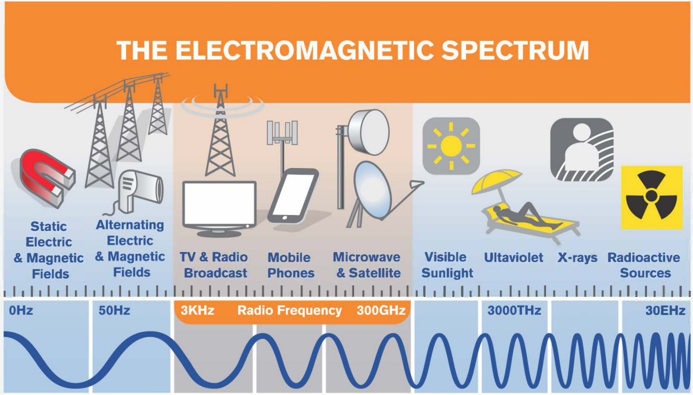
- Early communication systems were all analog: examples include
  - AM and FM radio, analog TV, audio cassettes
  - First generation cellular phone technology (based on FM)
- Analog communication getting obsolete

Basic Components of Transmitter/Receiver



Electromagnetic Spectrum

- Electromagnetic frequency spectrum (dc to light)
  - **Radio spectrum:** 3kH - 300GHz
  - **Optical spectrum:** 300GHz - 3×10^{21} HZ



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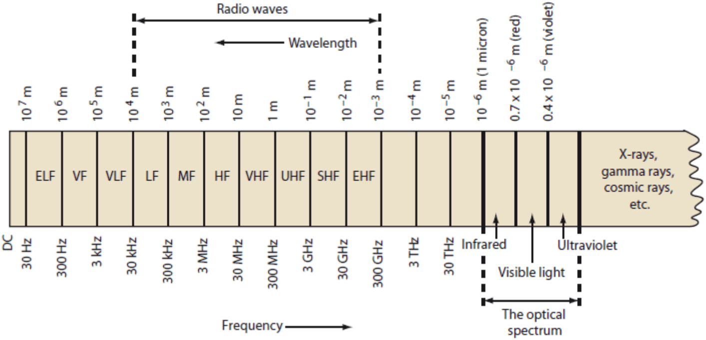
Wavelength and Frequency

- **Wavelength:** $\lambda = \frac{v}{f}$
  v = speed of light = 3×10^8 m/s



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Communication Resources

- **Bandwidth:** the range of frequencies a channel can transmit with reasonable fidelity
  - A precious and very expensive resource
  - An example of FCC auctions in 2017:
    84 MHz of wireless spectrum for about *$20 B*
- **Power:** Signal power P is related to the quality of transmission
  - Often measured in terms of *the signal power over the noise power* (SNR)
  - Limited by availability and/or regulation

Why are these important?

- Shannon's channel capacity equation

$$\boxed{\mathrm{C} = W \log_2(1 + \mathrm{SNR}) \quad bits/s}$$

That is, data rate (C) depends on bandwidth (W) and SNR (which is related to power)

Objectives of System Design

To transmit the message both *efficiently* and *reliably*, subject to certain design constraints: power, bandwidth, and cost.

- **Efficiency:** is usually measured by the amount of messages sent in unit power, unit time and unit bandwidth
- **Reliability:** is expressed in terms of *bit error rate* (BER) or SNR
  - Shannon capacity formula says zero error rate is possible as long as actual signaling rate is less than C