Digital Communications
EN5601

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Lecture 1: A Brief Introduction

Course Information

- Lecturers: Chathuranga Weeraddanana
- Lectures: in weekends, 3 hours/week, $14 - 15$ weeks
- Office Hours: weekends + weekdays (with appointments)

Course Information

- Course Website: moodle of UoM
- Textbooks:
  - indicated in the lecture notes/slides whenever necessary
- Evaluation of Performance:
  - assignments, quizzes, mid examination: **40±20%**
  - final examination: **60±20%**

What is the Relevance of the Module

- inevitable in enormous and rapidly growing society

Main Goal of the Module

- study the aspects of communication systems
- no hardware, no software, but as building blocks
- we learn lots of theories behind the digital communication systems, why theories ?

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- we learn lots of theories behind the digital communication systems, why theories ?
  - always has a powerful impact on system design
  - guided system development
  - based on abstract building blocks, simple models
  - toy problems, before addressing/understanding complex engineering problems

Main Goal of the Module

- a catalogue of simple minded things in the back of your mind
- analyse simple toy models, make conclusion
- $\rightarrow$ make you a good engineer

Prerequisites

- signals ans systems
- probability
- stochastic processes

Key Reference Books

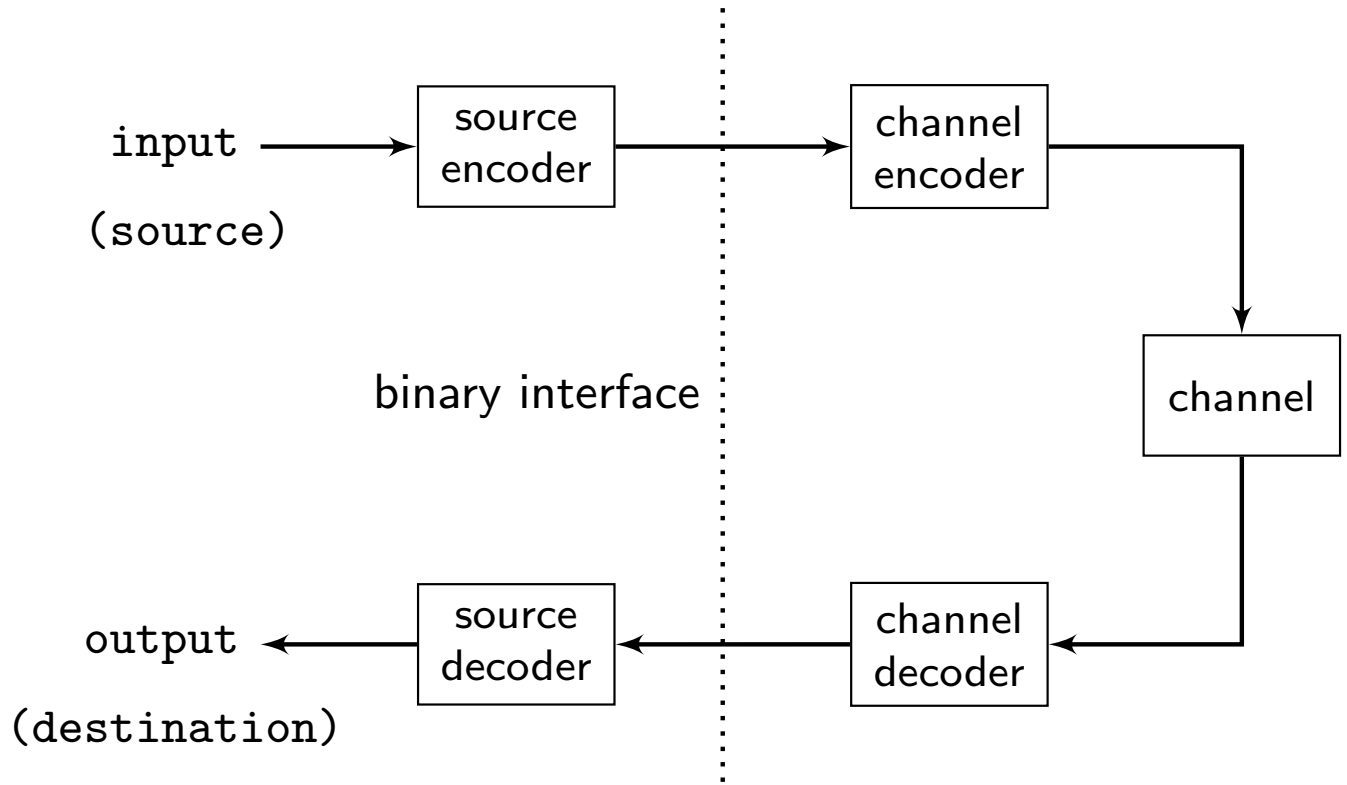
- R. G. Gallager, Principles of Digital Communications, Cambridge University Press, 2008 [Gallager-2008]
- S. Benedetto, E Biglieri, Principles of Digital Transmission with Wireless Applications, Kluwer Academic Publishers, 2002, [Benedetto-2008]
- J. M. Wozencraft, I. M. Jacobs, Principles of Communication Engineering, John Wiley & Sons Inc., 1965, [Wozencraft-1965]
- there can be some more

Overview

Major Keys to Make Things Simpler

- standardized interfaces and layering [see Gallager §1.1]
- standard interfaces
  - e.g., source and the channel interface, it is usually a binary data stream
  - the notion of binary interfaces is almost as commonplace
- layering
  - decompose the communication system into a sequence of sub systems which are linked by several interfaces, e.g., binary interfaces

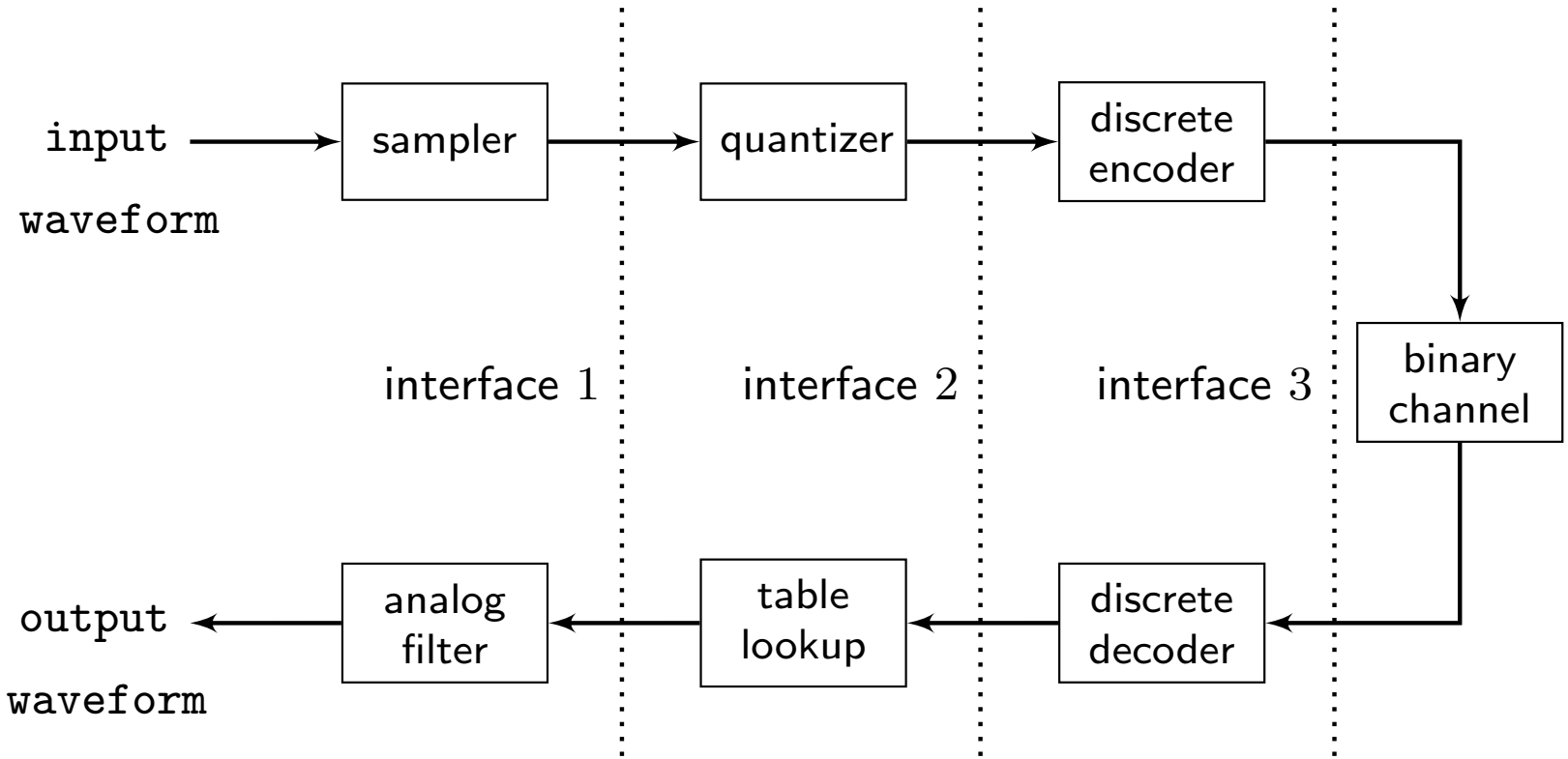
Communication System: A Major Layering



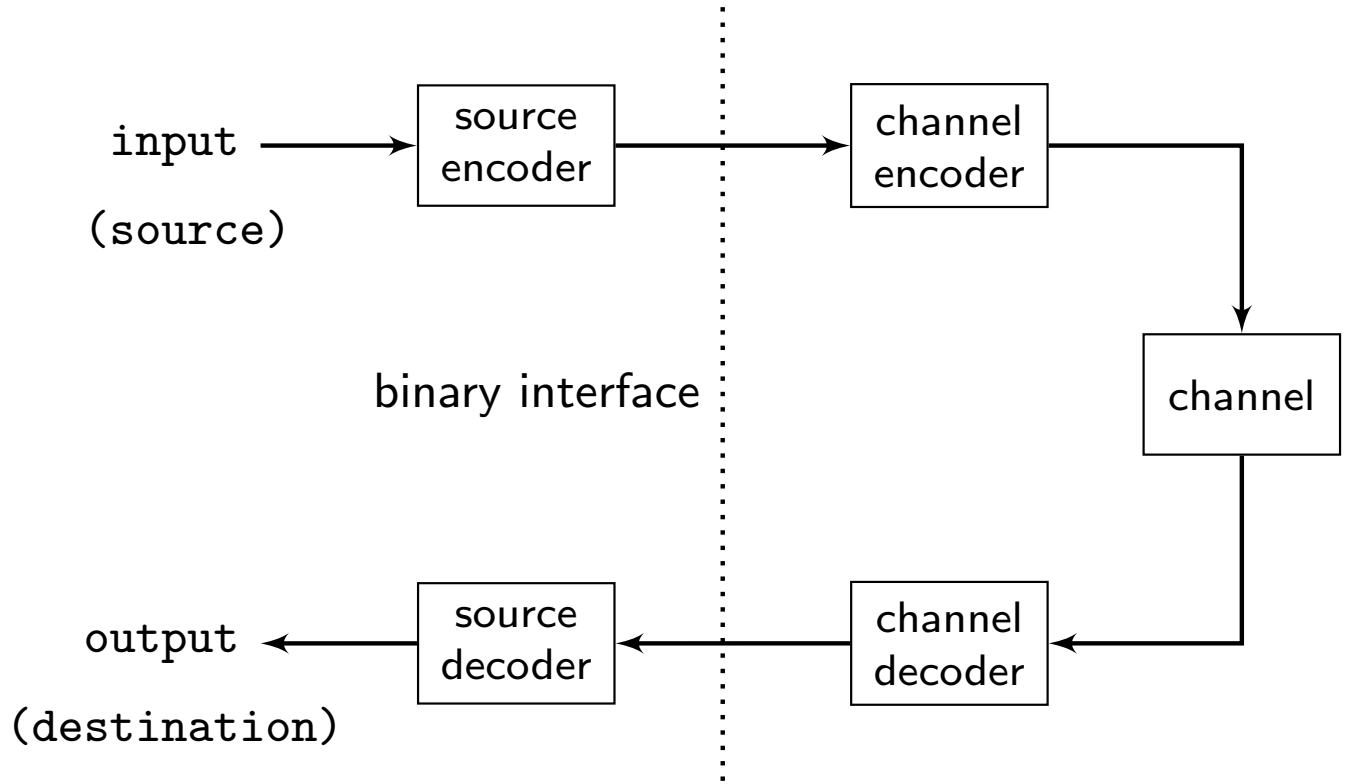
Why Digital Interfaces

- digital hardware: so cheap, reliable, and miniaturized
  - thus the digital interfaces are eminently practical
- what one subsystem is doing is irrelevant to the other
  - e.g., source coding/decoding can be done independently, similarly, channel coding/decoding
  - standardized interfaces between subsystems simplifies implementation and understanding
- simplifies networking, e.g., multiplexing many users' information

Source Encoder: A Layering



Communication System: A Major Layering



Input (Source)

- source might be discrete or even analog waveforms, e.g.,
  - speech waveforms
  - image waveforms
  - video waveform
  - output of a sensor
  - text files

Source Encoder

- functionality depends on the source itself
- converts input into a streams of bits
- e.g., textual information $\rightarrow$ ASCII (fixed length, one of the simplest)
  - can do better, preferably few bits as possible ?

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- e.g., textual information $\rightarrow$ ASCII (fixed length, one of the simplest)
  - can do better, preferably few bits as possible ? variable-length sequences
  - probabilistic description of the source (entropy)

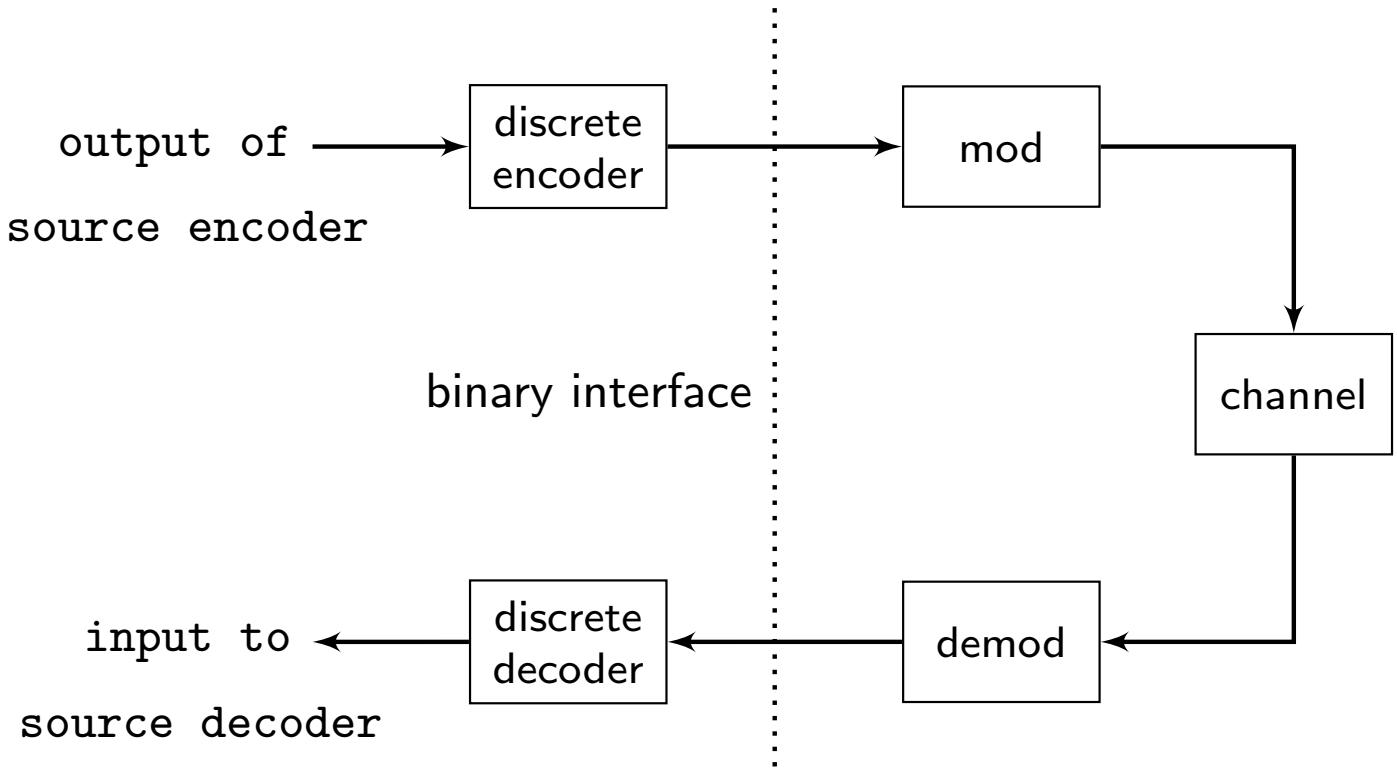
Source Encoder

- e.g., analog waveforms
  - sample (Nyquist sampling rate), quantize, assign binary sequences to quantized values
  - a general approach: source waveform $\rightarrow$ orthonormal expansion and use the coefficients of that expansion to represent the source output
- dispatches the binary sequences to the channel encoder

Channel

- not under the control of the designer
- for a source-code designer: it might be a digital channel with binary input and output
- what if the channel is taken to be the physical medium (twisted wire pair, wireless medium)?
  - amplifiers, antennas, lasers, etc. can be regarded as part of the channel
  - or as as part of the channel encoder
- more common to view these devices as part of the channel
- why ? their design is quite separable from that of the rest of the channel encoder

Channel Encoder: A Layering



Channel Encoder

- converts the source output into a binary sequence
  - usually add some redundancies to make the binary sequence from the source encoder more robust against the noise (e.g., repetition coding)
- moreover, (digital) modulation
  - the binary sequence $\rightarrow$ baseband waveform $\rightarrow$ bandpass
  - e.g., binary pulse amplitude modulation (2-PAM), quadrature amplitude modulation (QAM), FSK, PSK, ASK, PPM, PWM
- i.e., the binary sequence is converted into a form suitable for transmission over particular physical media, (i.e., channel)

Channel Decoder

- the noise on the channel $\rightarrow$ the received waveform is different from the transmitted waveform
  - a major block of the channel decoder is demodulator which performs the detection of the possible tx symbols
  - the detector attempts to choose which possible input symbol sequence is most likely to have given rise to the given received waveform
  - then, symbols $\rightarrow$ binary sequences $\rightarrow$ remove redundancies after detecting/correcting for errors (e.g., majority-rule decoding)

Source Decoder

- the reverse processes source encoder
- e.g.,
  - sequence of bits $\rightarrow$ ASCII
  - sequence of bits $\rightarrow$ sequence of quantized samples $\rightarrow$ LPF $\rightarrow$ a faithful replica of the input waveform