EITF25 – Internet: Technology and Applications

Physical Layer

2013, Lecture 01

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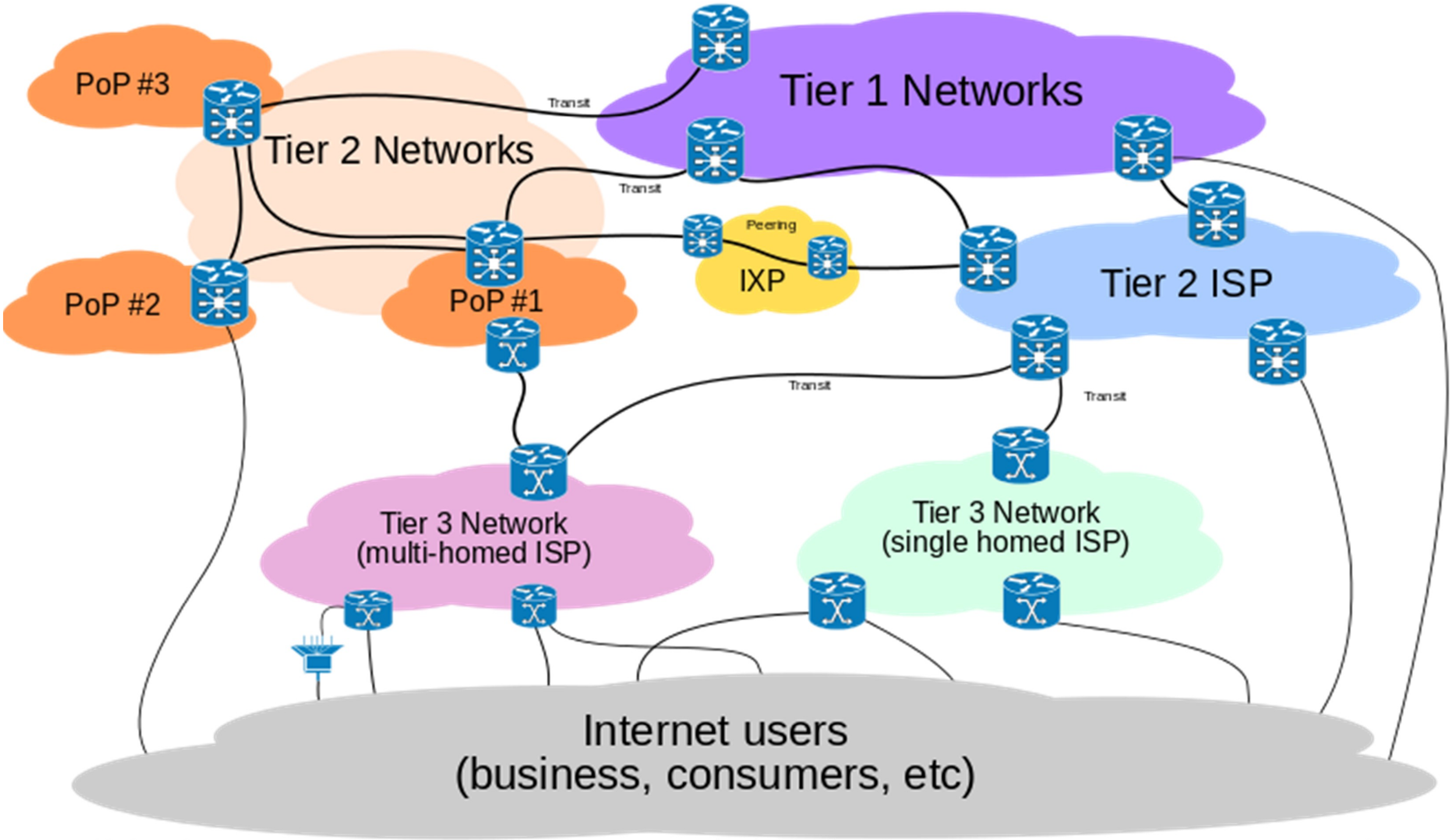
Internet – users' view

Internet – engineers' view



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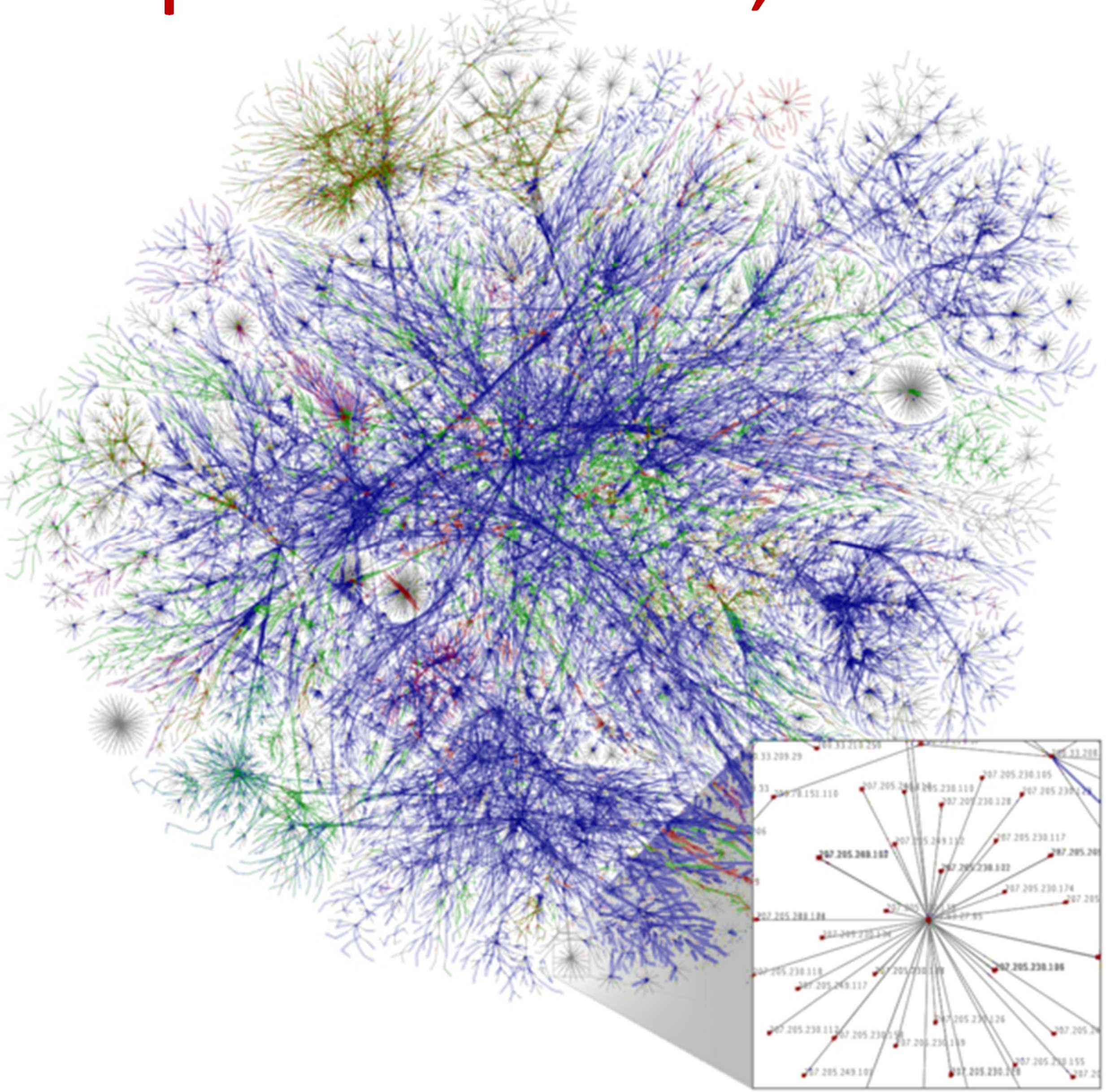
Map of Internet, 2003



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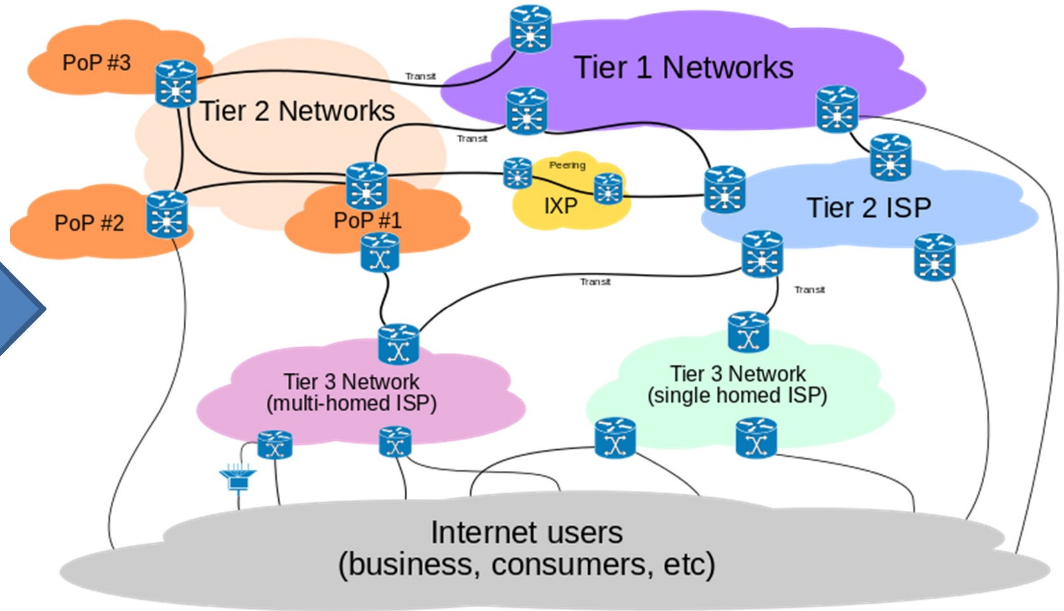
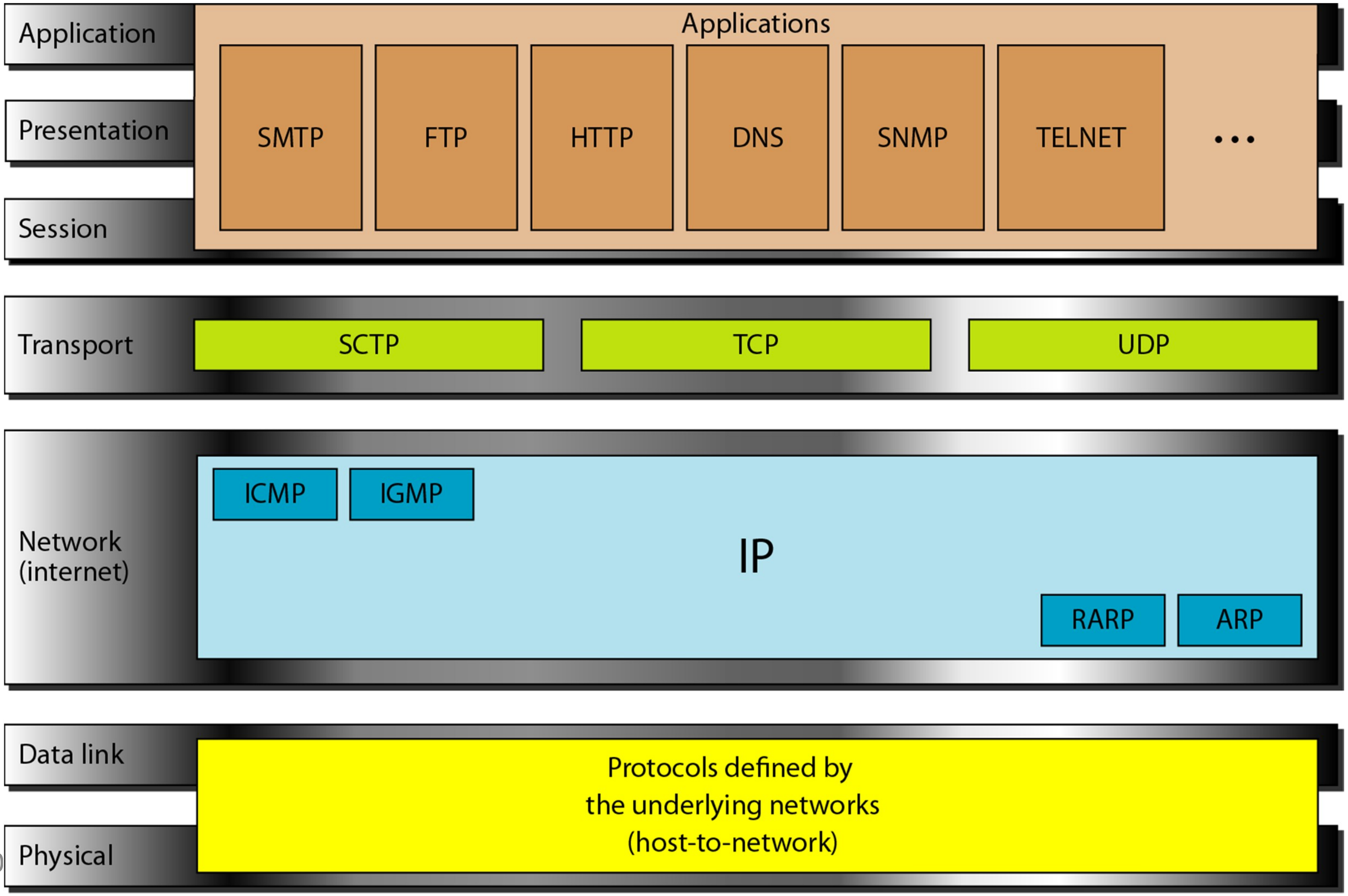
Purpose of this course



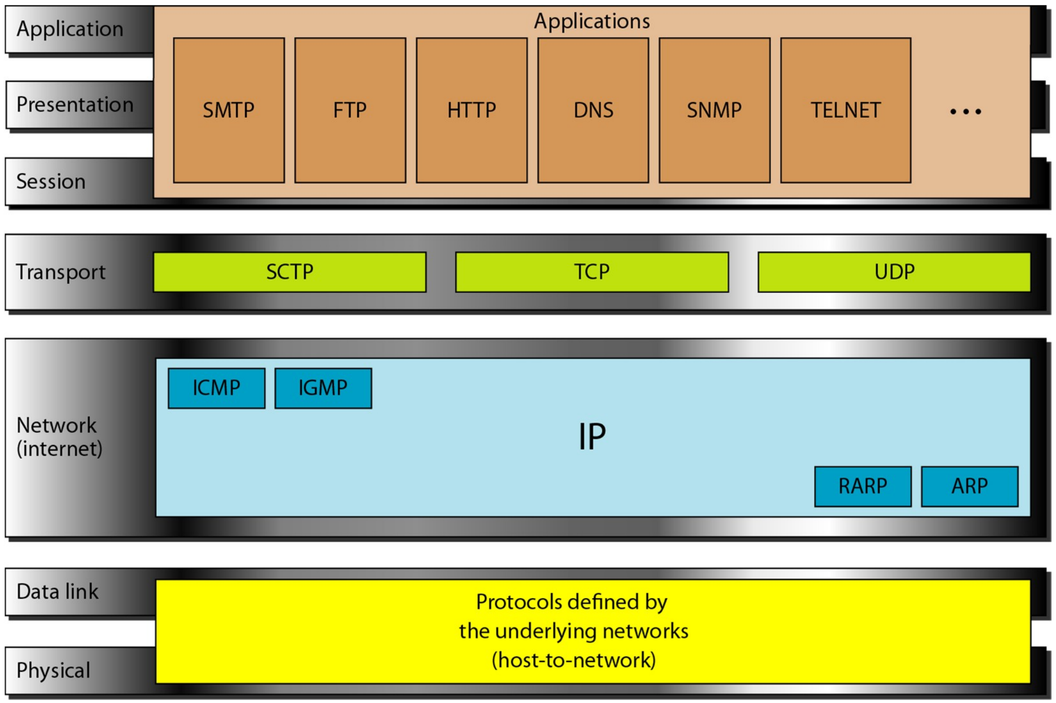
How do we get there?

- Internet Protocol Suite = TCP/IP model



A bottom-up approach

- **Principles of digital communications**
  - **From electrical signals to bits to packets**
- Using the physical infrastructure
  - Network access
- Finding your way
  - Addressing, routing
- Making use of it all
  - Applications



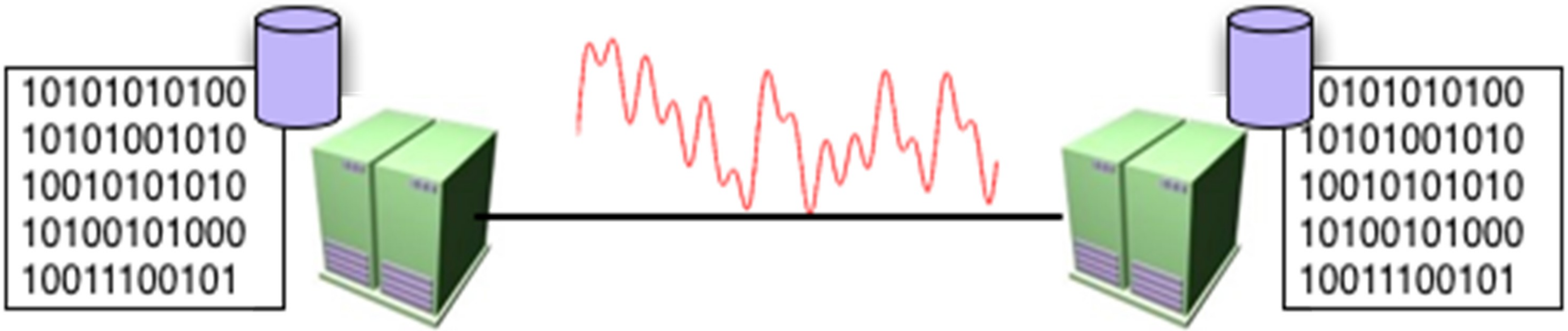
Internet: Physical Layer

- Data and Signals *[Forouzan ed.5 ch.3.1-4]*
  - Analog, digital
- Conversion to Digital *[Forouzan ed.5 ch.4.1-2]*
  - Coding
- Conversion to Analog *[Forouzan ed.5 ch.5.1]*
  - Modulation
- Multiplexing *[Forouzan ed.5 ch.6.1]*

**[Kihl & Andersson: 2.1-2.3, 3.1-2, 3.5-6]*

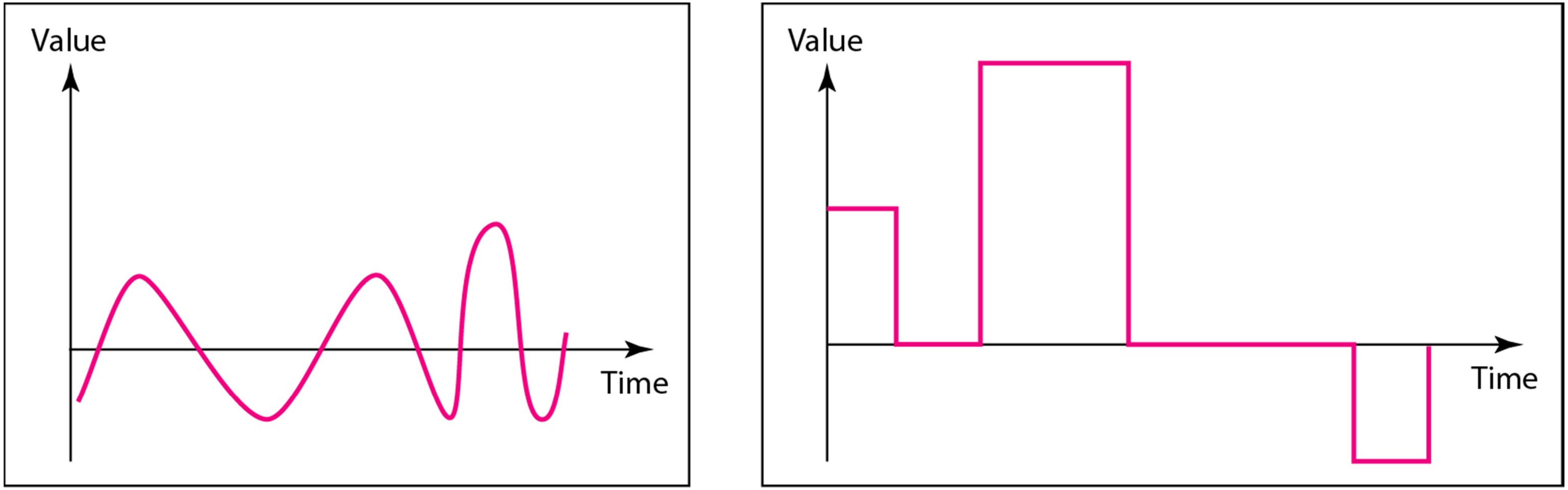
Data vs Signal

- Data: Static representation of information
  - For storage
- Signal: Dynamic representation of information
  - For transmission



Analog vs Digital

- Analog → continuous
- Digital → discrete



a. Analog signal   b. Digital signal

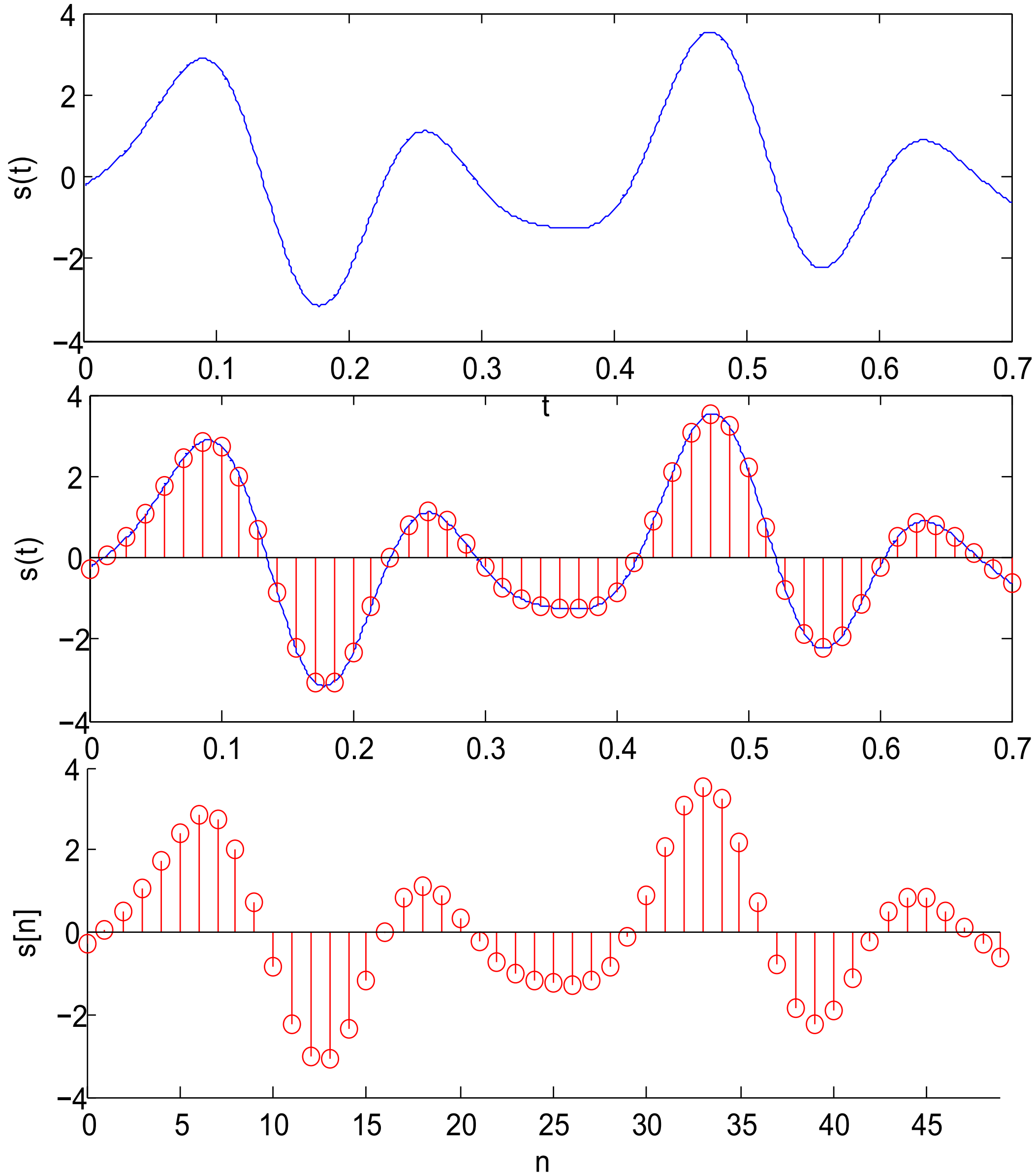
Digitalization of analog signals

- Performed in three steps:

1. Sampling
   – Discretization in time
2. Quantization
   – Discretization in amplitude
3. Encoding
   – Binary representation of amplitude levels

Sampling

- The process of discretizing the time of a continuous function.



Nyquist Sampling Theorem

- If *s(t)* is a band limited signal with highest frequency component F_{max}, then *s(t)* is uniquely determined by the samples $s_n = s(nT)$ if and only if

$$F_s = \frac{1}{T} \geq 2F_{\max}$$

- The signal can be reconstructed with

$$s(t) = \sum_n s_n \operatorname{sinc}\left(\frac{t - nT}{T}\right)$$

- F_{max} is the Nyquist frequency and F_s the Nyquist rate

Data Rate vs Signal Rate

Data Rate

- Number of bits transmitted per second
- Unit b/s or bps
- Often denoted R_b

Signal Rate

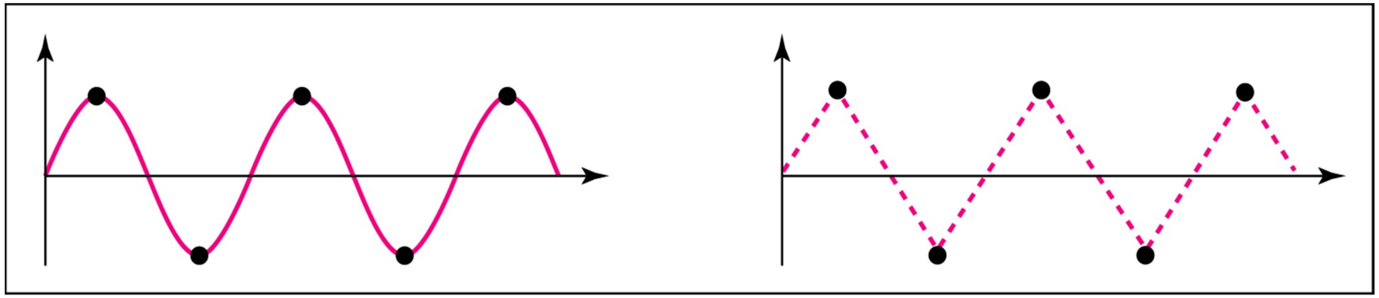
- Number of signal alternatives transmitted per second
- Unit Hz (sometimes baud)
- Often denoted T_s
- If there are k bits/signal
  – $R_b = kT_s$

Example: Bit rate for telephony links

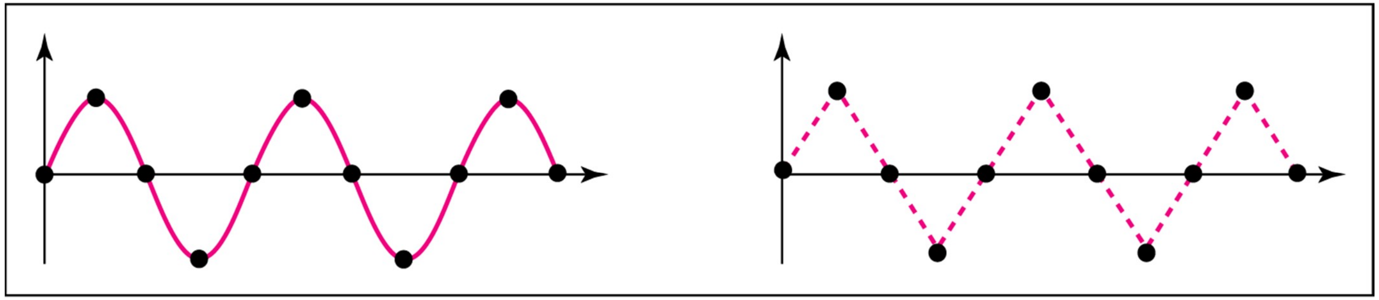
- Analog signal in frequencies from 0 to 4kHz
- Nyquist theorem → sampling frequency
  - 2 x 4000 Hz = 8000 Hz (samples per second)
- 8-bit encoding
  - 8000 Hz x 8 bits = 64000 bits/s

The bit rate is 64 kbps.

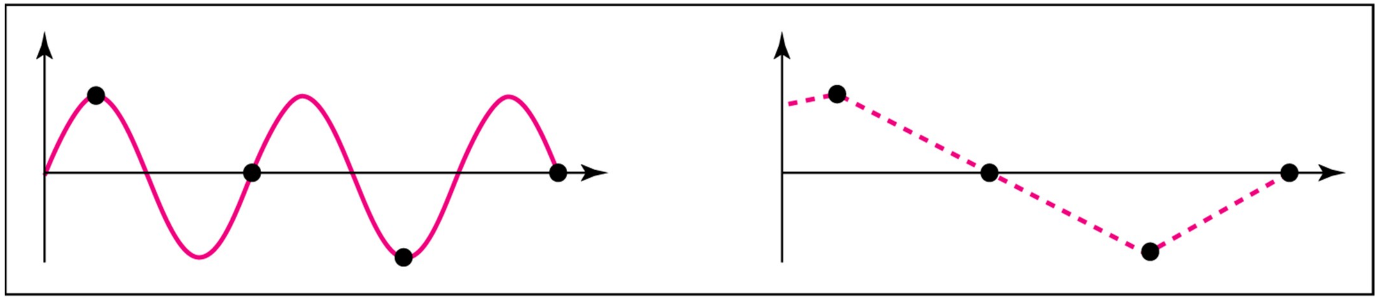
How sampling rate affects the result



a. Nyquist rate sampling: $f_s = 2f$



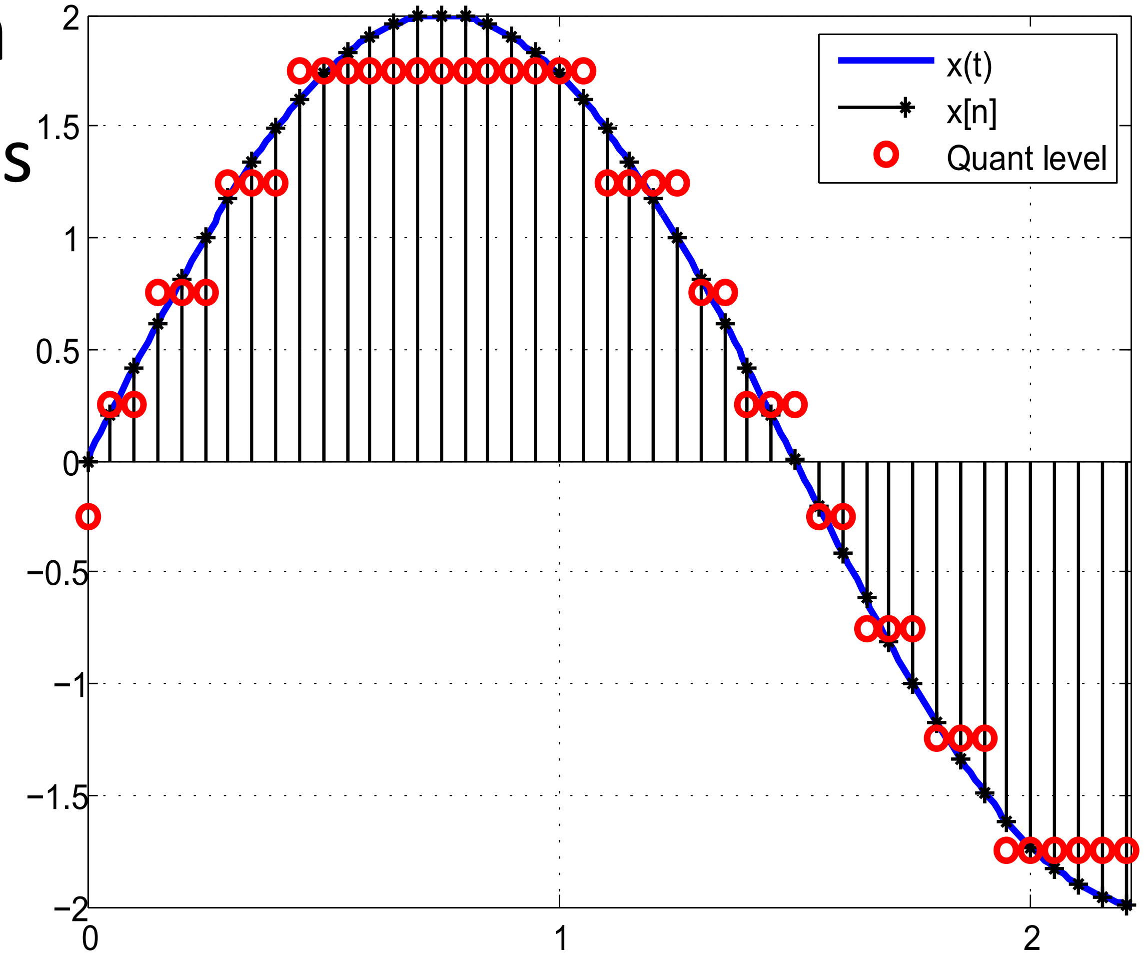
b. Oversampling: $f_s = 4f$



c. Undersampling: $f_s = f$

Quantization

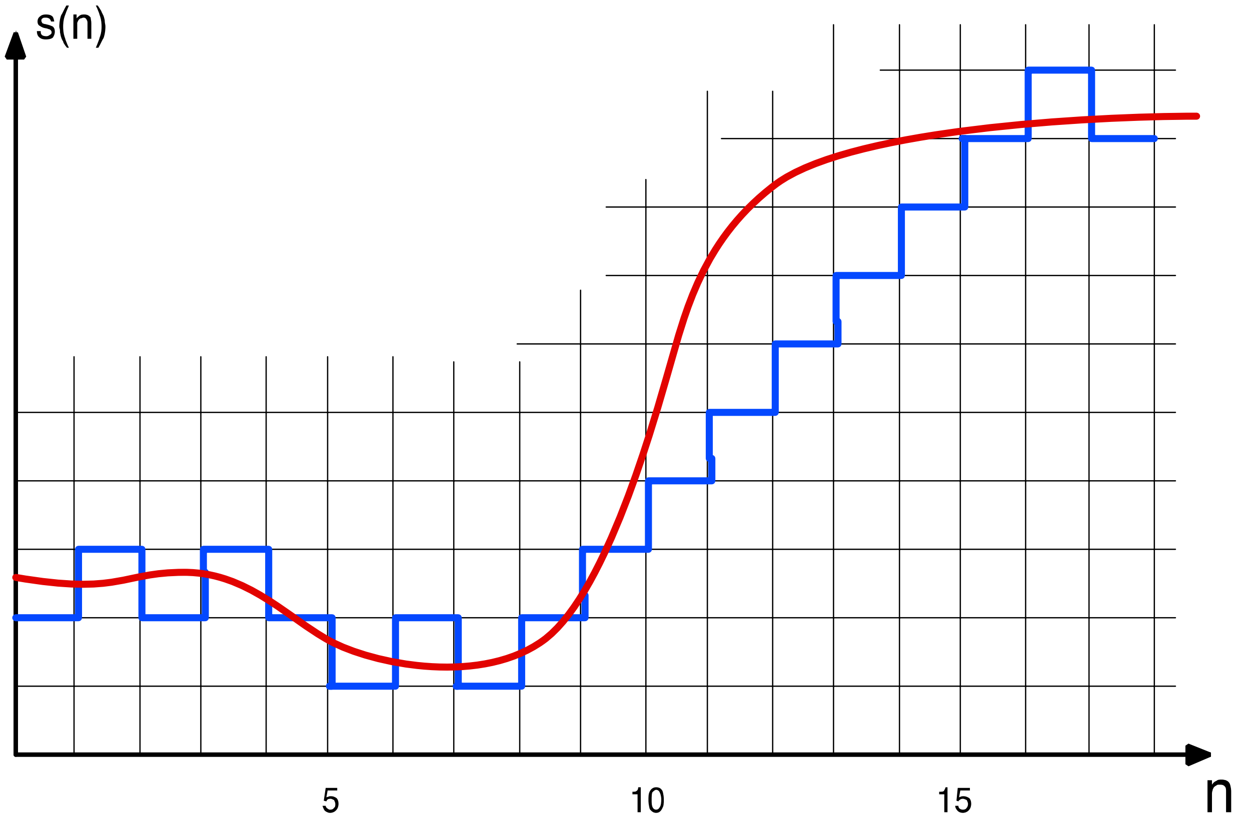
- Linear Quantization
  - 2^N equidistant levels
  - Represent sample with N bits



- Telephony
  - N=8 → 256 levels
- CD
  - N=16 → 65 536 levels

Quantization

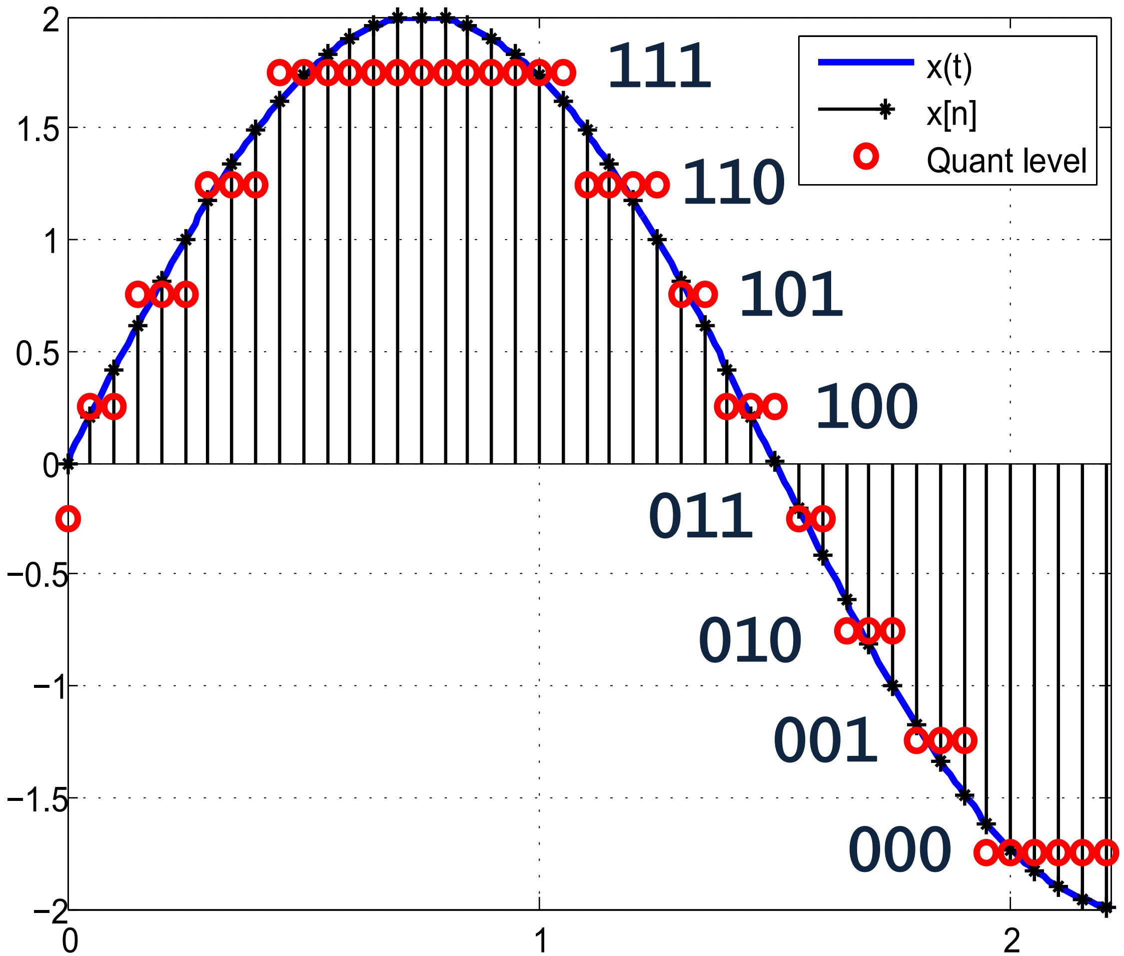
- Delta modulation
  - Represent change in amplitude with 1 bit
  - 1: +1
  - 0: −1



1 0 1 0 0 1 0 1 1 1 1 1 1 1 1 1 0 1

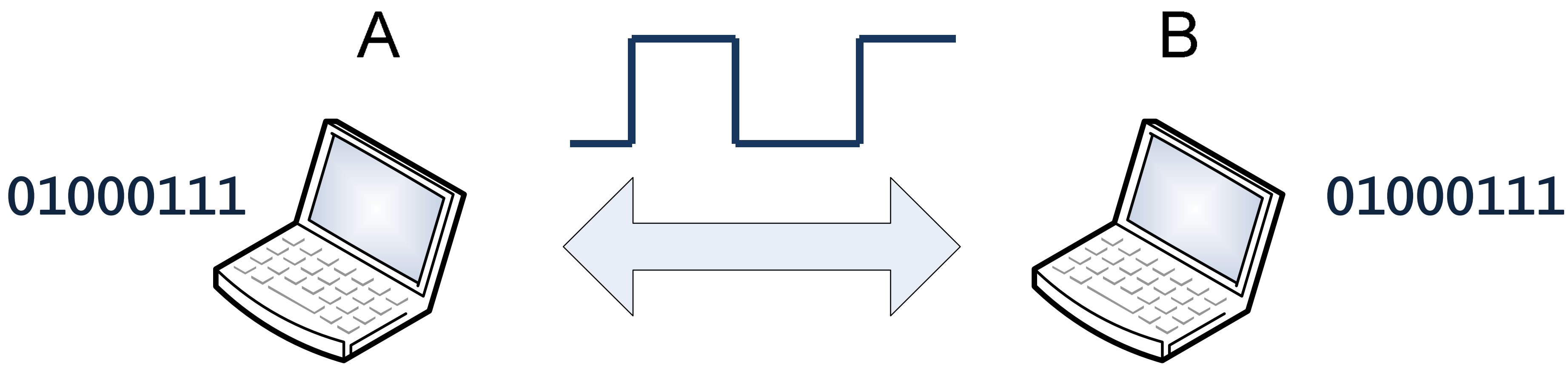
Encoding

- Representation of quantized samples in bits



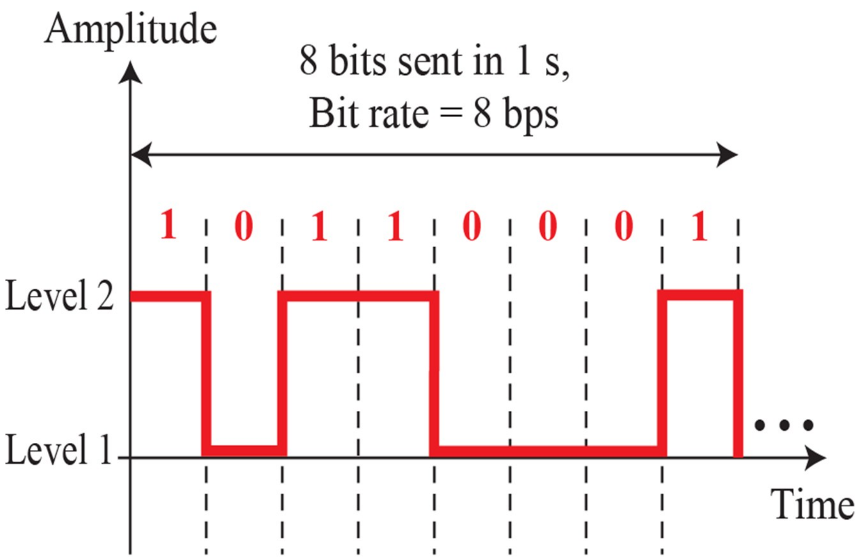
From bits to digital signals

- Transmission medium
  - Twisted pair
  - Coaxiel
  - Optical fibre
  - Air

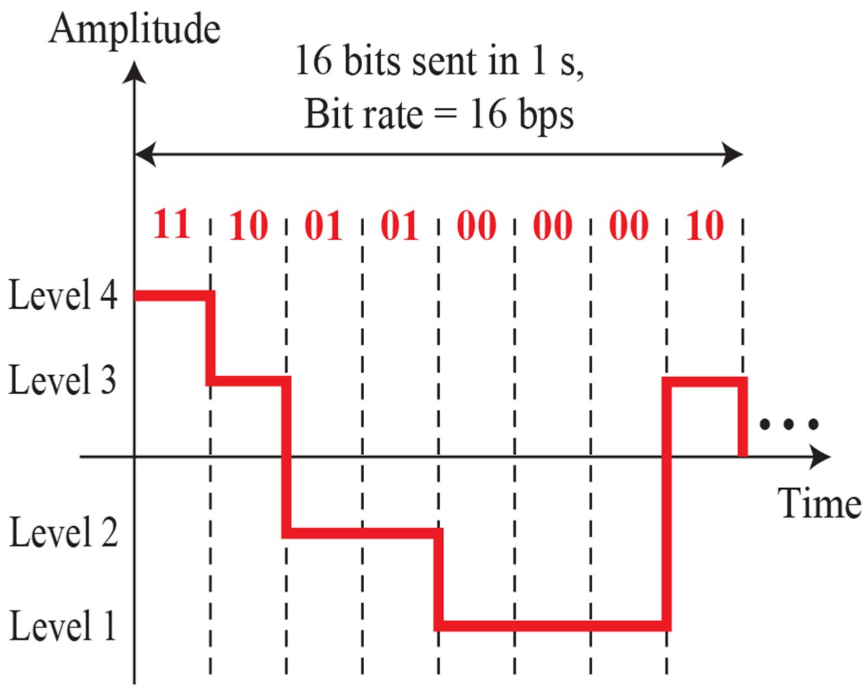


Digital signal transmission

- Signals coded by changes in voltage amplitude



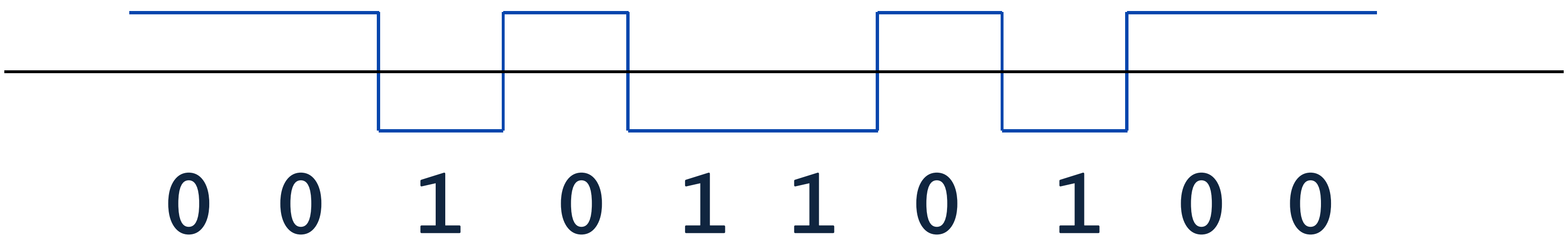
a. A digital signal with two levels



b. A digital signal with four levels

Non-Return to Zero (NRZ-L)

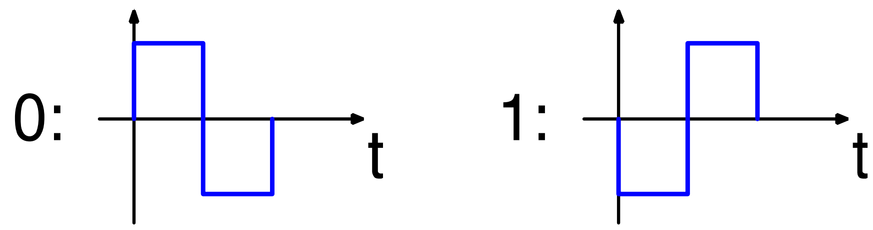
- 0 = high voltage amplitude
- 1 = low voltage amplitude

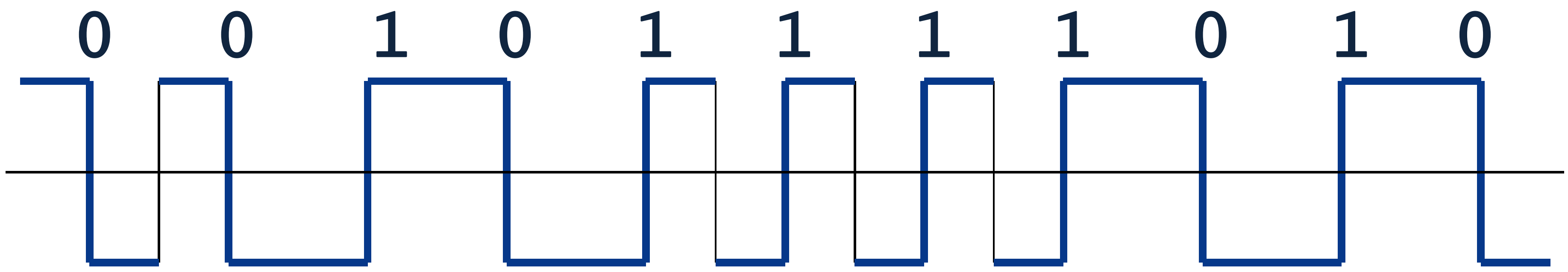


- Synchronisation problem

Manchester Coding

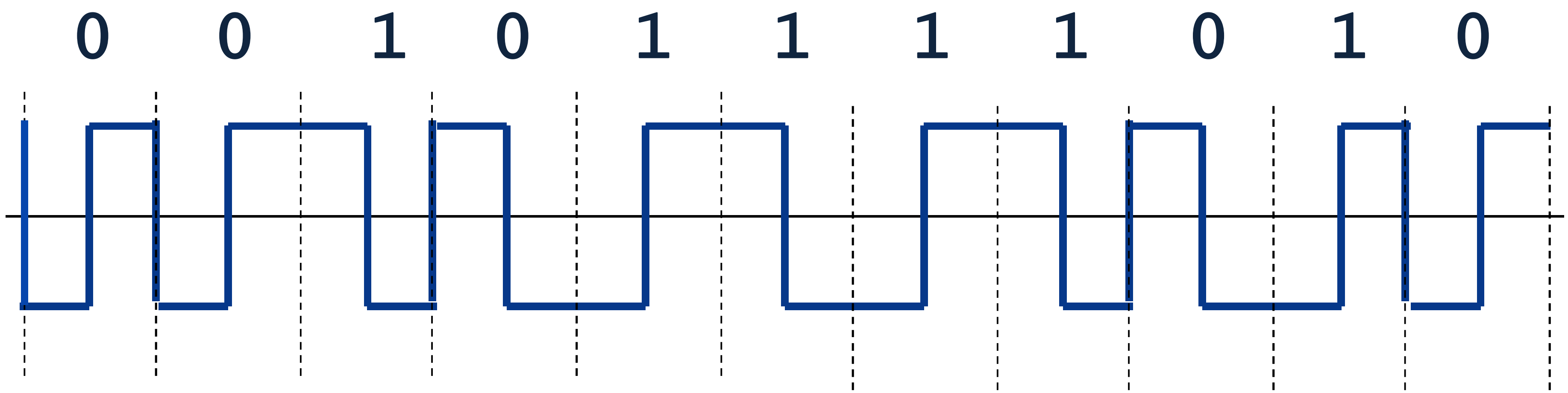
- Combines NRZ with a clock pulse





Differential Manchester

- 0 = Inversion at the beginning of the bit
- 1 = No inversion at the beginning of the bit

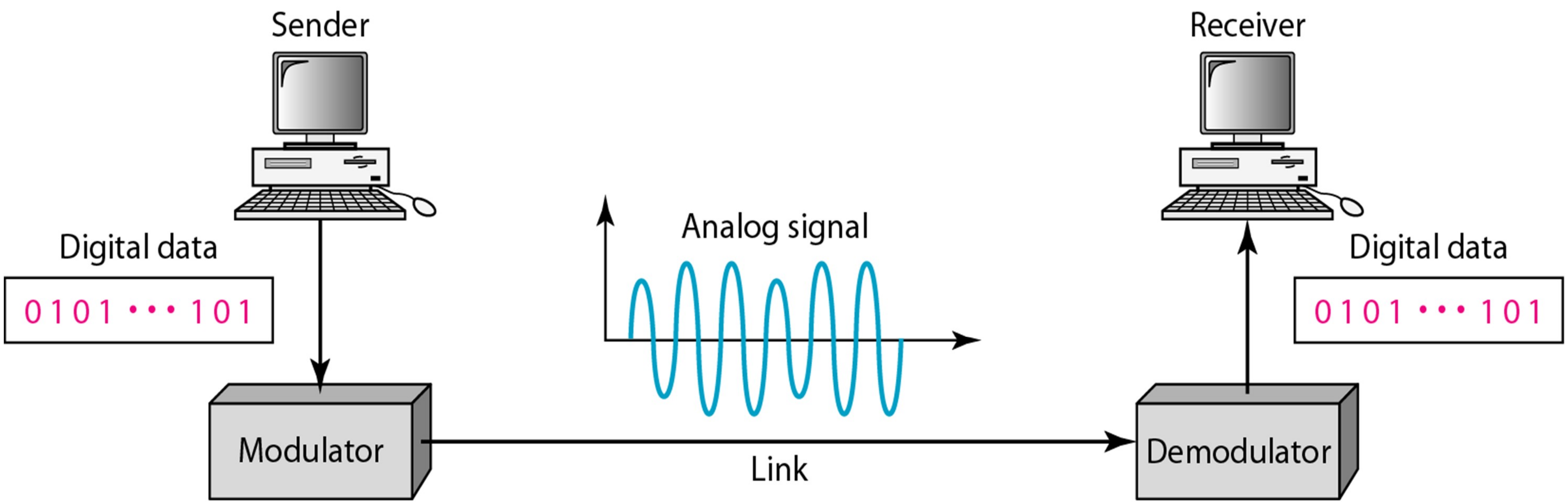


See you in 15' :)

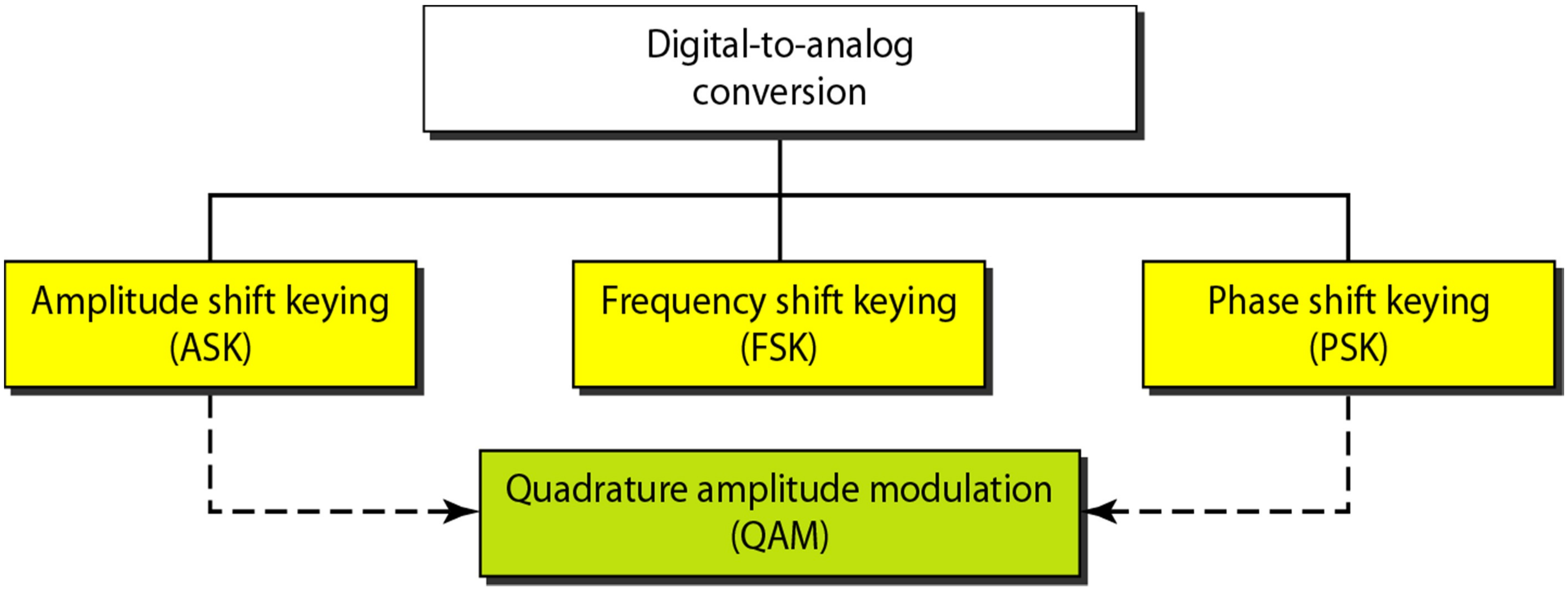
- After the break
  - Analog transmission
  - Transmission impairment
  - Multiplexing

Analog transmission

- Used in wireless communications
- Uses a technique called ”modulation”
- Digital data represented by sinus waves

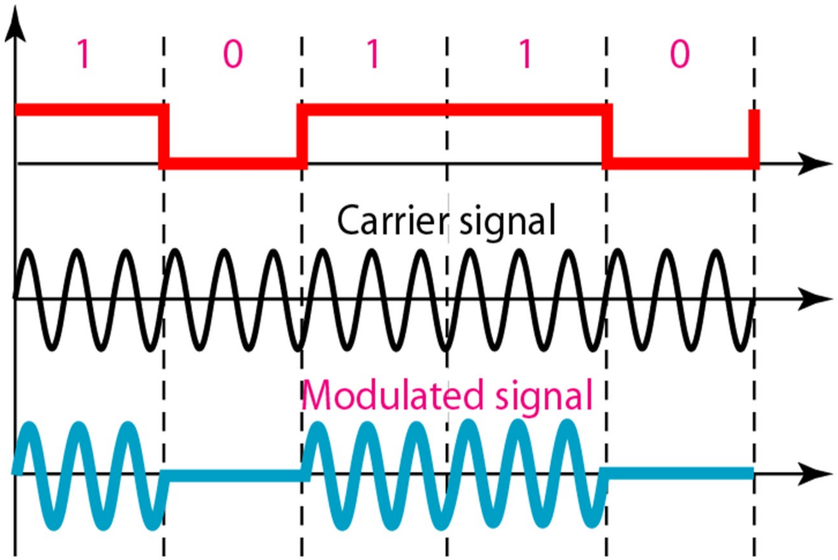


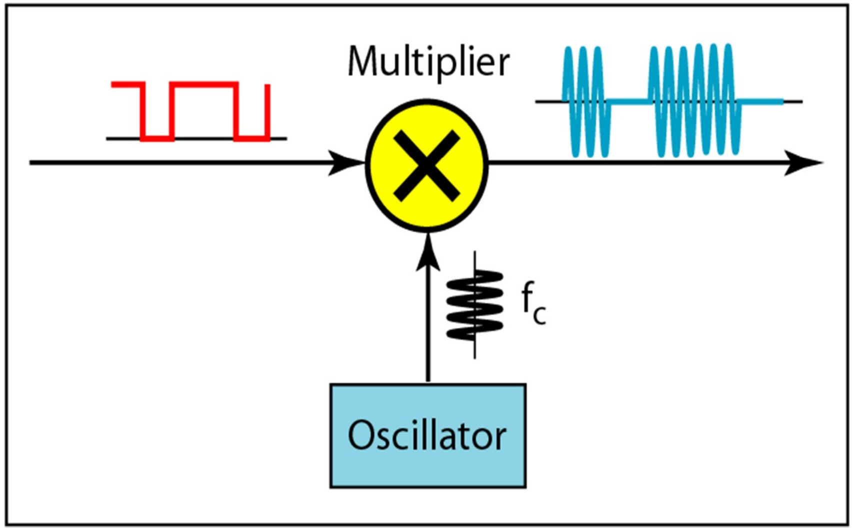
Types of modulation schemes



Amplitude Shift Keying (ASK)

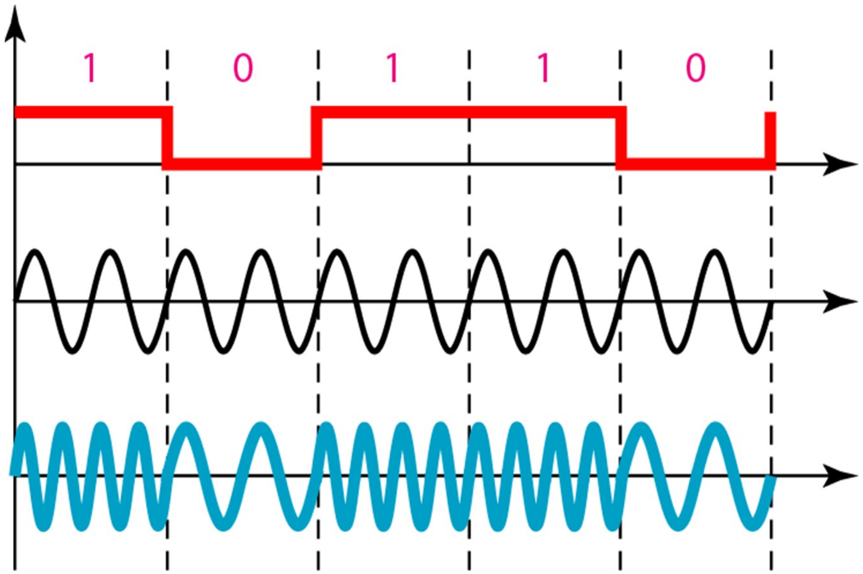
- Varies amplitude of carrier signal
- A.k.a. Pulse Amplitude Modulation (PAM)

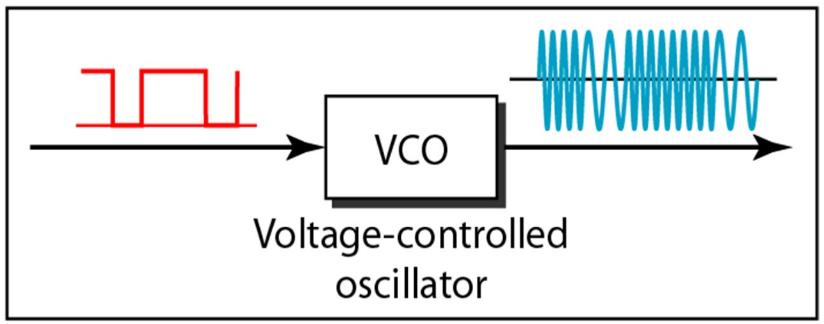




Frequency Shift Keying (FSK)

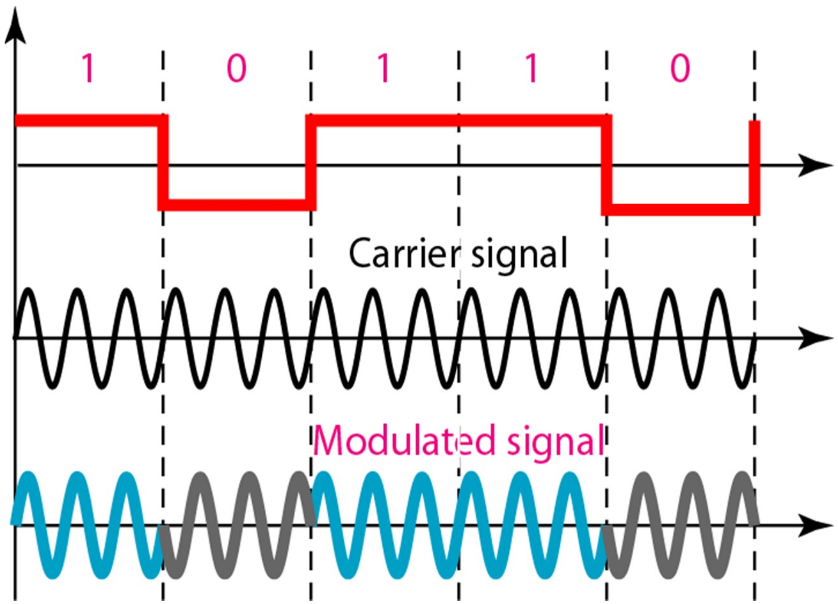
- Varies frequency of carrier signal

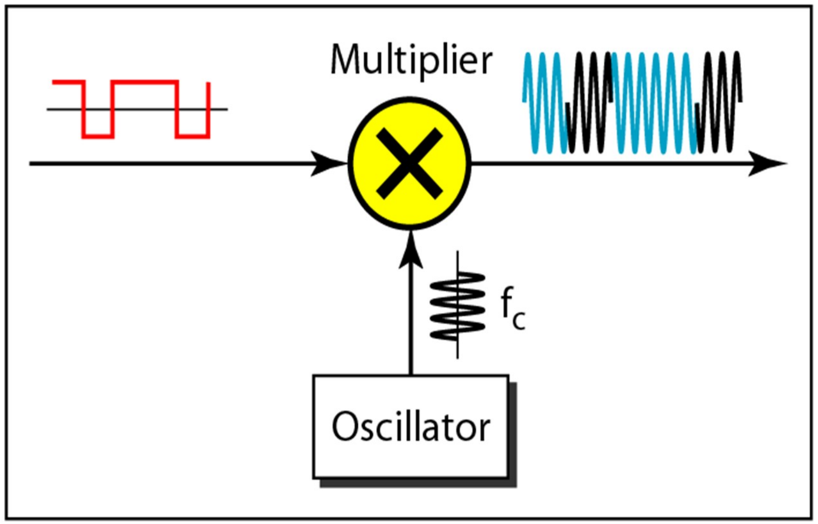




Phase Shift Keying (PSK)

- Varies phase of carrier signal





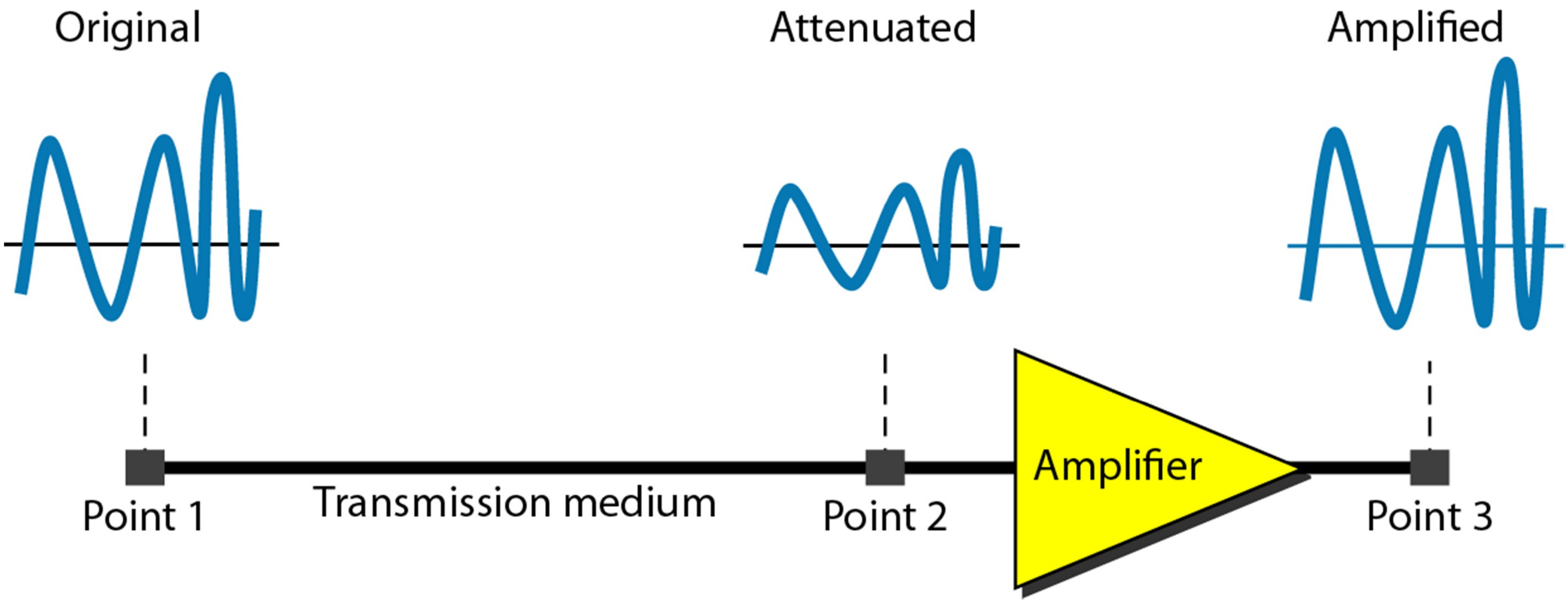
Transmission impairment

- When a signal travels on a link, it deteriorates due to transmission impairment.
  - Attenuation
  - Distortion
  - Noise

$$\textbf{Signal-to-noise ratio (SNR)} = \frac{\textbf{Average signal power}}{\textbf{Average noise power}}$$

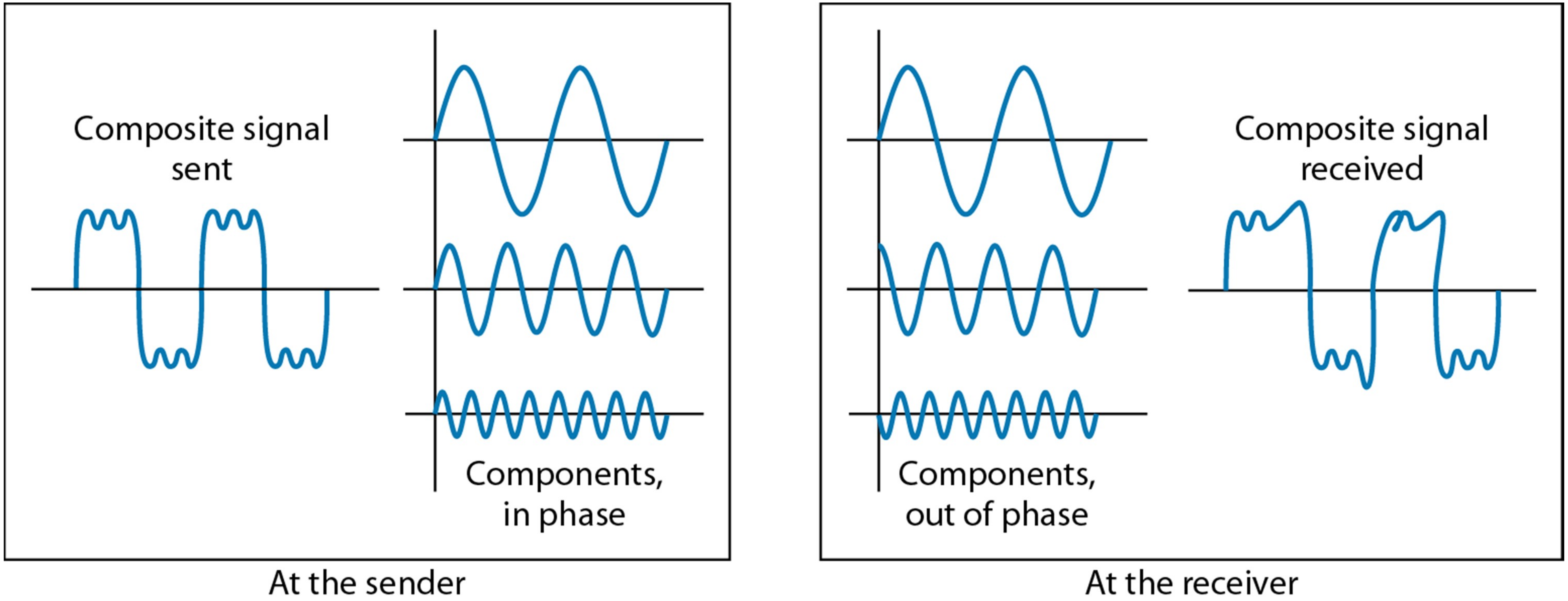
Attenuation

- Loss of energy



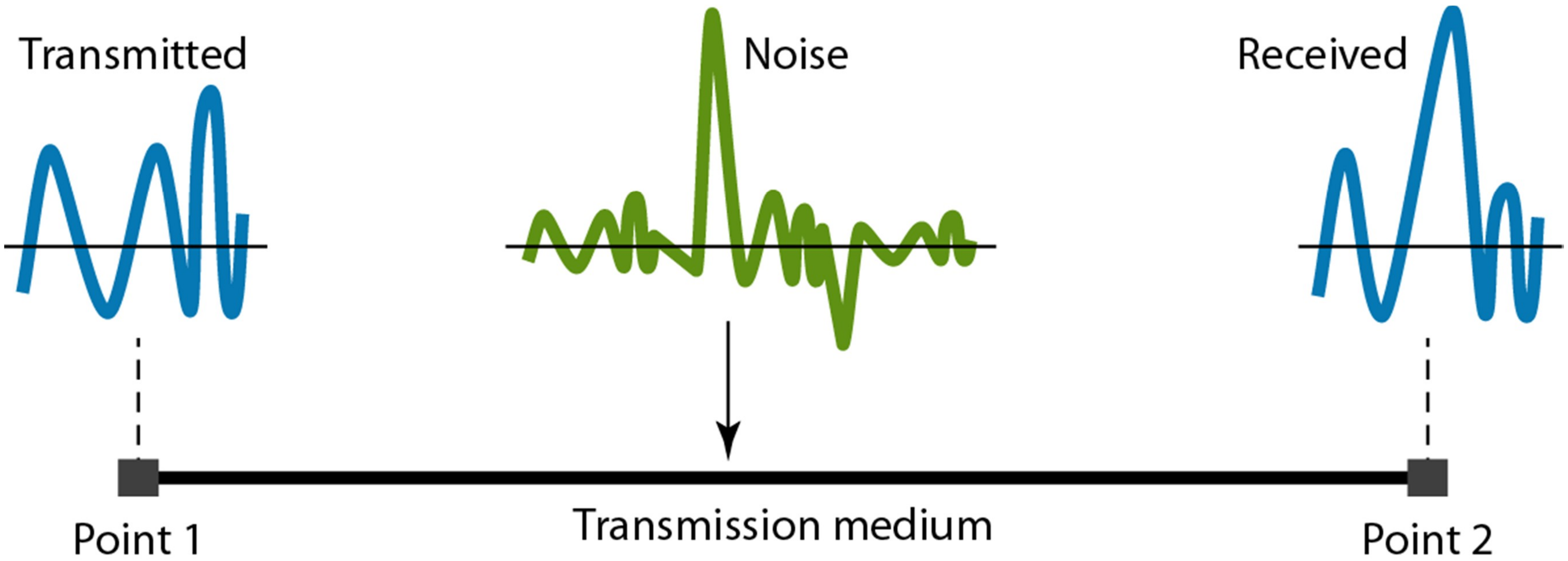
Distortion

- Change in signal shape



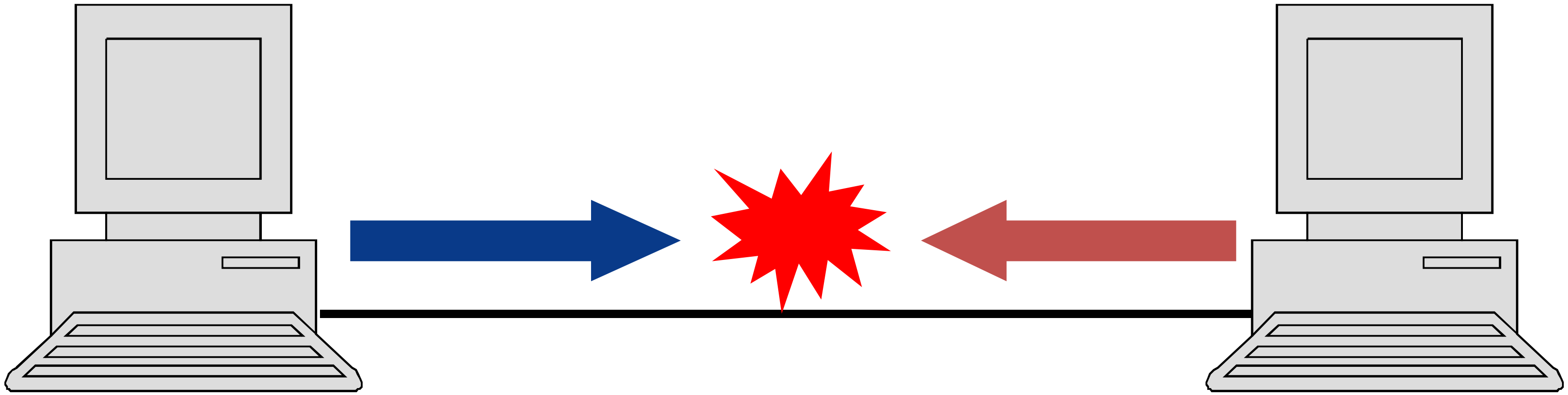
Noise

- Corruption due to e.g. thermal noise or crosstalk

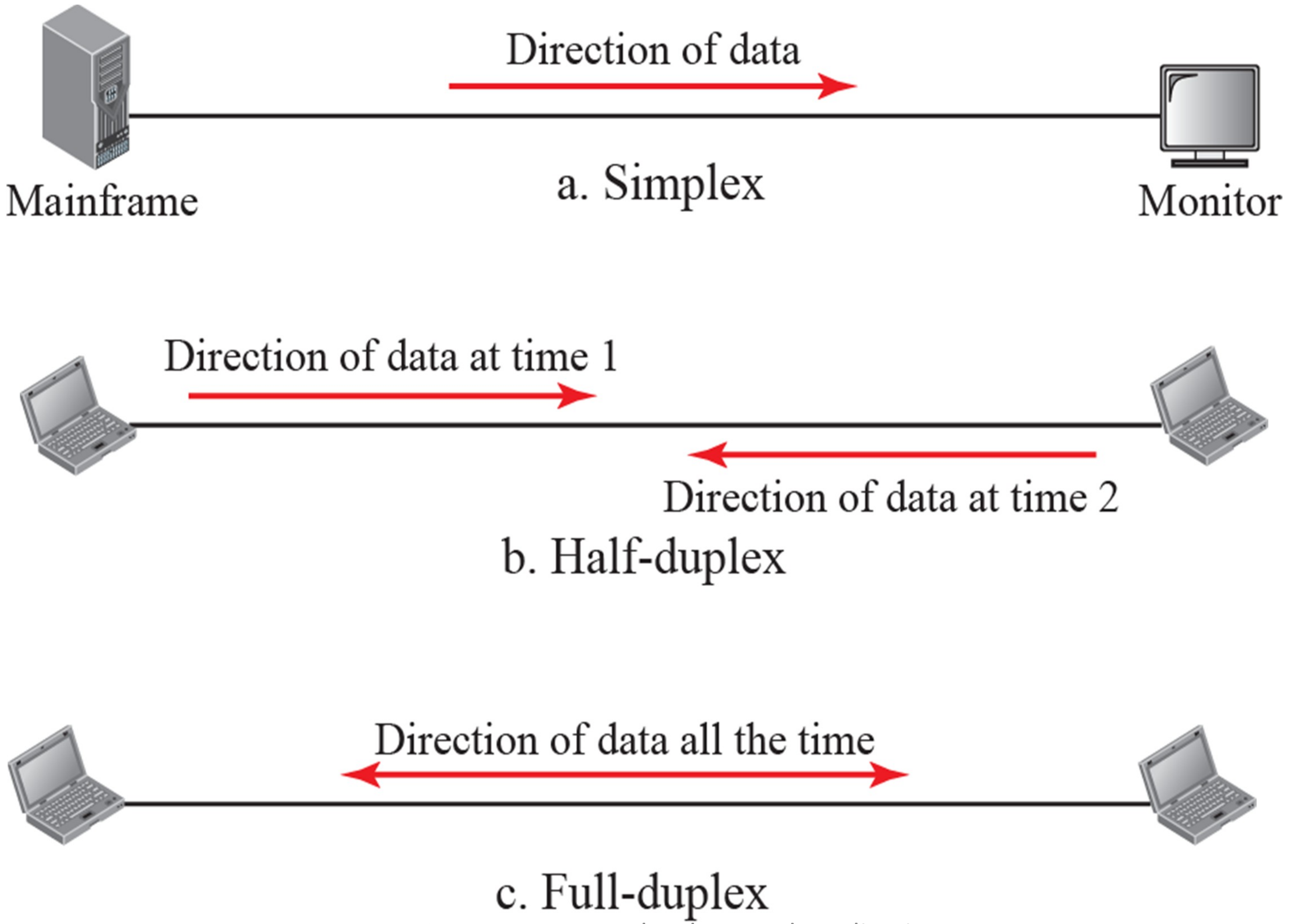


Multiplexing

- Why?
  - Two computers transmitting data on a link cannot do this simultaneously on the same frequencies with the same coding scheme.

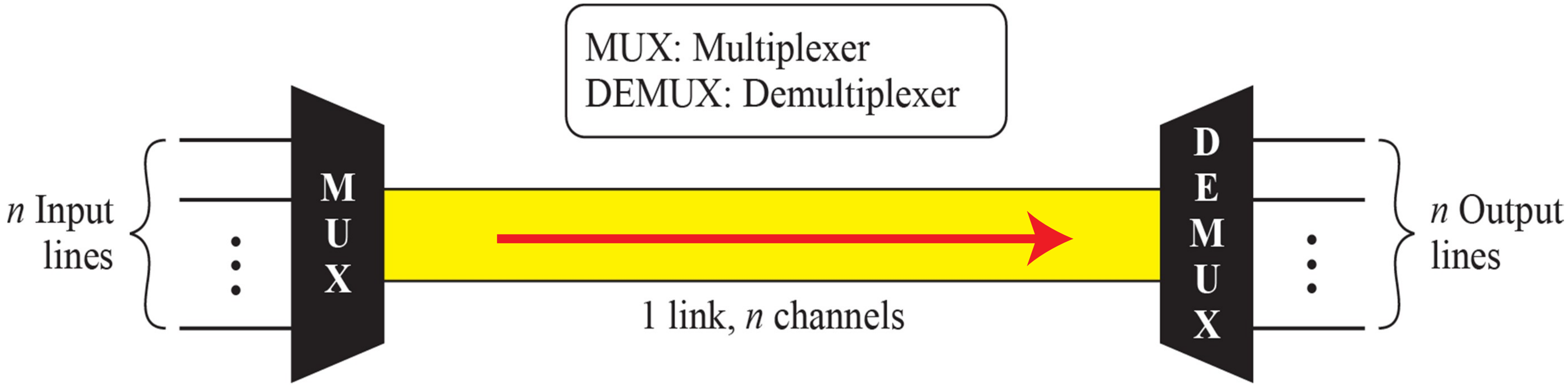


Data flow concepts



Multiplexing of links

- Physical links need to be shared.
- They are divided into several channels.

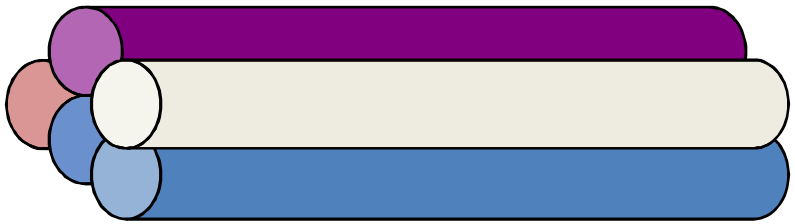


Multiplexing techniques

1. Space-Division multiplexing (SDM)
2. Frequency-Division Multiplexing (FDM)
3. Wavelength-Division Multiplexing (WDM)
4. Time-Division Multiplexing (TDM)
5. Code-Division Multiple Access (CDMA)

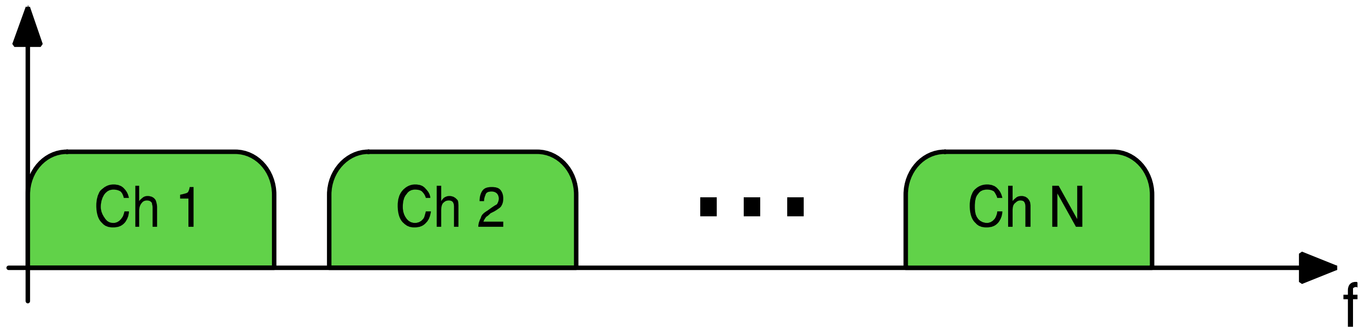
Space-Division Multiplexing (SDM)

- Used in fibre-optic cables
- Each channel uses one optical fibre.

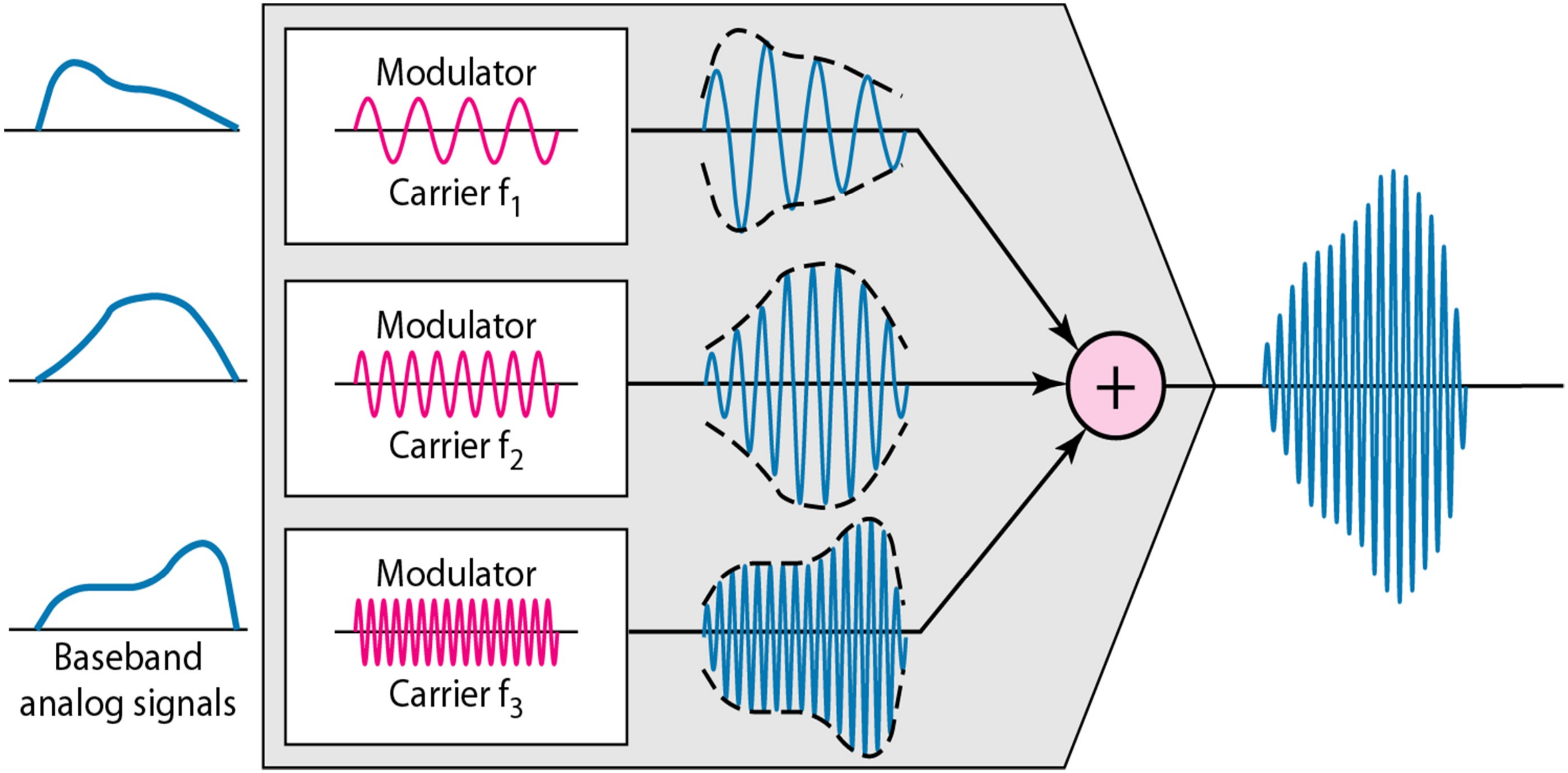


Frequency-Division Multiplexing (FDM)

- Analog multiplexing technique
- Physical link divided into frequency bands
- Each channel uses a unique carrier frequency.

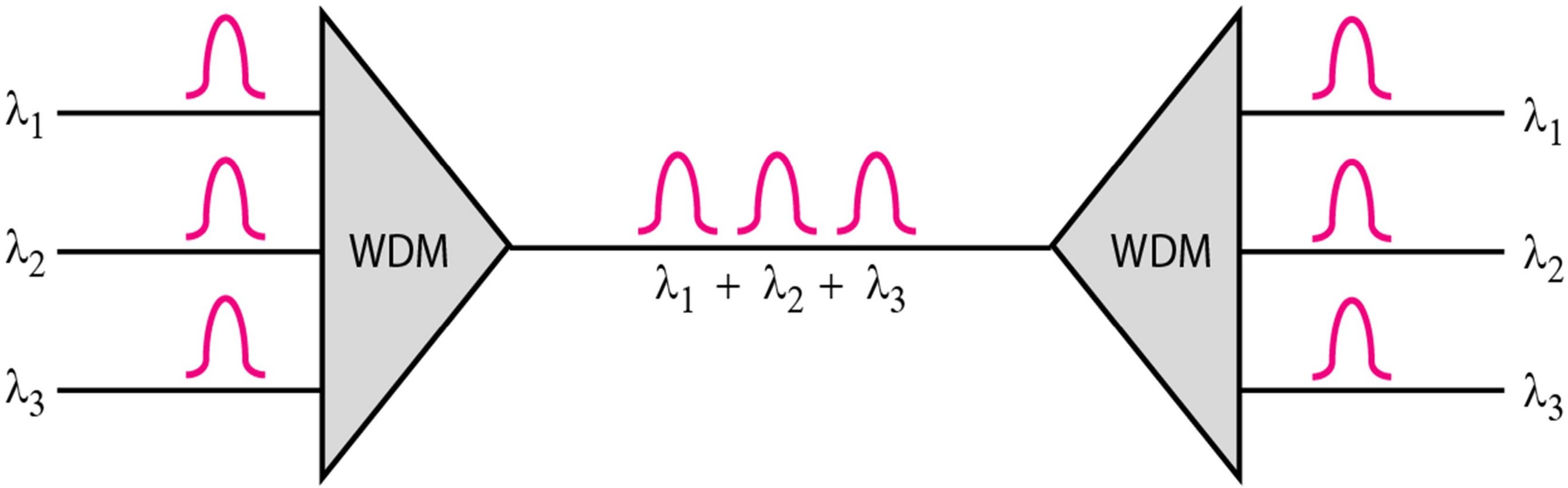


FDM process


Modulator
Carrier f_1
Modulator
Carrier f_2
Modulator
Carrier f_3
Baseband
analog signals
+

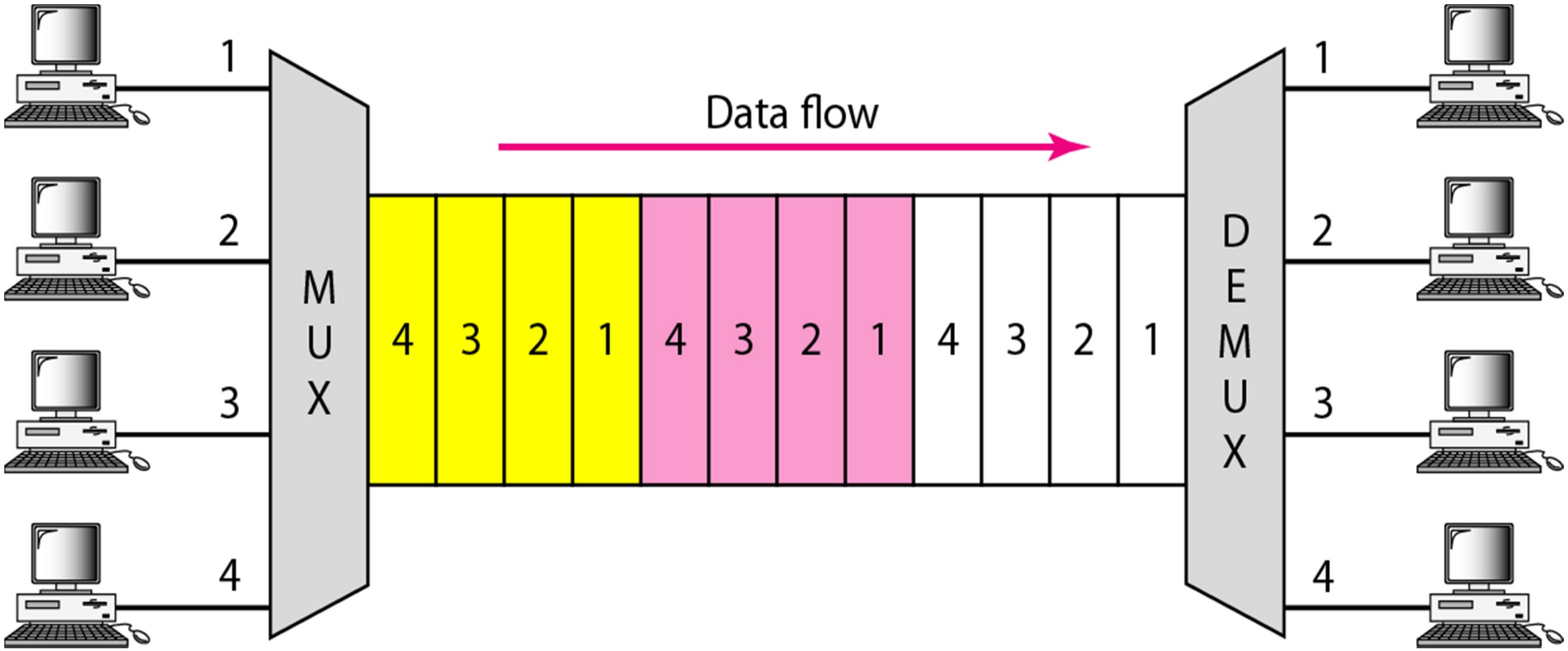
Wavelength-Division Multiplexing (WDM)

- Analog multiplexing technique
- Combines optical signals

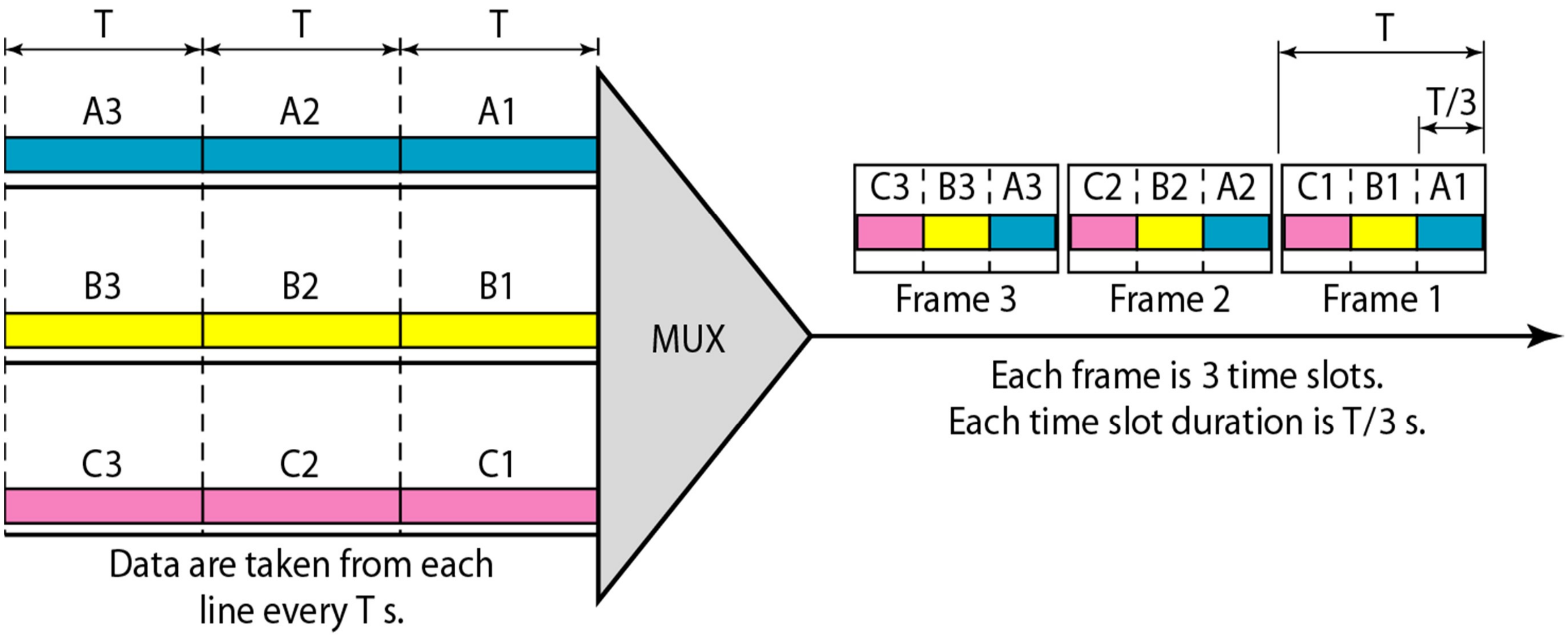


Time-Division Multiplexing (TDM)

- Each channel occupies a time slot on the link.

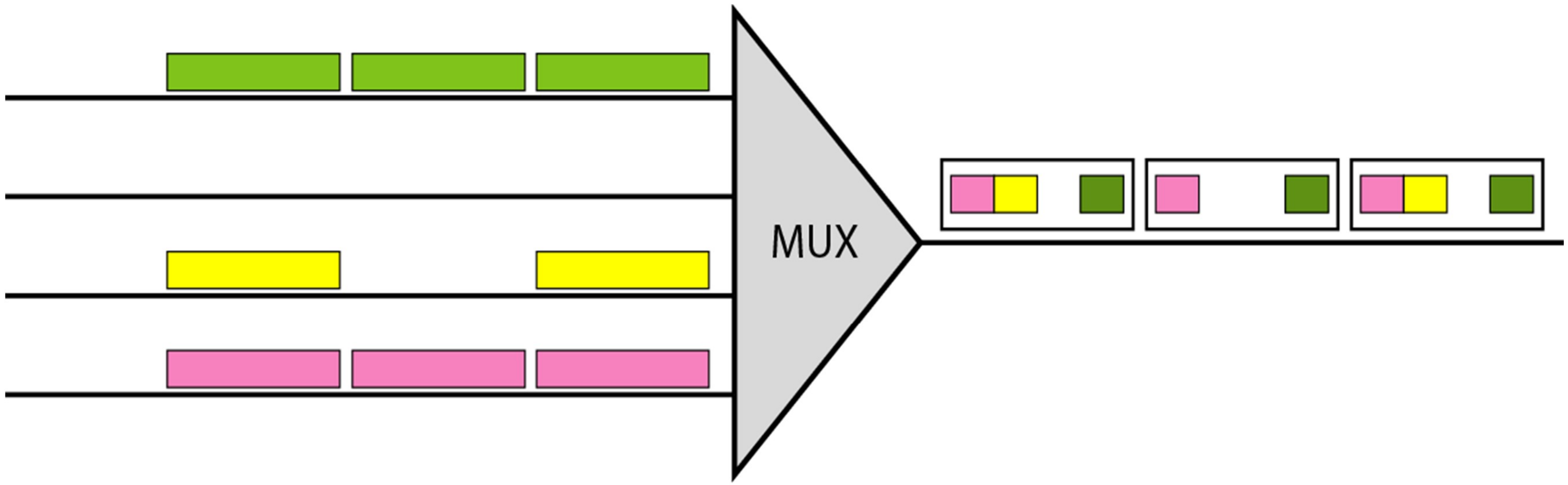


Synchronous TDM



Synchronous TDM

- If a channel has nothing to send, its time slots will be empty!

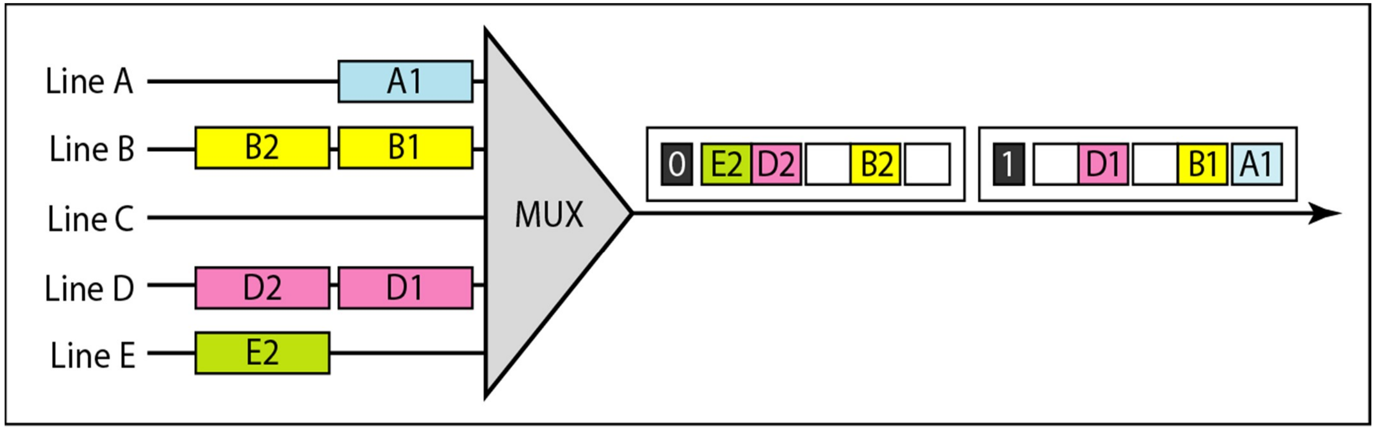


- Solution: Dynamic slot allocation

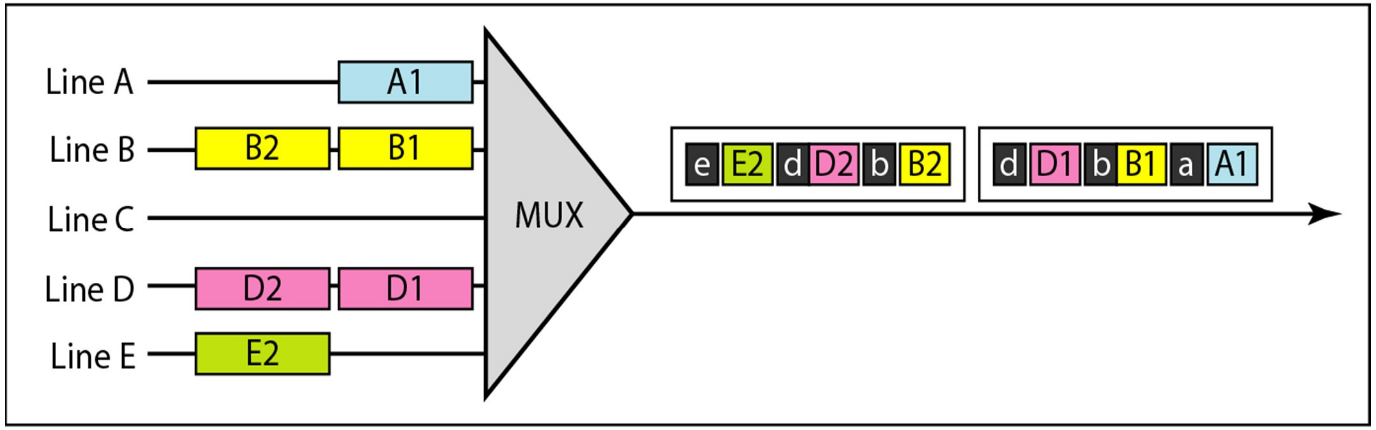
Statistical Time-Division Multiplexing

- Dynamic slot allocation
- No time slots reserved for channels
- Destination address added to each slot
- Better performance when not all channels transmit data all the time

TDM comparison



a. Synchronous TDM



b. Statistical TDM

Summary: Physical Layer

- Data, signal → analog, digital
- Digitalisation
  - Sampling, quantisation, encoding
- Digital transmission → coding
- Analog transmission → modulation
  - Attenuation, distortion, noise
- Multiplexing
  - Space, frequency, wavelength, time