COMMUNICATION THEORY AND ENGINEERING

Master of Science in Electronic Engineering, first year
As tought in the first semester of Academic Year 2024-2025

Instructor: Prof. Jocelyn Fiorina, Prof. Luca De Nardis
Website for the course: http://acts.ing.uniroma1.it/~lucadn/comel2.php

COURSE MEETING TIMES

4 sessions/week, 2 academic hours/session

COURSE OVERVIEW

Communication Theory and Engineering is a course of 9 credits that offers an introduction to the quantitative theory of information and its application to communication systems engineering. One of the goals is to provide some insight into the fundamental concepts of information representation, such as entropy, capacity, channel coding, and into source coding, with particular focus on speech and image. Within this theoretical framework, topics addressed in the course cover the understanding of principled design strategies of modern wireless communication networks, and in particular resource sharing and multiple access channels, multi-user interference, medium access, and achievable performance in terms of multi-user capacity.

COURSE PREREQUISITES

Fundamentals of probability theory; This is important because from the beginning we assume solid knowledge of probability.
Signals and systems; students who did not take a class on signals and systems at the undergraduate level are advised to take the online course: "Signals and Systems" MITOPENCOURSEWARE, Massachusetts Institute of Technology, Instructor: Prof. Alan V. Oppenheim, https://ocw.mit.edu/resources/res-6-007-signals-and-systems-spring-2011/

REQUIREMENTS AND GRADING

Certificate of the MATLAB course "MATLAB Fundamentals"
Written (50%) and oral (50%) exam

COURSE TEXTBOOK AND READING MATERIAL

In addition to the lecture notes, students may find the following texts to be of use.
Cover, Thomas, and Joy Thomas (2006). *Elements of Information Theory*. 2nd ed. New York, NY, USA: Wiley-Interscience, 2006. ISBN: 9780471241959. ***Recommended Reading***
Rabiner Lawrence R. and Schafer Ronald W. (2007), "Introduction to Digital Speech Processing", Foundations and Trends® in Signal Processing: Vol. 1: No. 1–2, pp 1-194. http://dx.doi.org/10.1561/2000000001
Free copy downloadable after registration. ***Recommended Reading***
Proakis John G., Salehi Masoud, Bauch Gerhard (2013). Contemporary Communication Systems Using MATLAB, 3rd ed. Stamford, CT, USA: Cengage Learning US, 2013. ISBN 9780495082514. ***Recommended Reading***

COURSE TOPICS

Information theory
Statistical measure of information. Entropy. Conditional entropy and joint entropy. Relative entropy. Distance of Kullback-Leiber.
Asymptotic Equipartition Property (AEP)
Discrete channel capacity. Continuous channel capacity. Theoretical limits of modulation.
Channel coding
Error correction codes. Block codes. Parity check codes and Hamming codes. Hammind distance.
Soft and hard decoding and performance analysis. The perfect code. Code gain. Parity check matrix. Syndrome. Cyclic codes, BCH codes, Reed-Solomon codes. Convolutional codes. Generator polynomial.
Source coding: speech and image
Speech. Production model. Frequency analysis of speech. Spectrogram. Digital representation of speech signals and telephone speech.
Quantization noise, signal-to-quantizaion noise. Uniform and non-uniform quantization. Adaptive and differential quantization.
Standards: Waveform coding, PCM, DPCM, ADPCM, ADM. Parametric coding LPC, GSM, MP3
Image. Representation of still black and white and coloured images. Aspect ratio. Luminance and crominance. Still image sampling.
Moving images sampling. Digital representation of moving images.
Standards: NTSC, SECAM, PAL, DVD,MPEG-2 Part 2 (H262) e MPEG-4 Part 10 (H264), DVB-T/DVB-T2, ATSC, DTMB, ISDB-T, Full HD, Super HD
From the single link to the network
Introduction to modern communication networks and 5G
Multiple access: Single and multiple carrier systems: TDMA, FDMA, CDMA, OFDMA. Interference models and performance analysis. Standard Gaussian Approximation.
Medium access: Cognitive radio. Random access. Aloha, slotted Aloha and CSMA
Performance evaluation and comparison.
Multi-user channel capacity
Application of theory using MATLAB
Throughout the course the theoretical material will be supplemented by practice work sessions addressing specific design and performance analysis problems and a variety of exercises that may be solved on a personal computer using MATLAB.
The practice work sessions material is available on the website of the course and form an integral part of the course topics.