EE-432
Systeme de Telecommunication

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Class Syllabus and Organization
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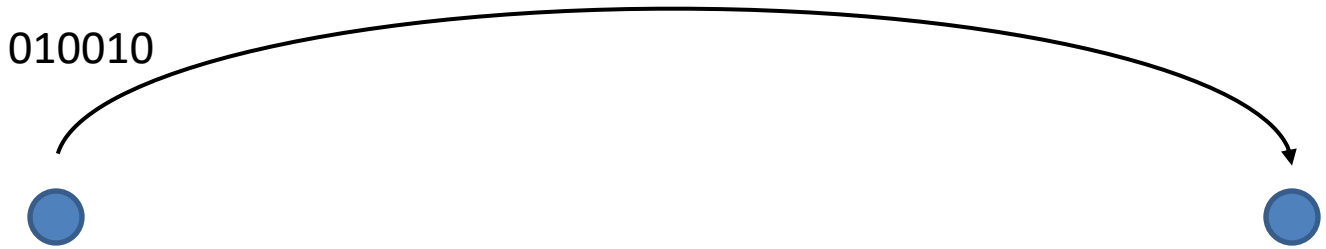
What do you mean with “Telecommunication”?

- **The term “telecommunication” involves everything related to getting messages or information from one point to another.**



What Does “Telecommunication” Involve?

- **Information comes in many forms and is not straightforward to define**
  - Analog physical observations
  - Natural digital information
  - Digitized analog observations
- **Telecommunication happens across different media**
  - Wired connections, electrical or optical
  - Wireless connections, with radio waves or light
  - Connections over large or even very short distances (e.g., between chips)
- **Different media pose constraints on signals that must be respected and accounted for**
  - Signal strength
  - Maximum (and minimum) bandwidth
  - Signal integrity and distortions (deterministic and random)
  - ...

What Does “Telecommunication” Involve?

- **Communication ultimately must deal with many more than just two parties**
  - Avoid interference from other communicating parties
  - Optimally allocate resources to maximize overall capacity/speed/reliability
  - Enable collaboration and broadcast

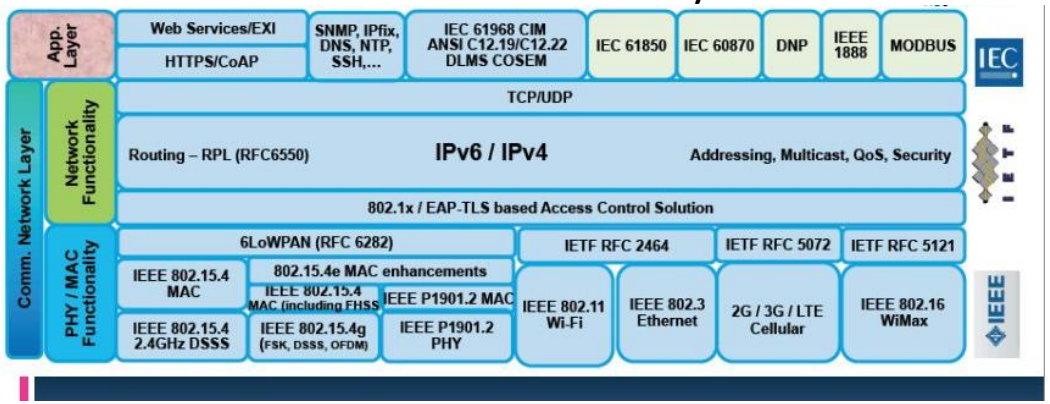
- **Information may travel along simple or complex routes**
  - Single point-to-point connections
  - Complex networks with multiple routes and hops

- **Complex routes and systems must be organized**
  - How to find the best route in a complex mesh
  - How to route information in a flexible manner
- **...**

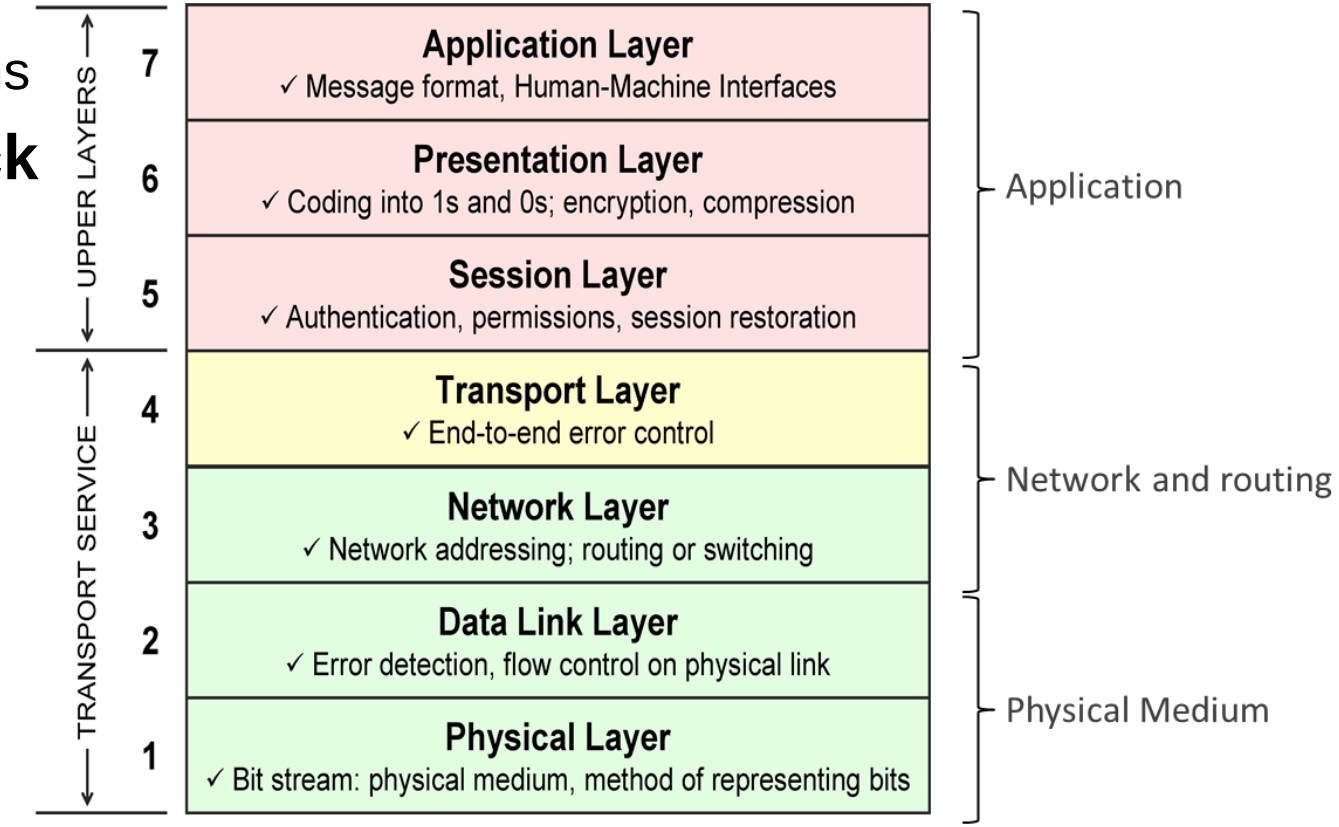
Manage Complexity with Layers

- **To manage complexity, "Telecommunication Systems" are built based on layers, following the 7-Layer OSI reference stack**
  - Each layer takes care of specific tasks
  - Layers can have different implementations
- **Data travels up and down the stack until it reaches its destination**

Concrete examples of layer stacks of various wireless systems

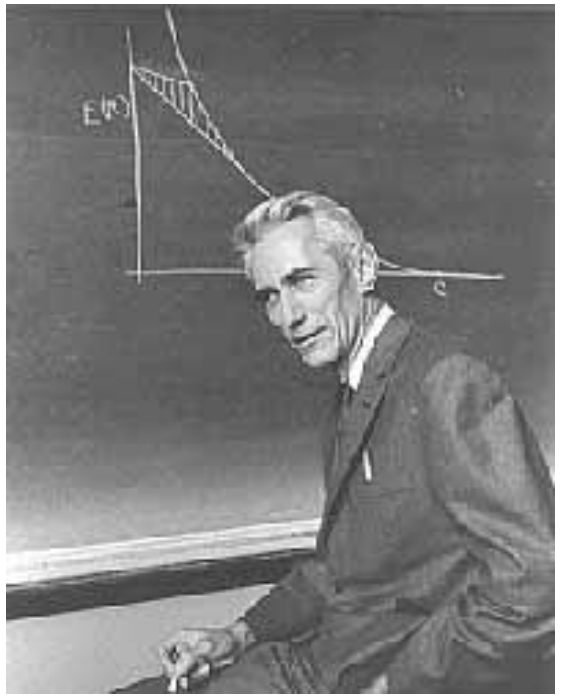


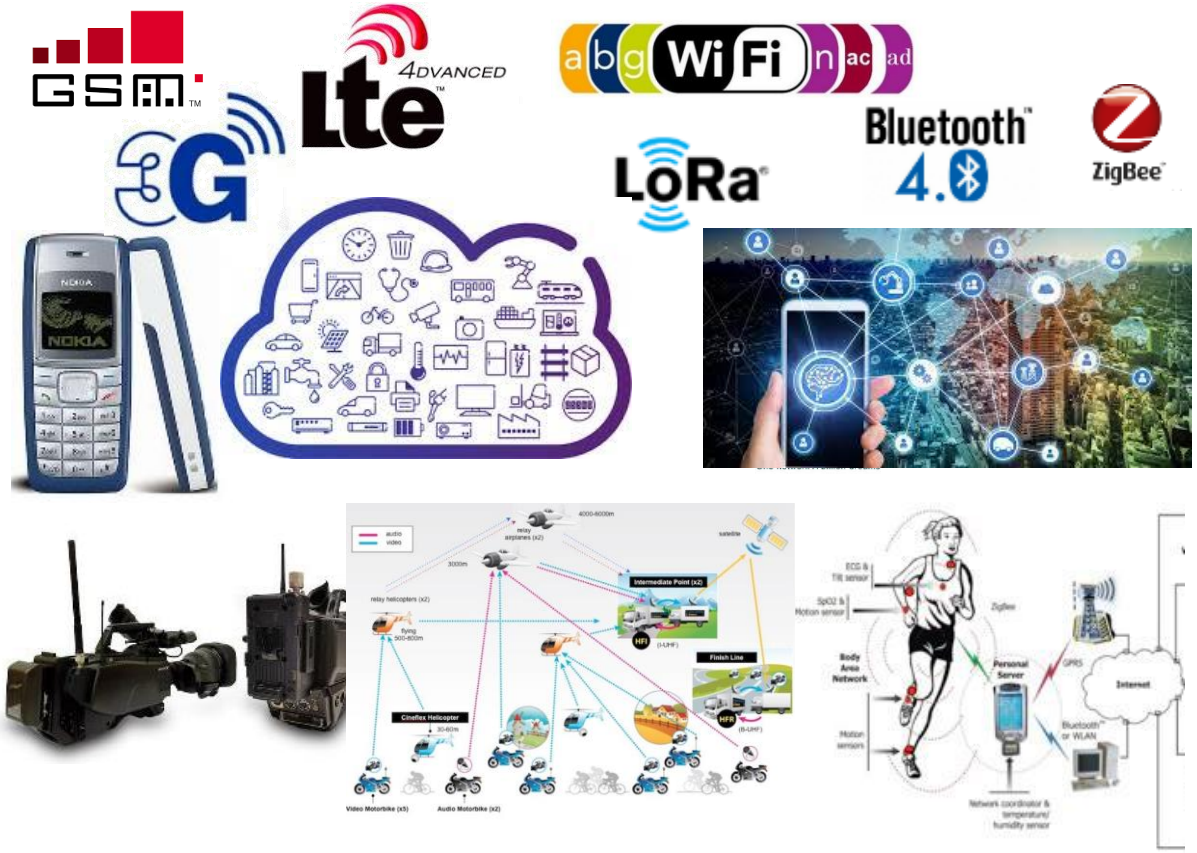
Source: David E. Culler - The Internet of Every Thing - steps toward sustainability CWSN Keynote, Sept. 26, 2011



Source: http://www.telecommunications-tutorials.com/tutorial-OSI-7-layer-model.htm

In this Introductory Class We Have Two Objectives:





Derive and understand the principles and key algorithms from rigorous mathematical foundations

Get to know and work on all the latest real standards and their features and capabilities

Unfortunately, ...

- **There are many interesting and relevant standards to discuss**
- **Even the most basic standards are today quite complex**
- **Even for a simple standard, building a real and working receiver involves many steps and components**
- **The required algorithms are non-trivial by themselves**

- **BUT, understanding the behaviour and optimizing telecom systems on all levels still requires a solid understanding of the foundations**

So We Try Three Things in Parallel ...

A. Discover and understand well the fundamental tools (from signal processing and statistics) and foundations that are essential to

1. understand the behaviour communication systems and
2. design and optimize many communication algorithms

B. Apply these mathematical tools and foundations rigorously, but to sufficiently simple, but fundamental examples and key algorithms to

- get proficiency in their use without side-cuts so you can do complex examples when needed
- get confirmation of the theory with specific examples

C. Enjoy a rather high-level inside look into few selected, but relevant and representative key standards and receivers (for different applications) to

- understand their motivation, principles, performance, and limitations
- learn to construct complex receivers with intuition and confidence into the foundations

With Some Further Limitations ...

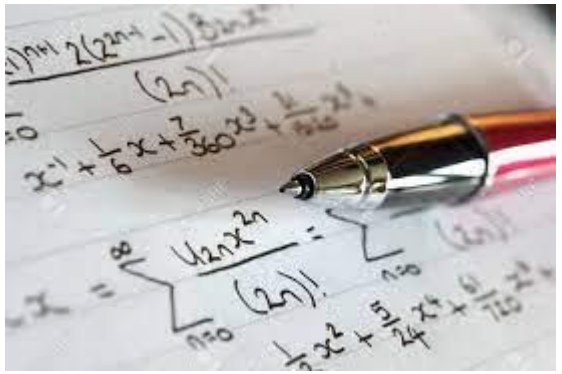
- **For A) and B) we focus mainly on the physical (PHY) layer as the foundation of any communication stack**
- **For C), we touch only slightly on the lower Medium Access Control (MAC) layer, a close companion of the PHY that regulates and coordinates**
- **We focus initially on wireline systems (“baseband”) and then switch to wireless systems (“passband”) which are ultimately translated into baseband**
- **For A) and B), we try to be rigorous and detailed. For C), we allow for some hand-waving arguments to deal with complexity for an initial shot**
  - For A) and B), we realize everything from scratch, while for C), we allow for using ready-made pieces, provided that we know what they are good for.

What Will You Learn?

- **Recap some fundamentals from “signals and systems” and from “analysis”** to describe communication signals and algorithms
- **Learn how adapt signals and information to be sent across a channel**
- **Understand what channels are and how they impact communication signals**
- **Learn how to recover information from received signals**
- **Understand and assess performance limitations and characteristics**
- **Learn about the key components in a communication system and their role**
- **Learn how to model and simulate communication systems and components**
- **Get a high level view of some interesting standards, including complex technologies and link them to the basic concepts**

Organization & Tools

- **Besides the lecture (theory), the course comprises**
  - **Pen & Paper exercises** that prepare you for the final exam
  - **GNU Radio labs** that help you understand the exercises and prepare you for the project



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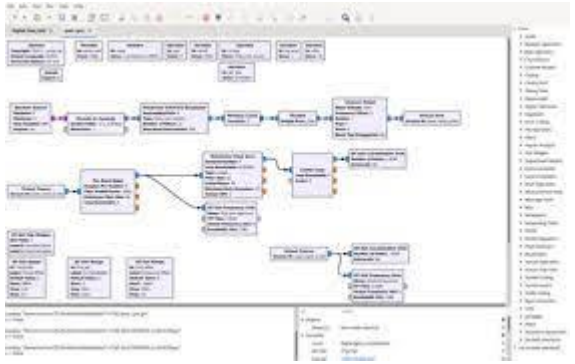

Outline (Subject to Adjustments)

Week	Date	Lecture	Standards	Exercise	Lab
1	17-Feb	Syllabus & Introduction Fundamentals of Signal Theory	None	None	
2	24-Feb	Fundamentals of Signal Theory (cont.)	Morse Code & Telegraphy	Signal Theory (Ex. 1)	
3	03-Mar	Analog Modulation: AM & FM	AM and FM Radio		GNU Radio Introduction
4	10-Mar	Sampling Theory	Analog TV (NTSC/PAL)		GNU Radio AM Transmitter
5	17-Mar	Quantization and PCM	TDM-based Telephony (ISDN, PSTN)	Stochastic Signals, Amplitude Modulation, Sampling (Ex.2)	
6	24-Mar	Digital Baseband Transmission	Fiber Optical Systems and Serial Links	Quantization, PCM and Transmission of Sampled Signals (Ex. 3)	
7	31-Mar	Symbol Error Rates & Digital Modulation			GNU Radio: PAM
8	07-Apr	Carrier Modulation & Bandwidth Efficiency	GSM (Global System for Mobile Communications)	Error Rates in Digital Transmission (Ex. 4)	
9	14-Apr	Information Theory & Channel Coding		Inf. Theory & Coding (Ex. 5)	
10	21-Apr	Easter Vacation			
11	28-Apr	Wireless Channel & Interference	GPS/GLONASS: Positioning Systems	Link Budget Calculation (Ex. 6)	
12	05-May	Advanced Modulation Techniques: OFDM, CDMA	WiFi (IEEE 802.11b/g/n) LTE (Long-Term Evolution, 4G)		
13	12-May	5G NR (New Radio)	LoRa & Low Power Wide Area IoT Networks		
14	19-May				Project 1
15	26-May				Project 2

Structure and Grading

- **The course connects to the TP on Inf. Technologies, which includes 3 sessions on communications. Attending encouraged, but not mandatory.**

- **The course will be graded based on**

▪ Final project	50%	based on a report
▪ Final exam	50%	pen & paper based on exercises & questions on standards

Learning Objectives

- **Understand the principles of communications including: modulation, transmission, and demodulation**
- **Be able to master basic signal analysis in time and frequency domain to extract and analyze important properties of communication signals (for digital and analog communication signals)**
- **Describe/model/analyze mathematically what happens to a signal/data in a communication system on its way from source to sink**
- **Understand key metrics of digital communication systems and analyze the performance and efficiency of digital communication systems**
- **Be familiar with a number of important communication standards and their basic principals and key technologies**

Course Material

- **Three types of material will help you through the course**
  - Lecture slides on Moodle
  - Exercises
  - Your notes from the experiments

  - The following book: available online at
    Modern Digital and Analog Communication (The Oxford Series in Electrical and Computer Engineering): Lathi, B.P., Ding, Zhi: 9780190686840: Amazon.com: Books

    https://bank.engzenon.com/tmp/5e7faa2e-e8d4-43f7-9bb4-42efc0feb99b/61745999-d5b4-4245-9269-4e72c0feb99b/Modern_digital_and_analog_communications_Lathi_5ed.pdf