Chapter 1: Introduction

1.1. Information theory

1.2. Communication system

1.1. Information theory

- Branch of math
  - Probability theory
  - Linear algebra
- Study transmission, processing, extraction, and utilization of information
  - Ensure required amount of information is obtained through the processing mentioned above
    - E.g. Image processing: must ensure that information loss through it is within acceptable limits

1.1. Information theory (Cont.)

- It was build upon the work of Shannon (1948)
- It answers to two fundamental questions in *communications theory*:
  - What is the fundamental limit for information compression?
    - Source coding theorem
  - What is the fundamental limit on information transmission rate over a communications channel?
    - Channel coding theorem

1.1. Information theory (Cont.)

- What is information?
  - Several different notions
  - One of the most famous: **Information can be thought of as the resolution of uncertainty. It is abstract concept that describes understanding of objects in social life, in nature.**
    - Uncertainty: situation in which something is not known, or something that is not known
    - When we acquire information, uncertainty situation becomes certainty situation (uncertainty is released)
    - Quantitatively, amount of information equals uncertainty
  - E.g:
    - A lottery buyer:
      - When waiting for results, he/she is having an uncertainty about the outcome
      - Upon receiving the result, he/she gets the information and his/her uncertainty is released

1.1. Information theory (Cont.)

- Information is abstract, to be able to represent and transmit information, information needs to be converted into a material that holds this information (data)
  - We only perceive the information through the data that contains it
- Example1: human knowledge is information. This knowledge can only be expressed through speech or text
  - Speech and text: string of data
- Example 2: content of the book is information. Book is string of data.

1.1. Information theory (Cont.)

- Data is elementary material that carries information
  - Elementary: first material that information is assigned
- Typical data: audio(speech…), video(image, text…), measurement results of the state of physical objects (room temperature…)
  - Each data is called a media for transmitting information
  - System transmits only one media: single-media system
  - System transmits different medias: multi-media system
- Audio, video is continuous data → its information is continuous information
  - Data is represented by a continuous function
- Measurement results may be continuous or discrete data
  - Discrete data: only appears at separate times
- Digital data: discrete data has quantized values
  - Quantized value: physical quantity can have only certain discrete (separate) value

1.1. Information theory (Cont.)

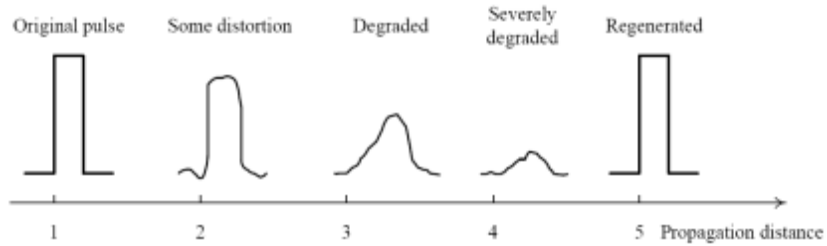
- Normally, to transmit or process the data, the data is converted into discrete data that have only two values called binary data
  - Traditionally, value is labeled as 0 and 1
- E.g.: Computer data, transmitted data in digital telephone systems…
- Binary information: represented by binary data

1.2. Communication system

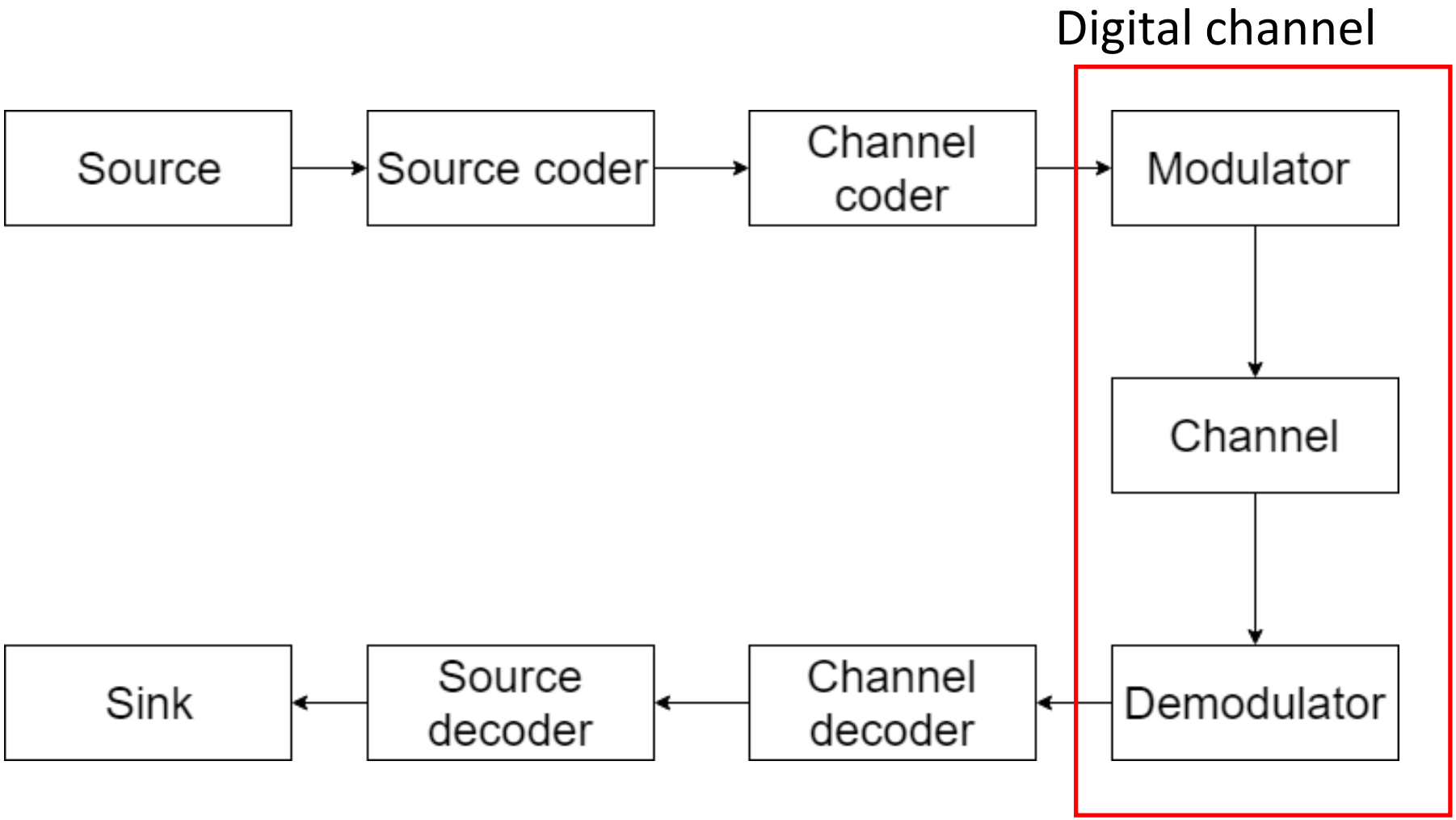
- The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point (Shannon 1948)
- Normally, information represented by string of data is sent in each transmission session
  - String of data in each session: data message
  - Carried information by each data message: information message

1.2.1. Digital communication system

- Digital communication system: use digital data that carry digital information
- Advantages of digital communication when compared to analog communication system:
  - Easy to convert from analog information to digital information and vice versa
  - Popular
    - Cheaper
    - More reliable
      - 1: original pulse: has only two levels (high and low)
      - 2,3,4: obtained pulses after transmission.
        - The more distance, the more degradation
      - Having 2 levels, it is easy to regenerate the pulse what is similar to original pulse



1.2.2. Block diagram of digital communication system (communication model)



1.2.2. Communication model (Cont.)

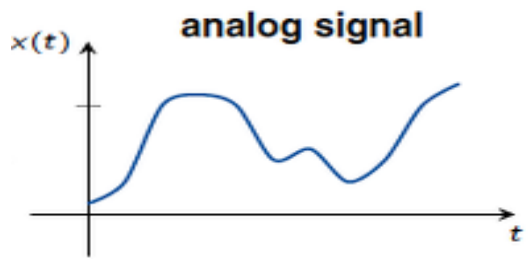
- Source: generate transmitted data
  - Consists of two functional blocks:
    - Information source : generate information
    - Materialization : transform information into data
- Source Coder: use finite set of code symbols to represent information (carried by data) of source by minimum number of symbols.
  - Symbol: sign or word represents data or information
  - Output of source coder: sequence of code symbols.
    - In case of binary code → binary sequence
- Channel Coder: Protection against errors in the channel
- Modulator: Each binary sequence is assigned to a waveform (signal)
  - Signal: physical entity
    - Hold the information
    - Suitable with channel
- Channel: Physical Medium to send signal from transmitter to receiver.
- Demodulator, Channel Decoder, Source Decoder, Sink.
- Modulator + channel + demodulator = digital Channel

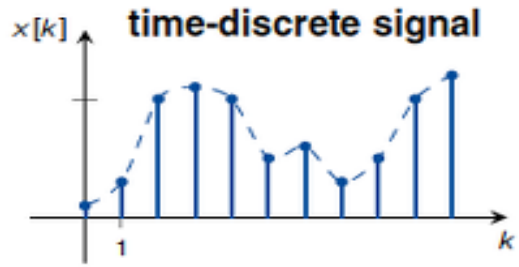
1.2.3. Typical communication channel

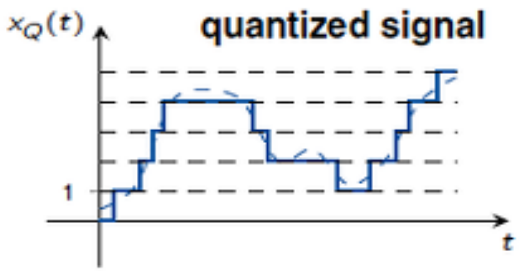
- Analog channel: both input and output signals are analog
- Discrete channel: both input and output signals are discrete
- Digital channel: both input and output signals are digital

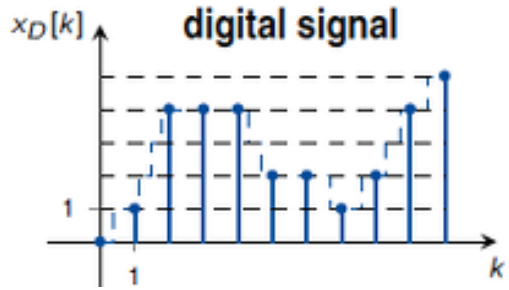
1.2.3. Typical communication channel

- Analog signal: x(t)
- Discrete signal:
  - Time discrete signal x(k): Only appear at separate times
  - Discrete value signal (quantized signal) $x_Q(t)$: take separate values from finite set of possible values
- Digital signal $x_D(k)$: discrete time and discrete value signal









1.2.3. Typical communication channel (Cont.)

- Binary Symmetric Channel (BSC)
  - Binary channel: input signal and output signal are binary
    - For example: 0 and 1
  - Symmetric channel: The channel matrix is symmetric across the main diagonal
    - Channel matrix: contain transmission probability *P(y|x)*
      - *P(y|x)*: conditional probability of receiving output signal *y* when input signal *x* is sent
  - Binary symmetric channel = binary channel + symmetric channel
    - Example: channel matrix of one BSC

$$P(Y|X) = \begin{array}{|cc|c} 3/4 & 1/4 & x1 \\ 1/4 & 3/4 & x2 \\ \hline y1 & y2 & \end{array}$$

Remind

- Information: abstract concept that describes understanding of objects in social life, in nature.
- Data: representation of the information by physical object (physical representation of the information)
- Message: string of the data
- Signal: data which is suitable for propagation medium
- Channel: medium for signal propagation
- Symbol: sign or word represents data or information
- Source coding: using finite set of code symbols to represent information (carried by data) of source by minimum number of symbols
- Channel coding: protection against errors in the channel.