Chapter 1: Conceptual Basis

Section 4

V 2.5 19th /Mar/2020

Based on textbook *Conceptual Computer Networks* by:

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Real-world communications

Signals and transmission media

Goals

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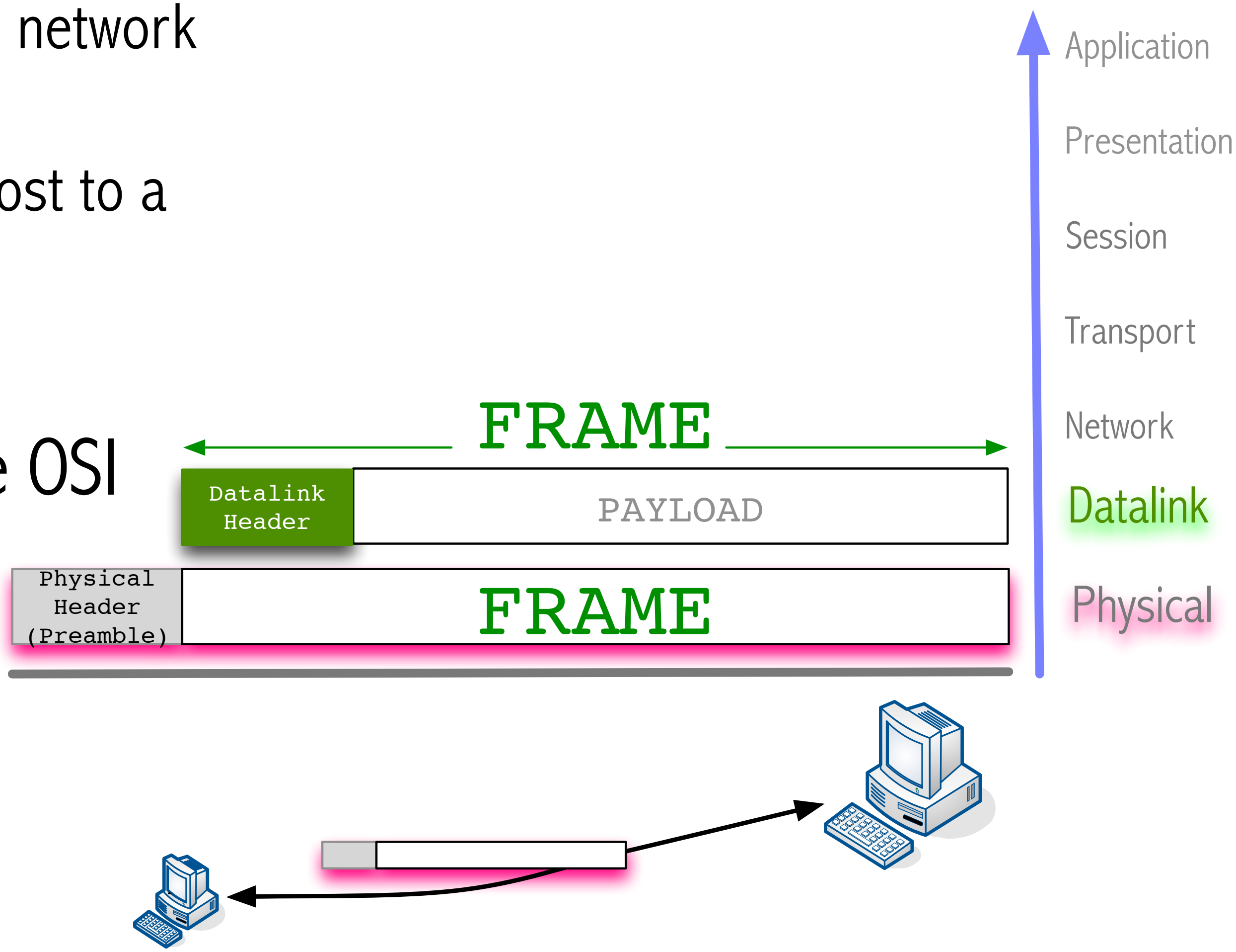
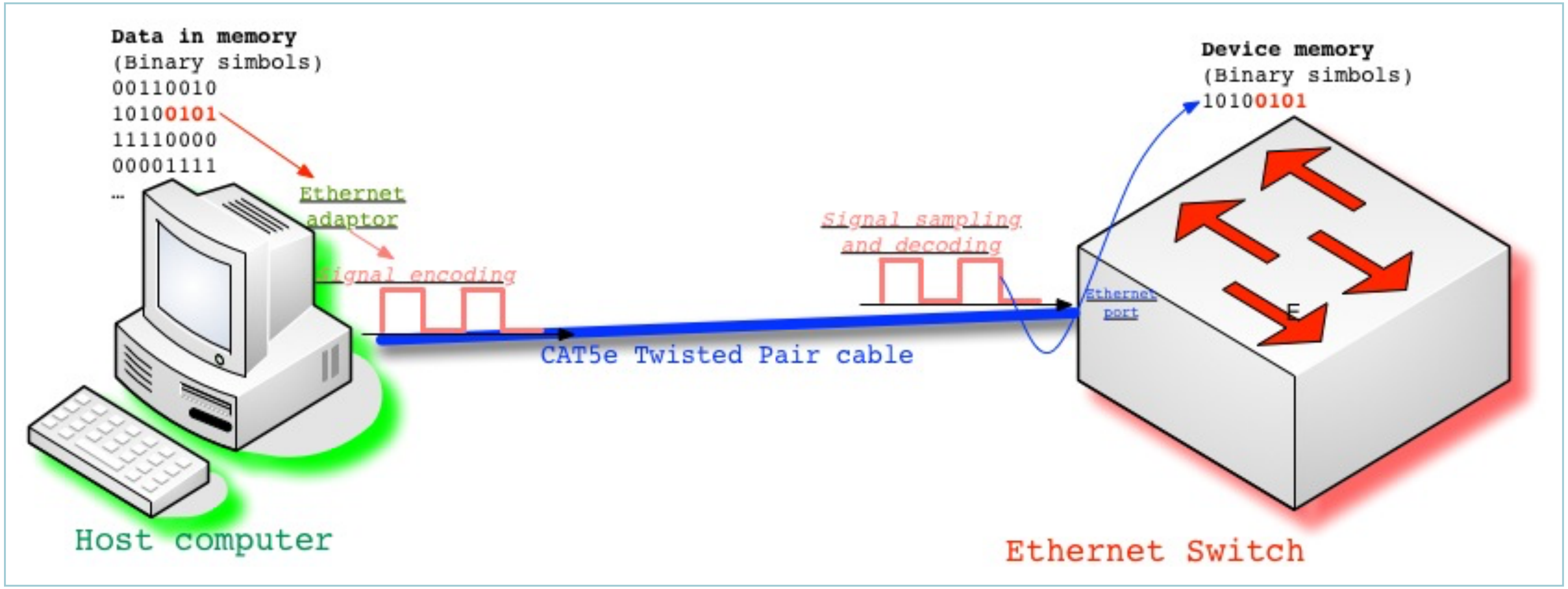
- Addressed problems:
  - How to connect two network nodes together?
  - How to connect a host to a network?

- The focus is on the OSI layers 1 and 2



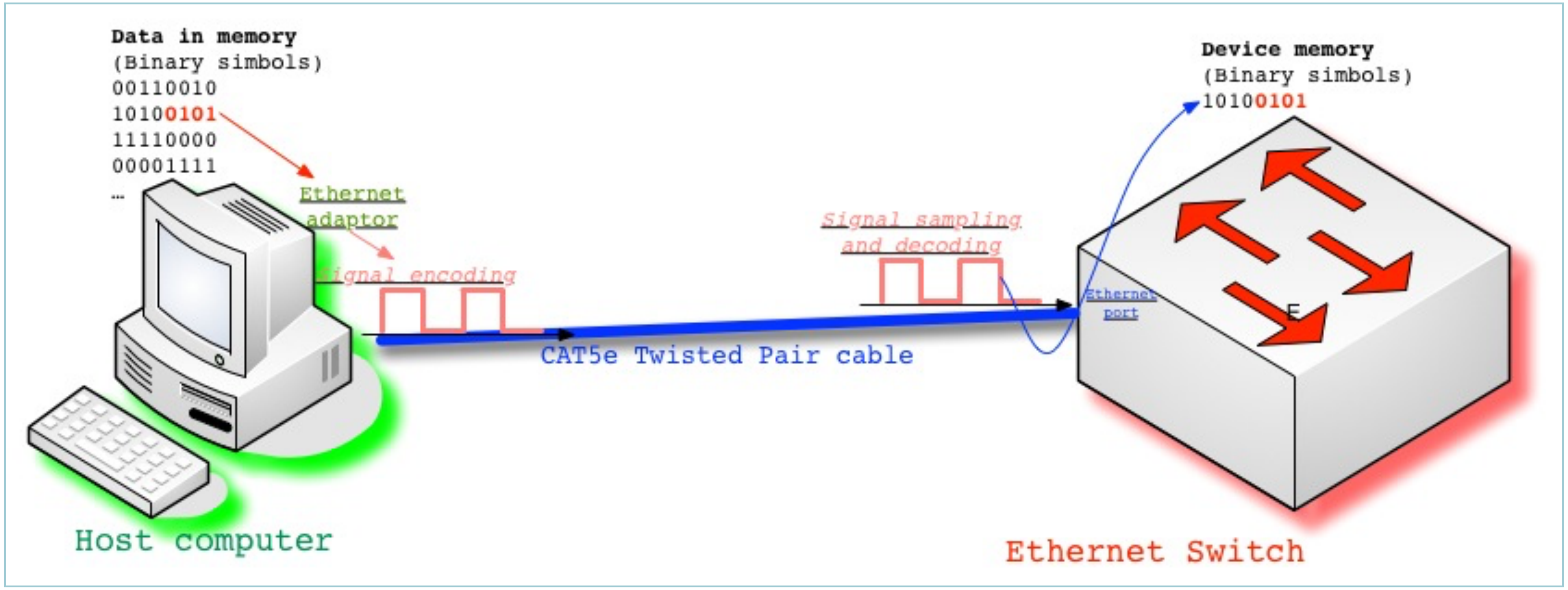
Bit transmission

- Bit transmission entails turning each bit into a signal
  - Electrical: Ethernet over Twisted Pair cables
  - Optical: Gigabit Ethernet over Optical Fibers
  - Electromagnetic waves: Wi-Fi



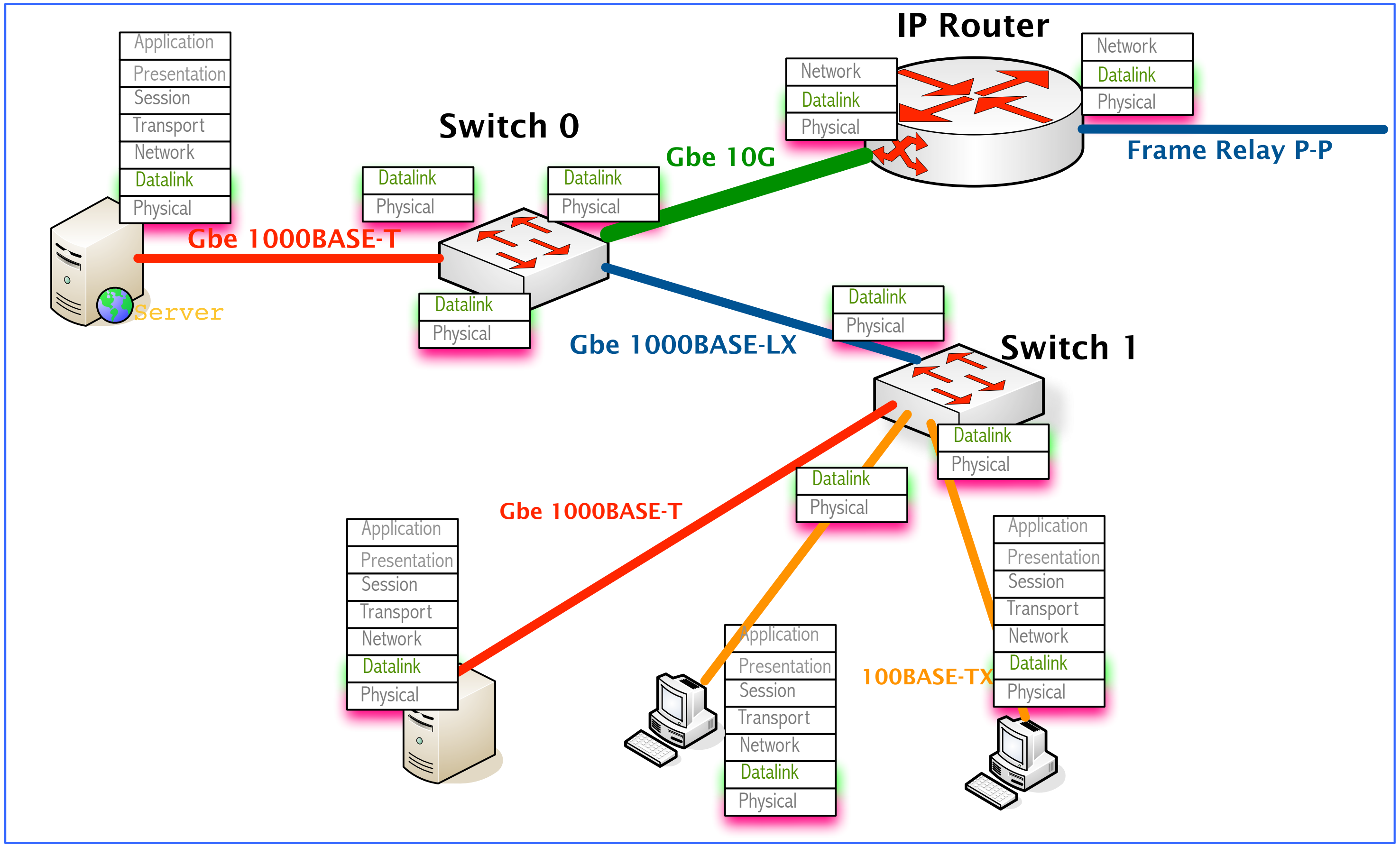
Transmission link

- A **link** is made up of:
  - A transmission medium (CAT5e cable in this case)
  - Signal encoding technique
  - A Datalink protocol



Datalink protocols in an Internetwork

- Each direct connection between any two network nodes (Hosts, switches, routers) has a link in between



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Encoding

Turning bits into signals for appropriate transmission

Line encoding: concept

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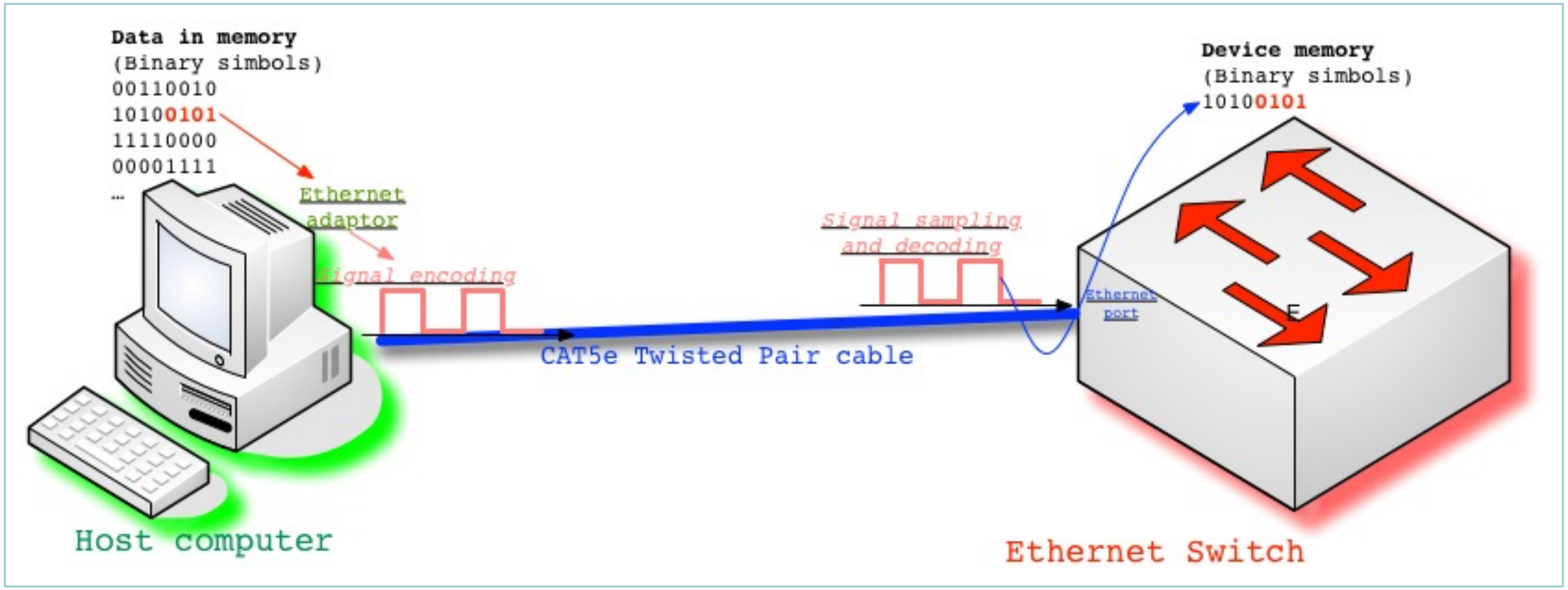
- The data to be transmitted are stored in the host's memory
- Data bits must be translated into signals appropriate for the transmission media
  - There exist multiple ways of encoding a 0 bit and a 1 bit:
    - Line encoding techniques
  - An essential group signal waveforms is PCM:
    - Pulse Code Modulation



Line encoding at the Physical Layer (Ethernet)

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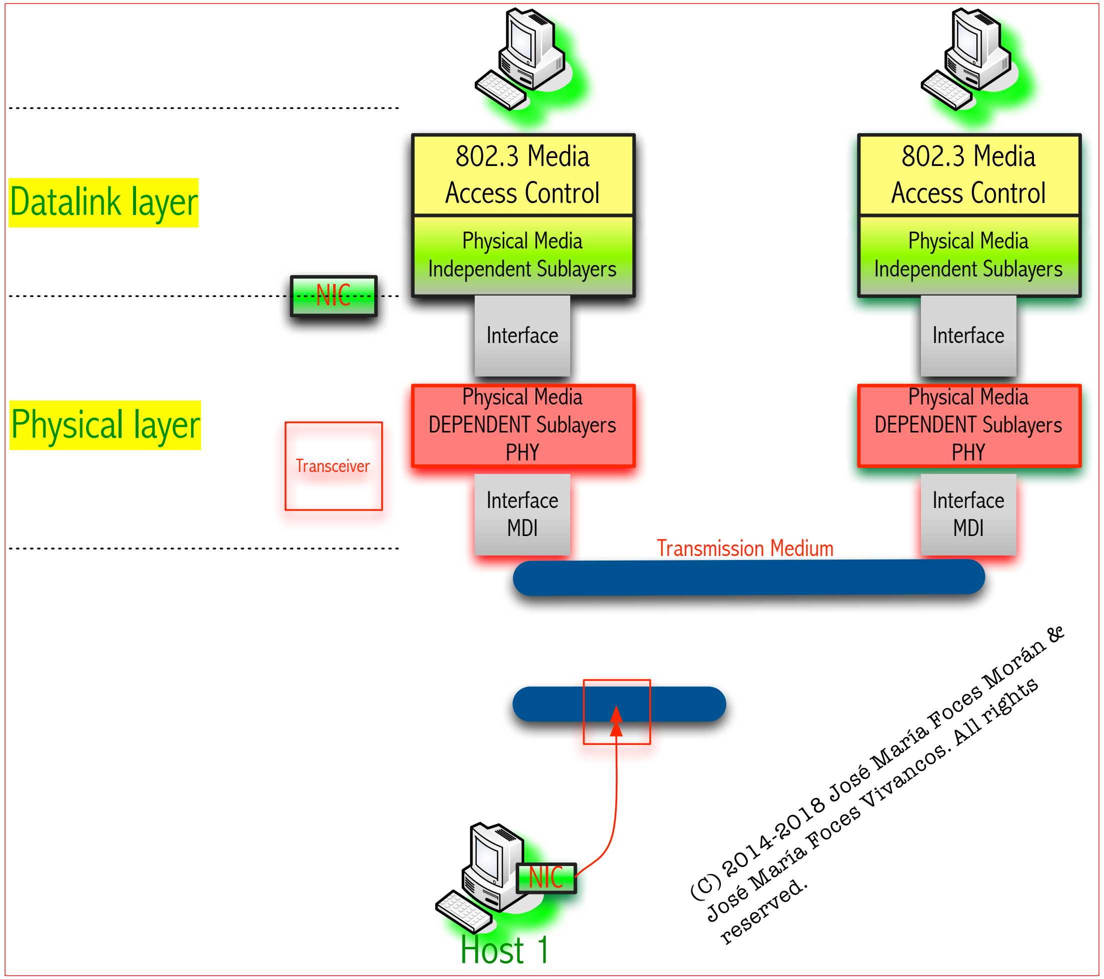
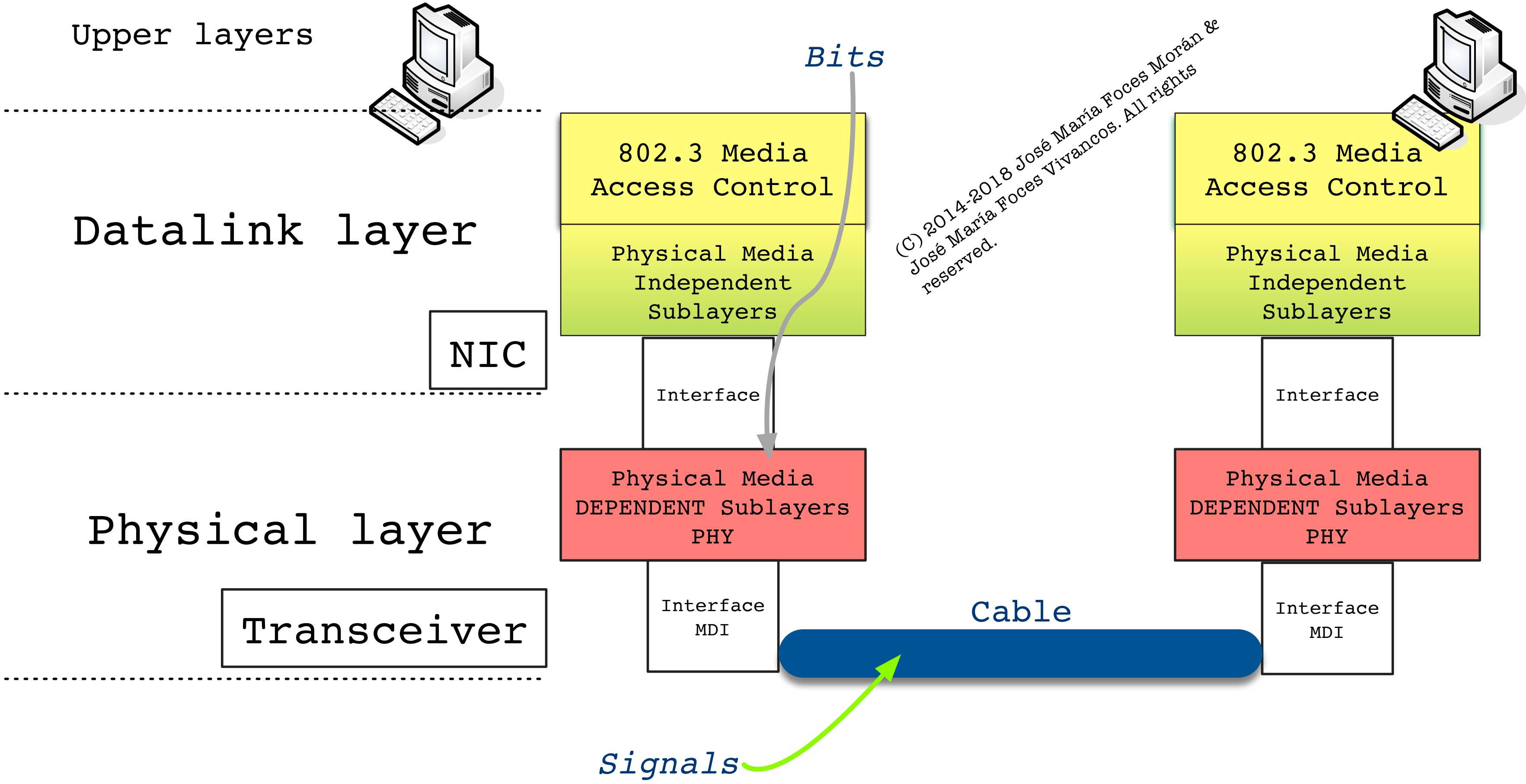
Line Encoding is performed by the electronic circuits comprising the Physical Layer



Bits of information and signals



Bit detection

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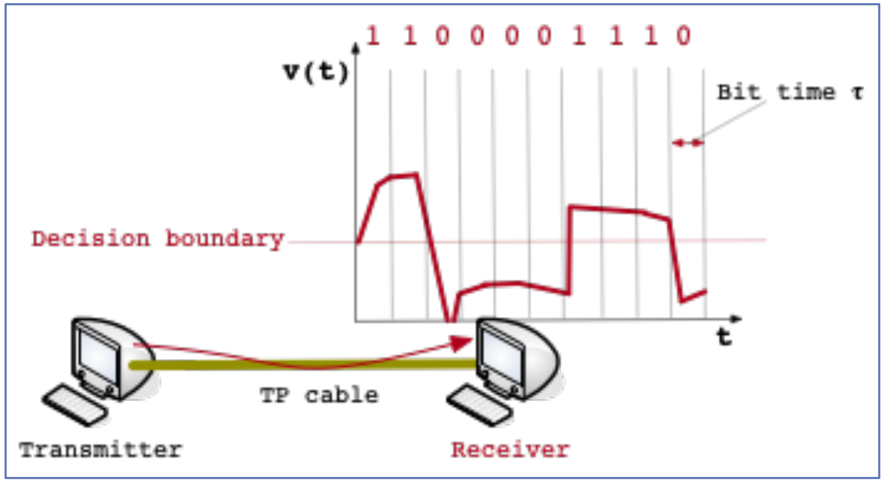
- Binary symbols 0 and 1 are assigned separate signals
- Usually, the voltage level of a signal that varies over time represents 0's and 1's
  - Level usually refers to the signal's voltage at each instant in time: v(t)
- Actually, signal level refers to a continuous range of voltages that is different from the range of voltages assigned to the other level
  - Distinguishing a high level from a low level reduces to establishing whether the signal's volatge is above or below a specific boundary: The decision boundary
  - Setting that boundary correctly is essential for the receiver's ability to correctly interpreting each received signal value
- The time dedicated to the reception of each bit is known as *bit time, τ*



Encoding

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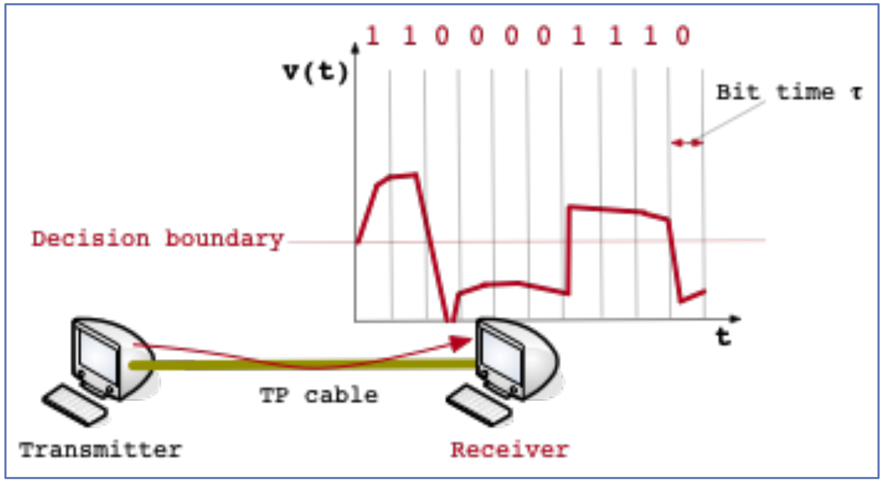
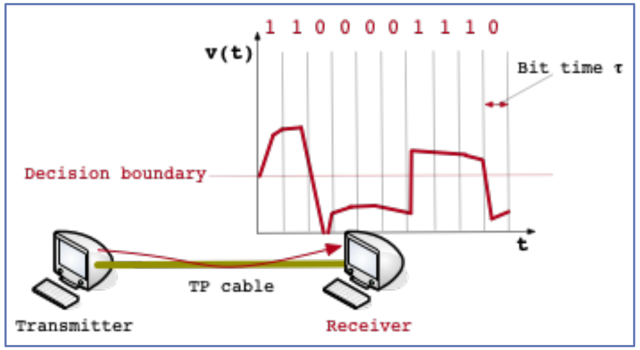
- Translating bits into signals is known as encoding
- There exist **many** encoding schemes available
- All of them represent bits by using different **properties** of signals related with
  - Time t
  - Signal value v(t)
- NRZ-L
- NRZ-I
- Manchester
- In all cases, we pursue a detection technique that reliably returns the **correct bit value** (0 or 1)

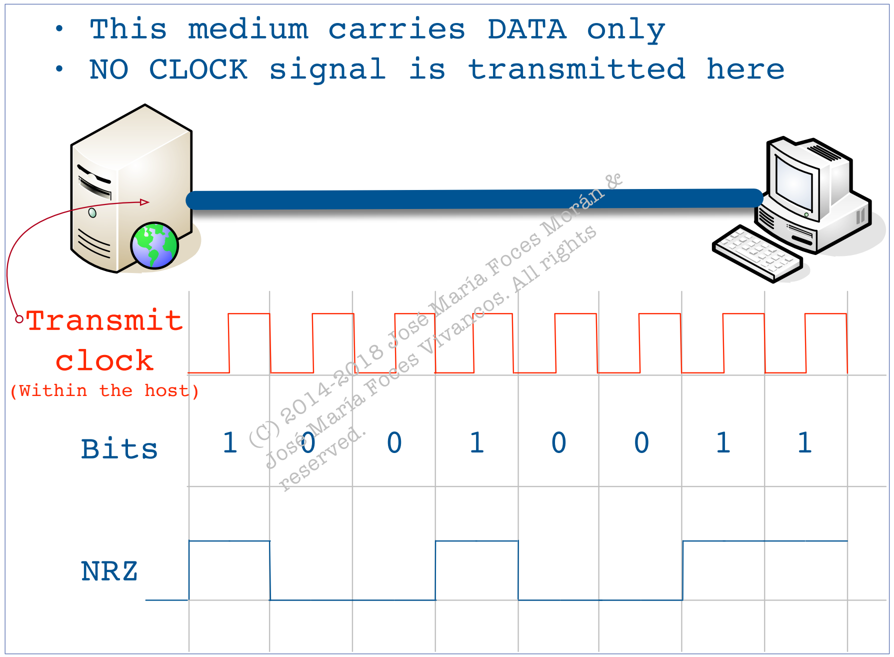


NRZ-L encoding (Non-Return to Zero Level)

- A binary 1 is assigned a level; a binary 0 is assigned the other level
  - Level usually refers to the signal's voltage at each instant in time: v(t)
  - Actually, signal level refers to a continuous range of voltages that is different from the range of voltages assigned to the other level
  - Distinguishing a high level from a low level reduces to establishing whether the signal's volatge is above or below a specific boundary
  - Setting that boundary correctly is essential for the receiver's ability to correctly interpreting each received signal value

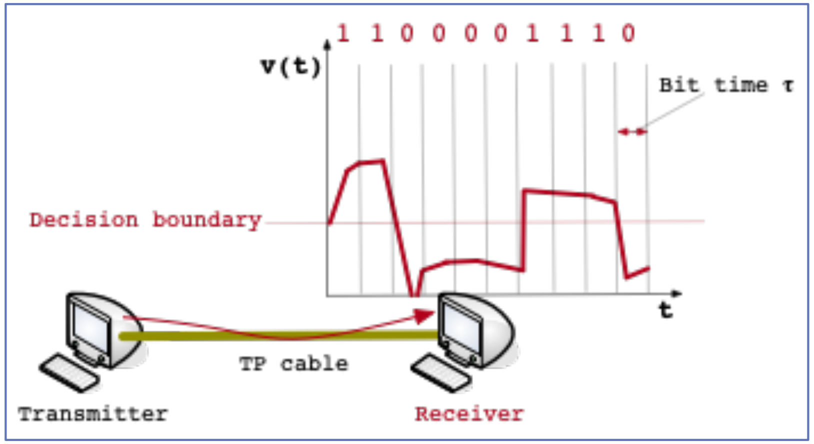
  - Extensively used in the digital electronics lab





Problems with NRZ-L

- Baseline wander
  - The **receiver keeps the average signal level** up until this moment
  - When a signal is significantly low than the average, it is interpreted as a low level, otherwise, it is interpreted as a high level
  - Too many consecutive 0's and 1's cause this average to bias, thereby making it more difficult to differentiate between the levels

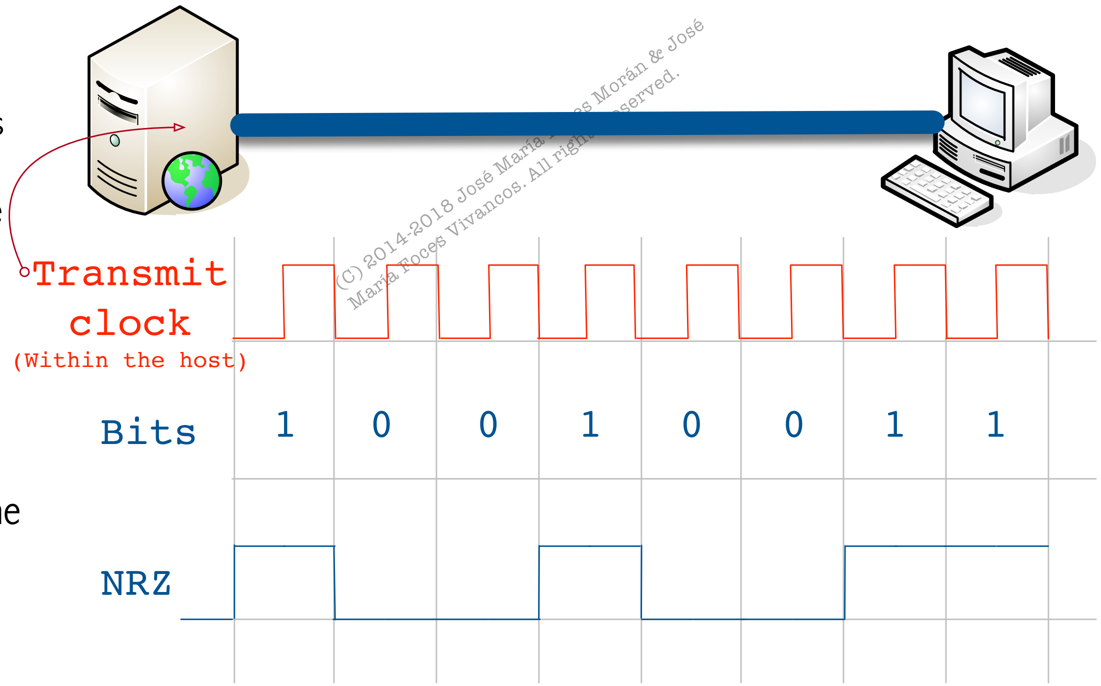


Problems with NRZ-L

Clock recovery

- The transmitter sends symbols (0/1) at some transmission speed determined by an internal clock signal generated within the sender:
  - At every clock cycle, the sender transmits a new bit
  - In data communications, usually, the clock signal is not sent from sender to receiver
  - Then, how does the receiver become aware of the used transmission speed and of the clock edges that mark data (bits) as valid?
    - By having the transmitted signal carry the data alongside with frequent level changes which will help the receiver in recovering the clock signal used for transmission
- The receiver must be able to deduce the transmission speed from the signal containing the data
  - This entails frequent transitions from high to low and vice versa in the received data signal
  - This is known as clock recovery
  - Clock recovery yields a precise synchronization of sender and receiver

- This medium carries DATA only
- NO CLOCK signal is transmitted here



NRZ-i: a partial solution to NRZ

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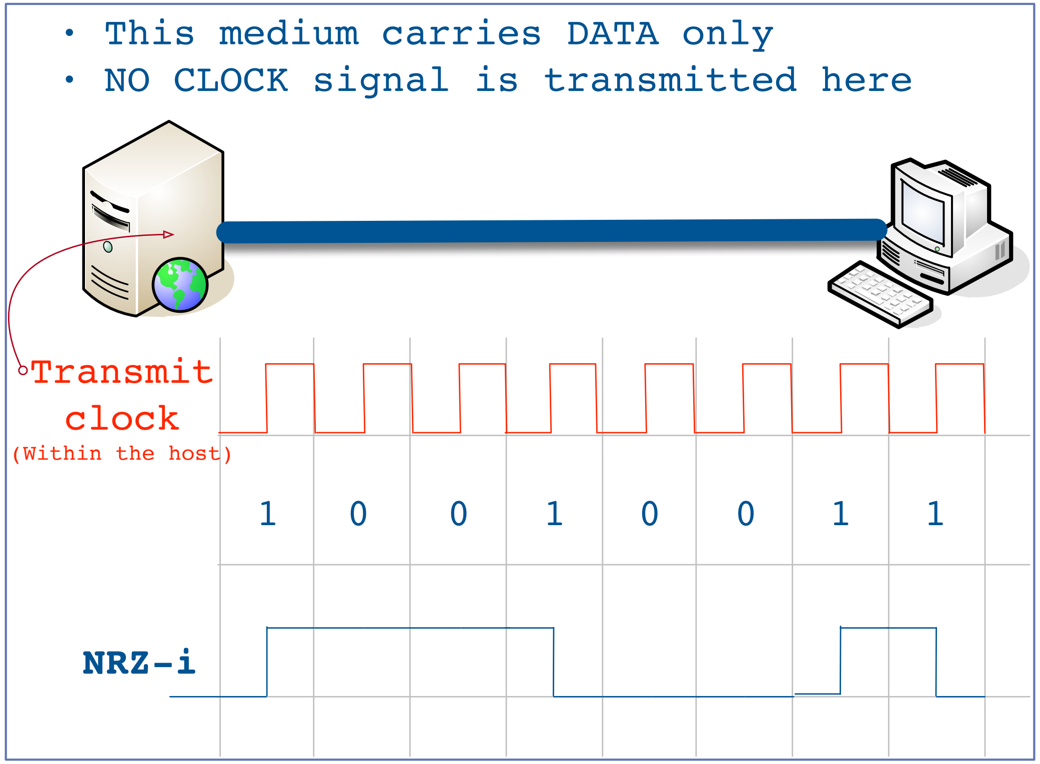
- A.K.A.: NRZ-M (Mark)
- Non Return to Zero Inverted
- Sender makes a transition from the current signal level to encode 1 and stays at the current signal level to encode a 0
- <u>Solves for the consecutive 1's problem of NRZ</u>



Channel Encoding: 4B/5B

- It's a channel (block) encoding technique
- Performed by the transmitter before transmission, the sender inserts extra bits into bit stream so as to break up the long sequences of 0's
  - Every group of 4-bits of actual data are encoded into a 5-bit code which is transmitted to the receiver
  - 5-bit codes are selected in such a way that each one has
    - no more than one leading 0 (zero)
    - no more than two trailing 0's
    - `01100 Ok,` *`00111 Not ok, 11000 not ok`* …
  - No pair of 5-bit codes results in more than three consecutive 0's

4B/5B table from Wikipedia

Data		4B5B code
(Hex)	(Binary)	
0	0000	11110
1	0001	01001
2	0010	10100
3	0011	10101
4	0100	01010
5	0101	01011
6	0110	01110
7	0111	01111

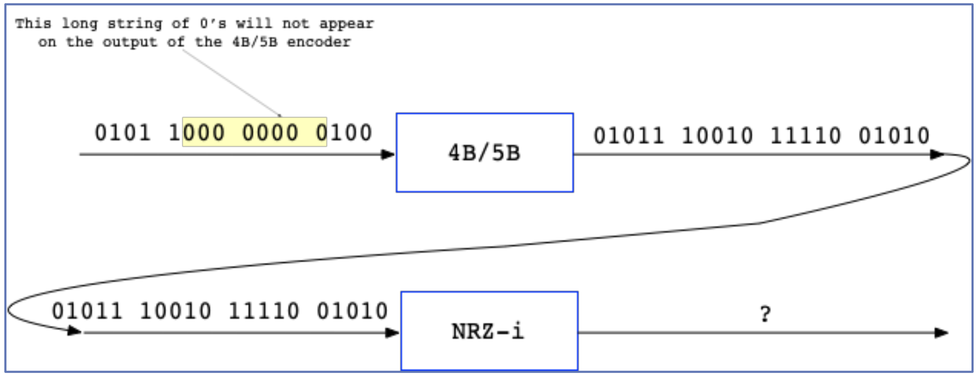
Data		4B5B code
(Hex)	(Binary)	
8	1000	10010
9	1001	10011
A	1010	10110
B	1011	10111
C	1100	11010
D	1101	11011
E	1110	11100
F	1111	11101

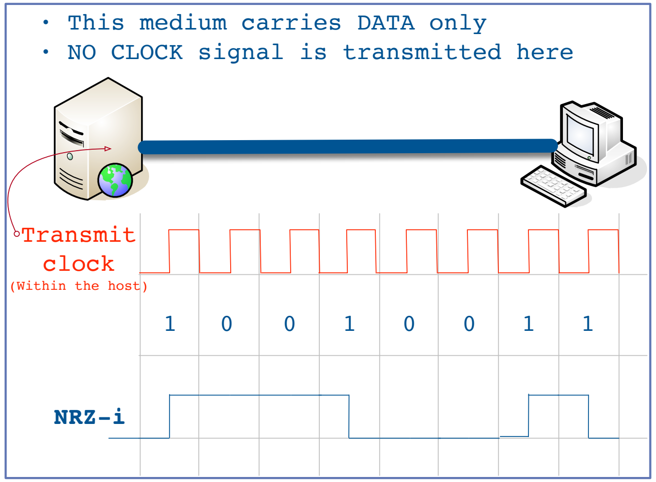
Symbol	4B5B code	Description
H	00100	Halt
I	111111	Idle
J	11000	Start #1
K	10001	Start #2
L	00110	Start #3
Q	00000	Quiet (loss of signal)
R	00111	Reset
S	11001	Set
T	01101	End (terminate)

Channel Encoding in the first place, then Line Encoding

- 4B/5B solves the problem of long sequences consecutive of 0's
- NRZI solves the problem of long sequences of consecutive 1's

- These encodings are used in tandem:
  - 4B/5B is applied first to the data to be transmitted
    - This is known as CHANNEL ENCODING
  - Then, the resulting bit stream is NRZI encoded
    - This is known as LINE ENCODING





Manchester: complete solution to NRZ

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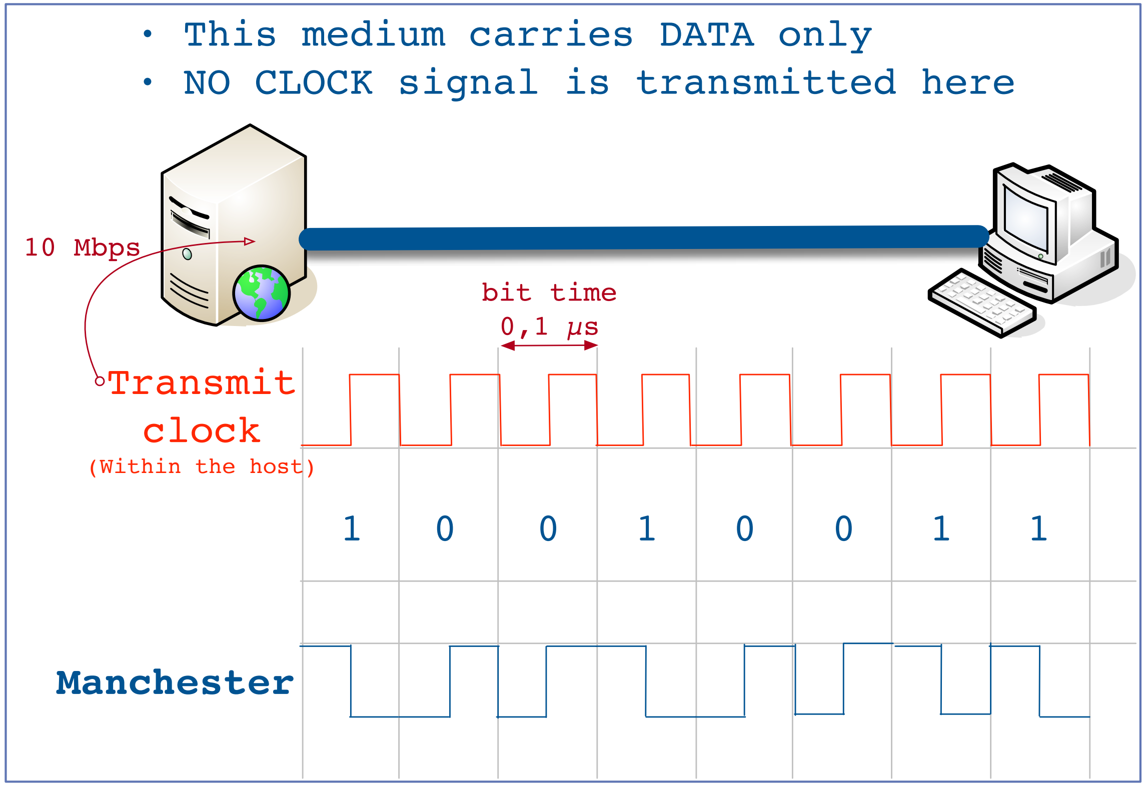
- Strategy:
  - Merge the clock with signal by transmitting Ex-OR of the NRZ encoded data and the clock
  - Clock is an internal signal that alternates from low to high, a low/high pair is considered as one clock cycle
  - In Manchester encoding
    - 0: low→ high transition
    - 1: high→ low transition



Manchester encoding problem

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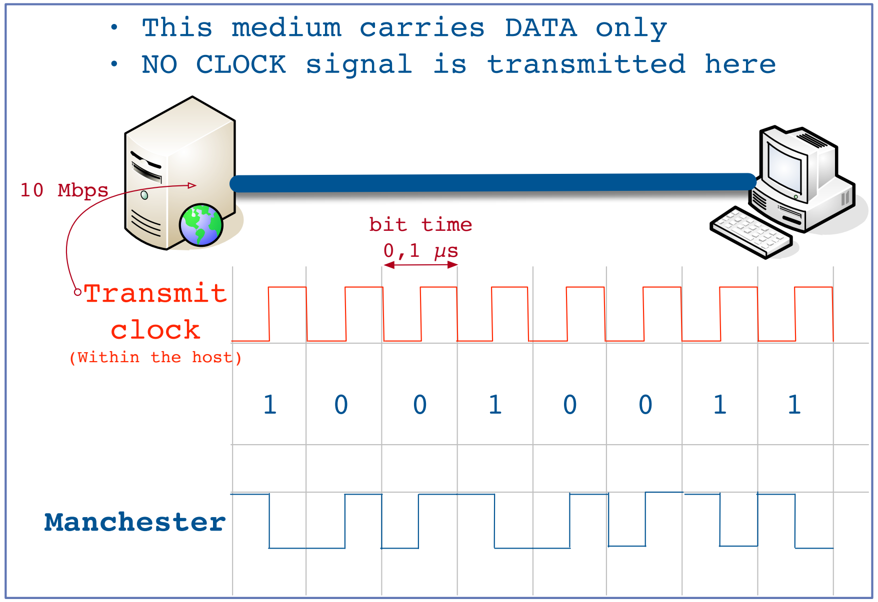
- Manchester doubles the rate of signal transitions present on the link
  - Which means the receiver has half of the time to detect each pulse of the signal
  - The rate at which the signal changes is called the link's **baud rate**
  - In Manchester the *bit rate* is **half** the *baud rate*



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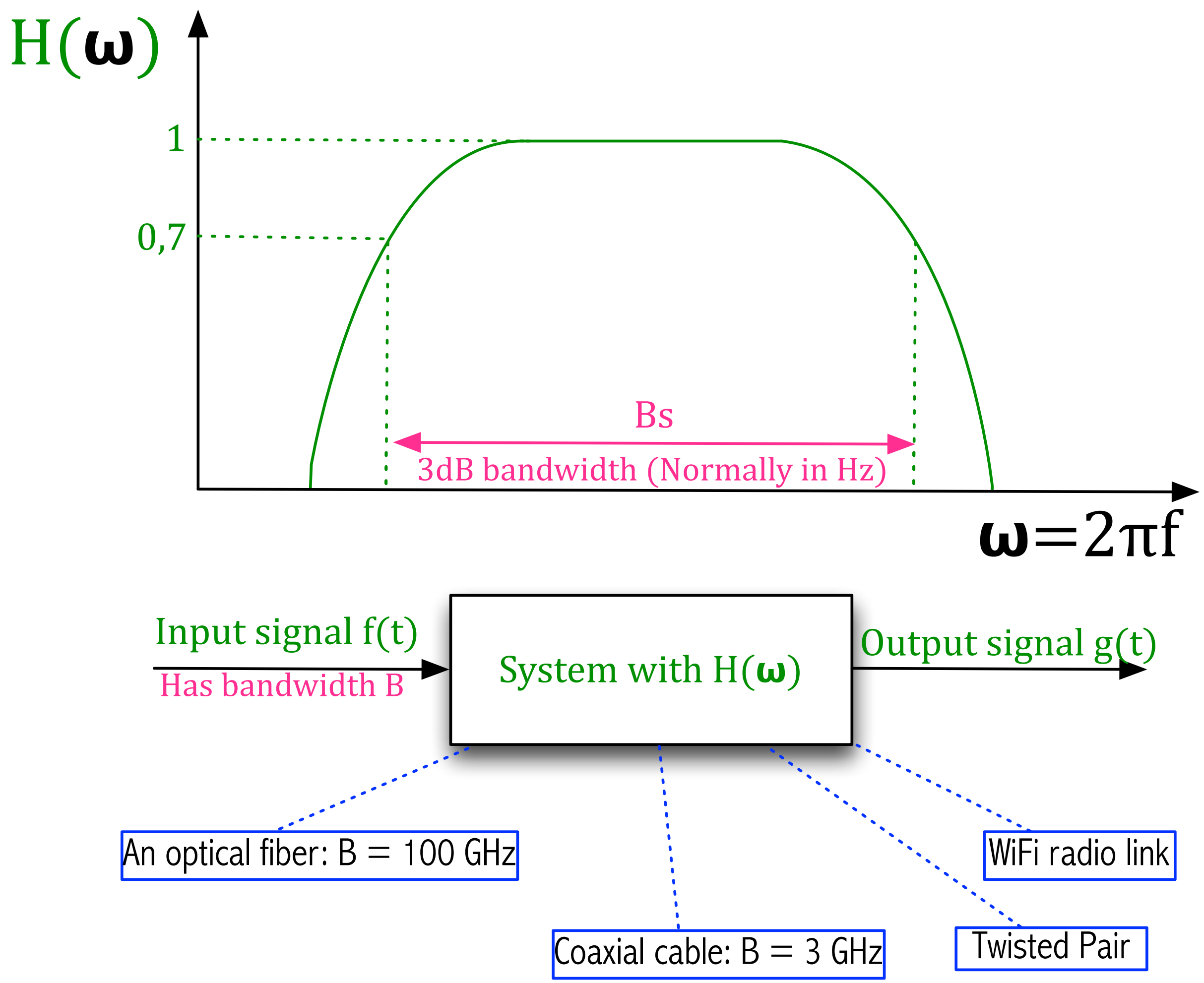
Communication theory, intro

If link bandwidth is limited

- How can we determine our data **signal's bandwidth**?
- So that the link properly transmits it



Communication theory: Fourier transform

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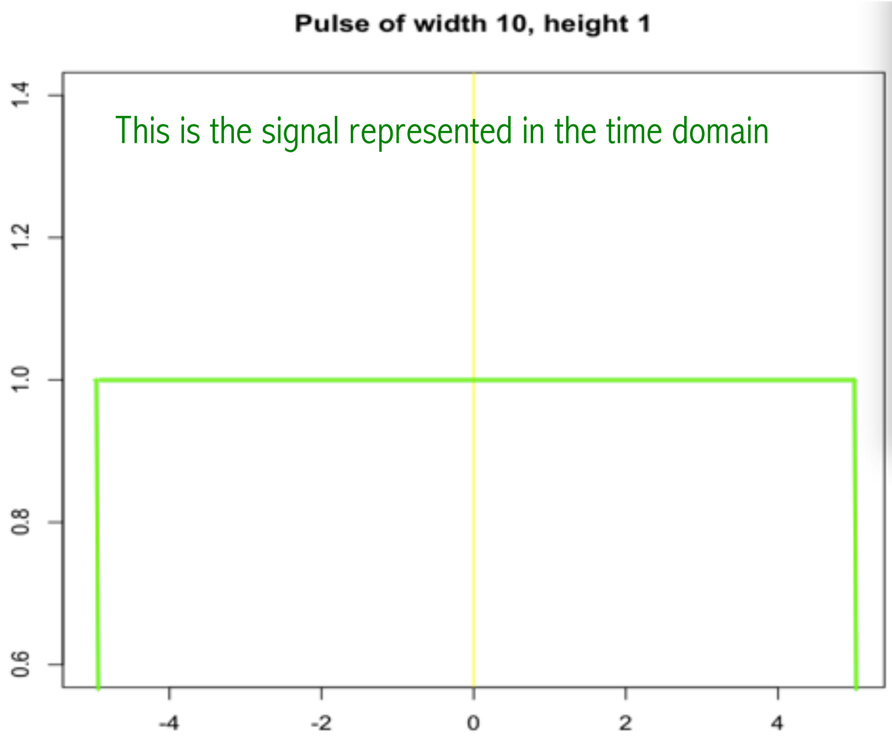
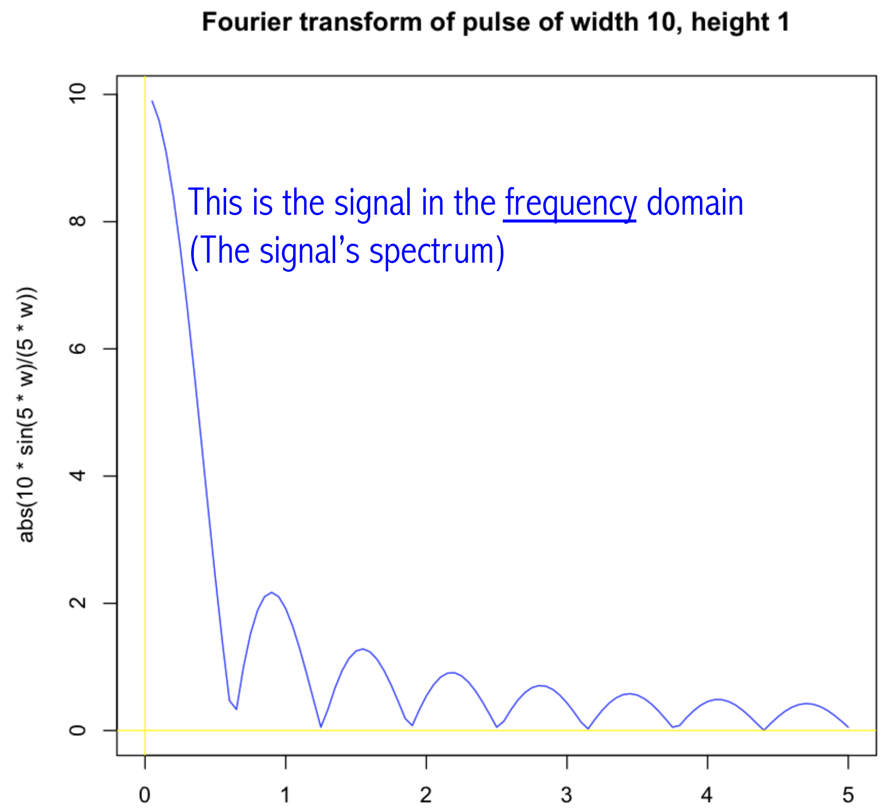
- Real signals are composed of an infinite number of sinusoidal signals whose frequency is a real number
  - t is the real-valued, independent variable of time domain function f(t)
- Fourier transform yields the frequency domain representation of a real signal
  - w is the real-valued, independent variable of function F, the complex frequency
  - Natural frequencies f is such that: $w = 2\pi f$

$$F(jw) = \int_{-\infty}^{+\infty} f(t) \cdot e^{-jwt} dt$$

Signal's bandwidth derived from its Fourier transform

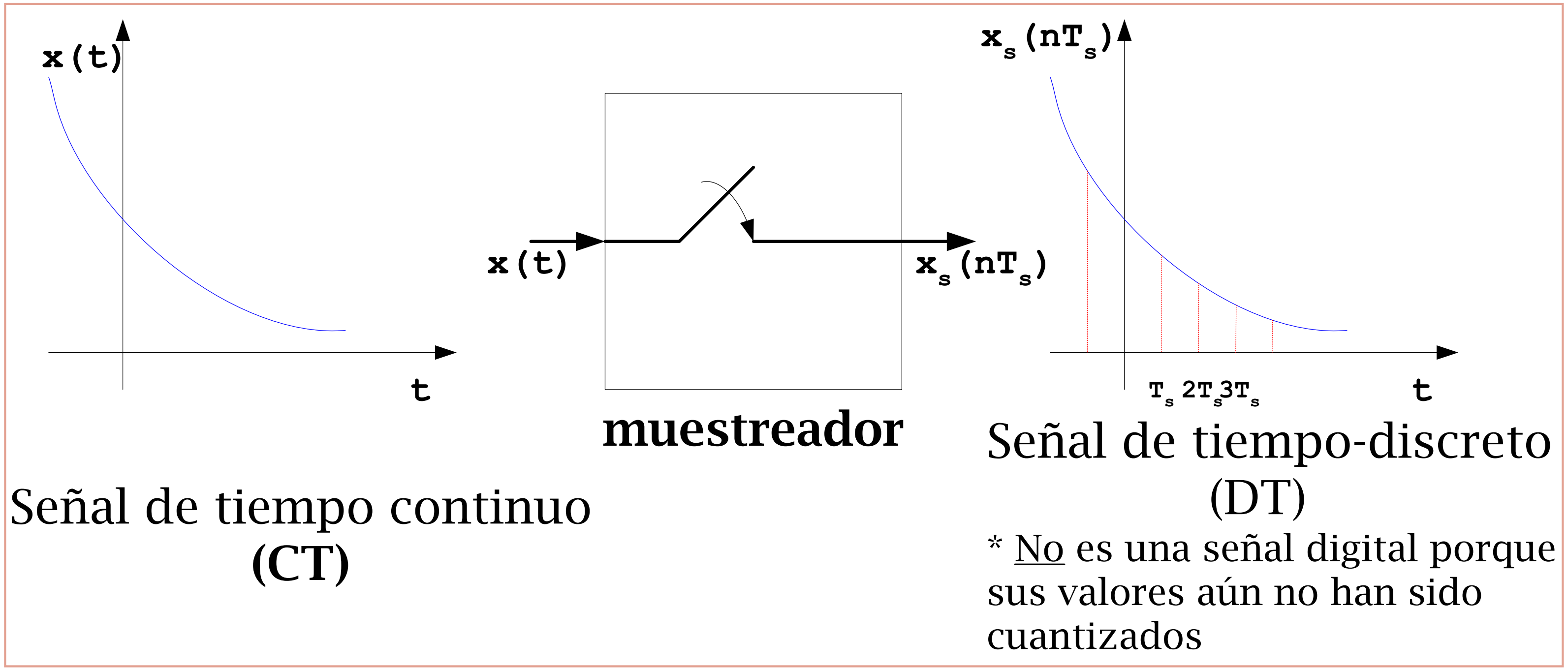




$$F(jw) = \int_{-\infty}^{+\infty} f(t) \cdot e^{-jwt} dt$$

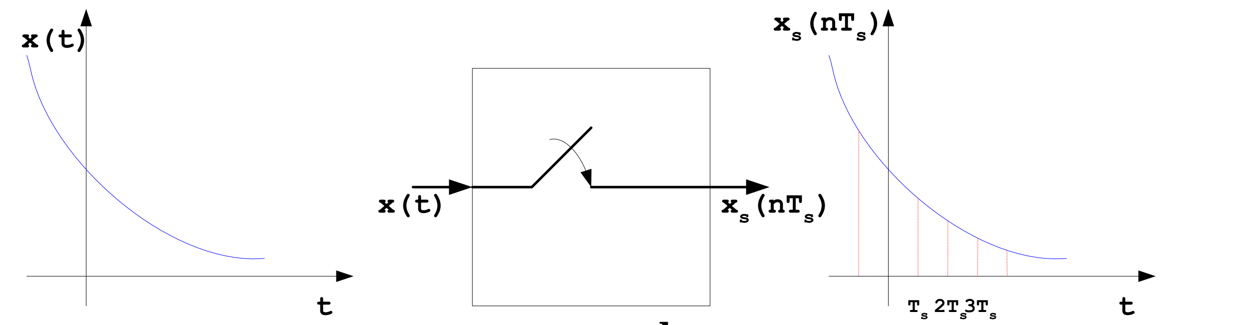
Communication theory: Signal sampling

- Analog signals can be represented digitally
  1. First, they are sampled (in time)
  2. Then, each sample is quantized



Communication theory: Nyquist's criterion

- If we want to recover a real signal from its samples:
  - The sampling process must be carried out **<u>at least</u>** at a speed twice the maximum significant frequency contained in the spectrum of the real signal
  - Otherwise, aliasing will occur: new frequency components will appear which will create distorsion
- If we sample the real signal at a frequency lower than twice its bandwidth, then reconstruction of of the original signal from its samples will be impossible.



Señal de tiempo continuo **(CT)**

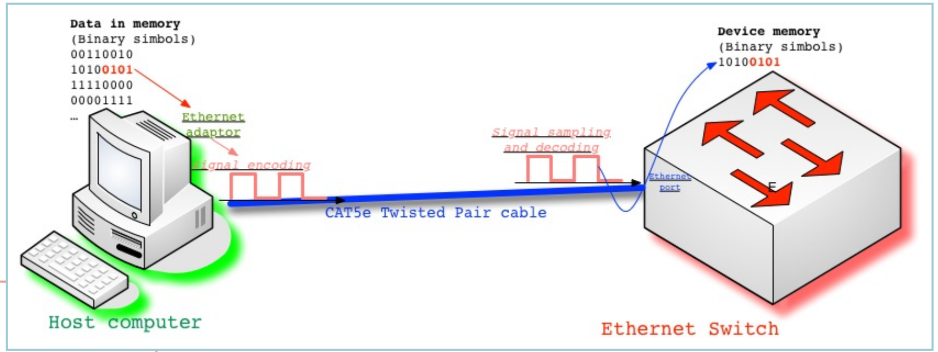
Señal de tiempo-discreto (DT)

* <u>No</u> es una señal digital porque sus valores aún no han sido cuantizados

Communication theory: Shannon-Hartley Theorem

- Establishes an upper bound to the capacity of a channel in bps
- If we try to send information through a channel at a higher rate, on the receiving side, the probability of error in the estimation of the received symbols will be unbounded

  - Where B = 3300 – 300 = 3000Hz, S is the signal power, N the average noise.
  - The signal to noise ratio (S/N) is measured in decibels is related to dB = 10 x $\log_{10}$(S/N). If there is 30dB of noise then S/N = 1000.
  - Now C = 3000 x $\log_2$(1001) = 30kbps.
  - How can we get 56kbps?



$$C = B \cdot \log_2\left(1 + \frac{s}{n}\right) \quad bps$$

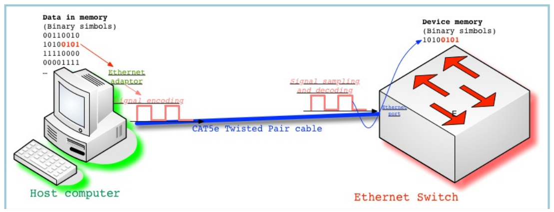
Links

- All practical links rely on some sort of electromagnetic radiation propagating through a medium or, in some cases, through free space
- One way to characterize links, then, is by the medium they use
  - Typically copper wire in some form (as in Digital Subscriber Line (DSL) and coaxial cable),
  - Optical fiber (as in both commercial fiber-to-the home services and many long-distance links in the Internet's backbone), or
  - Air/free space (for wireless links)

Links

- Another important link characteristic is the *frequency*
  - Measured in hertz, with which the electromagnetic waves oscillate
  - Electromagnetic waves propagate as the electric field generates a magnetic field that generates an electric field …

- Distance between the adjacent pair of maxima or minima of an electromagnetic wave measured in meters is called *wavelength:* $\lambda = v / f$
  - Speed of light divided by frequency gives the wavelength.
  - Frequency on a copper cable range from 300Hz to 3300Hz; Wavelength for 300Hz wave through copper is speed of light on a copper / frequency
  - $2/3 \times 3 \times 10^8 / 300 = 667 \times 10^3$ meters.
- Placing binary data on a signal is called *encoding*
- *Modulation* involves modifying the signals in terms of their frequency, amplitude, and phase
  - So that transmission over the physical medium is improved



Links

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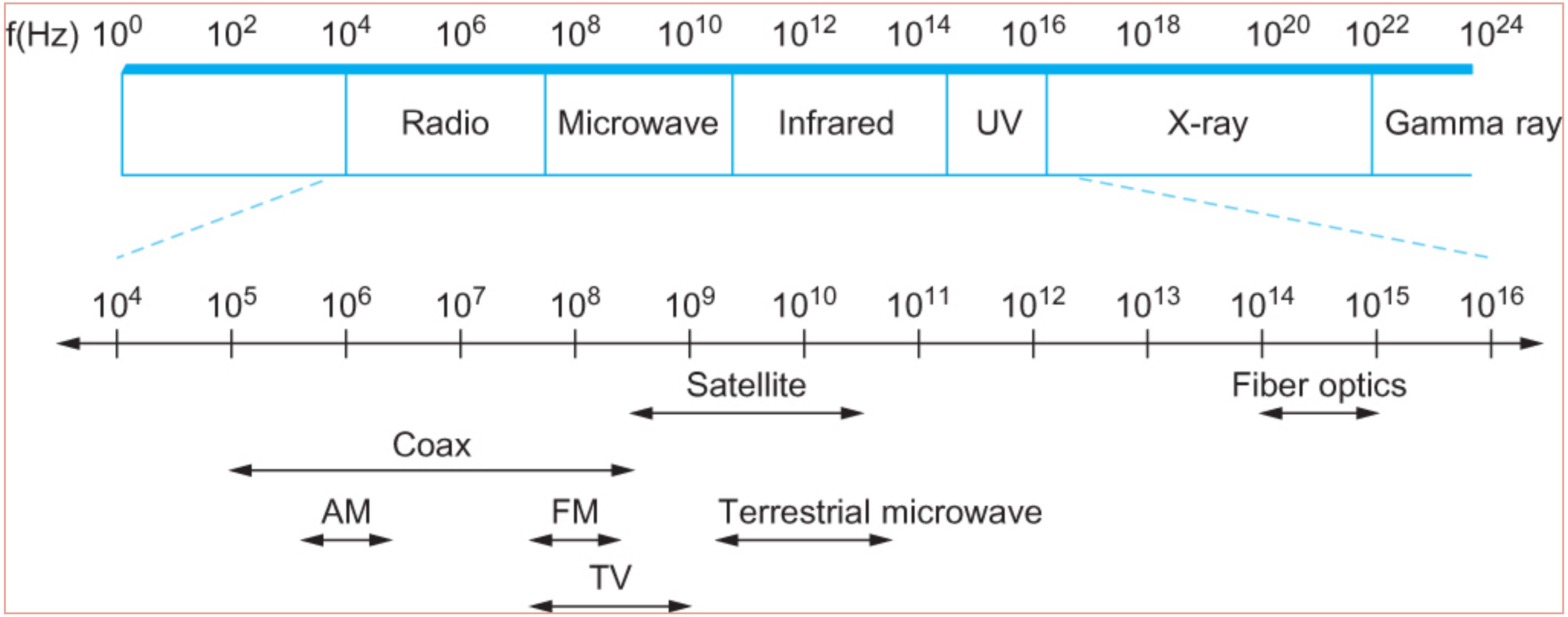

Electromagnetic spectrum

Links

Service	Bandwidth (typical)
Dial-up	28–56 kbps
ISDN	64–128 kbps
DSL	128 kbps–100 Mbps
CATV (cable TV)	1–40 Mbps
FTTH (fibre to the home)	50 Mbps–1 Gbps

Common services available to connect your home

End of Ch 1 Section 4