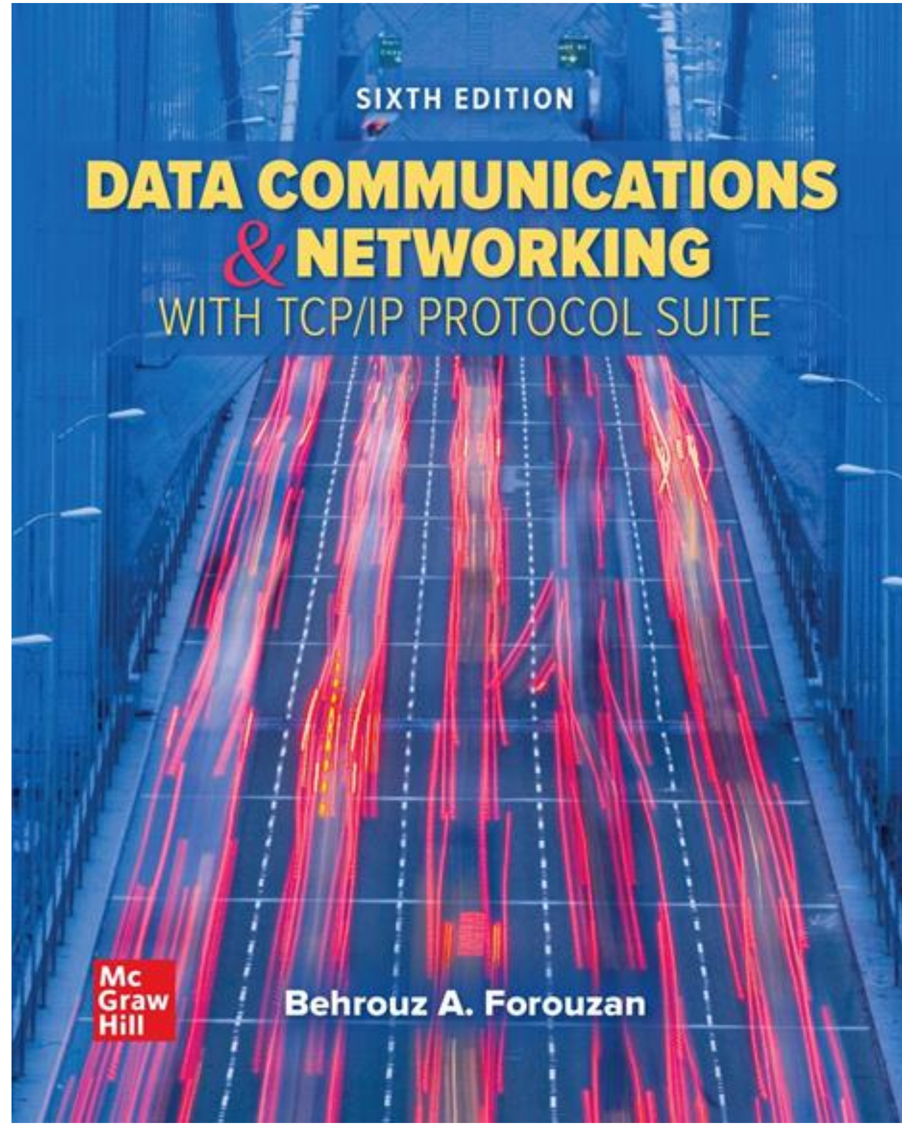
Wed 31 Dec

Chapter 02

Physical Layer

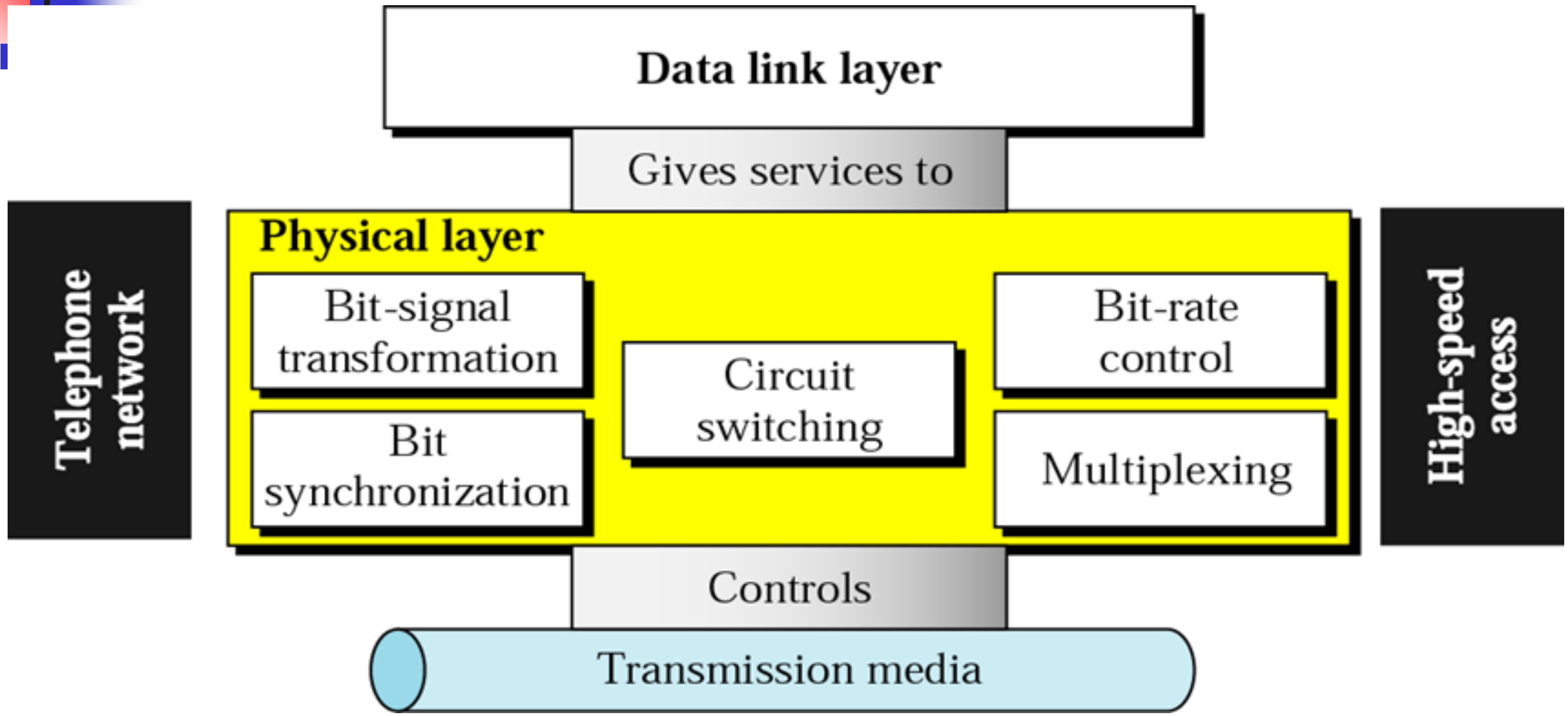
- Data Communications and Networking, With TCP/IP protocol suite Sixth Edition
- Behrouz A. Forouzan

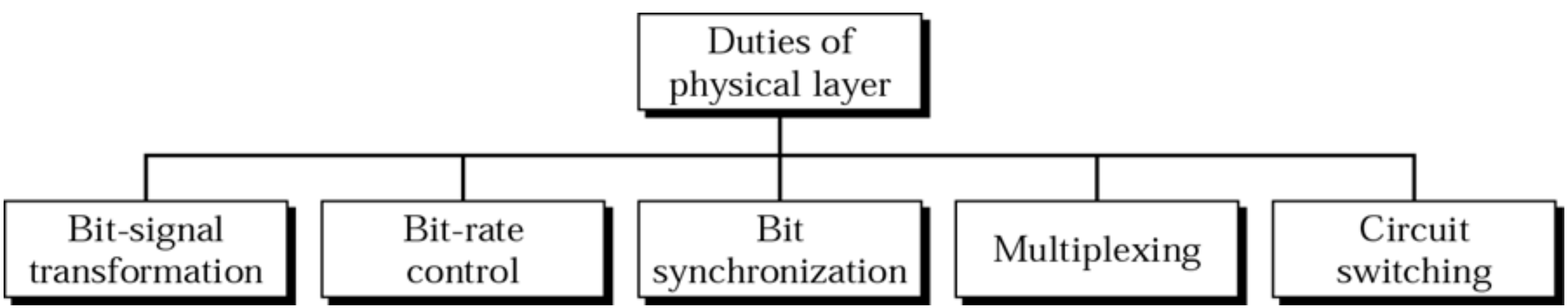


Chapter 2: Outline

- SIGNALS
- TRANSMISSION IMPAIRMENT
- PERFORMANCE

Position of the physical layer & Services

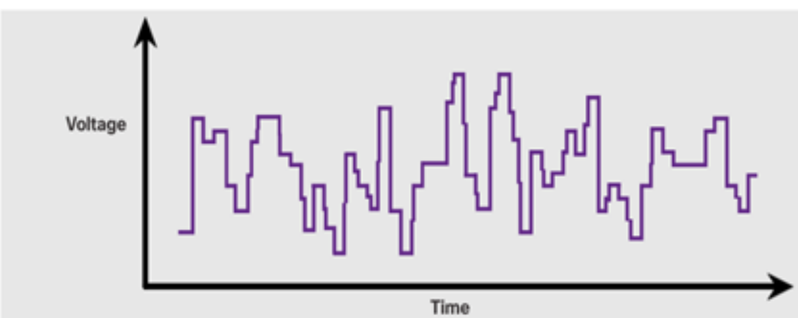




Signals

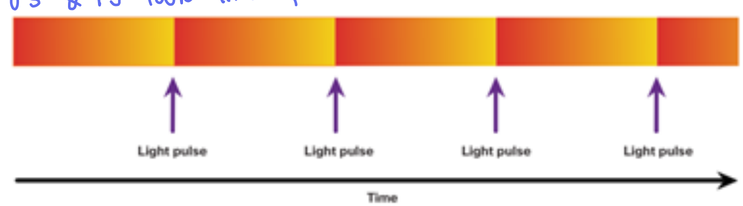
Note

To be transmitted, data must be transformed to electromagnetic signals.



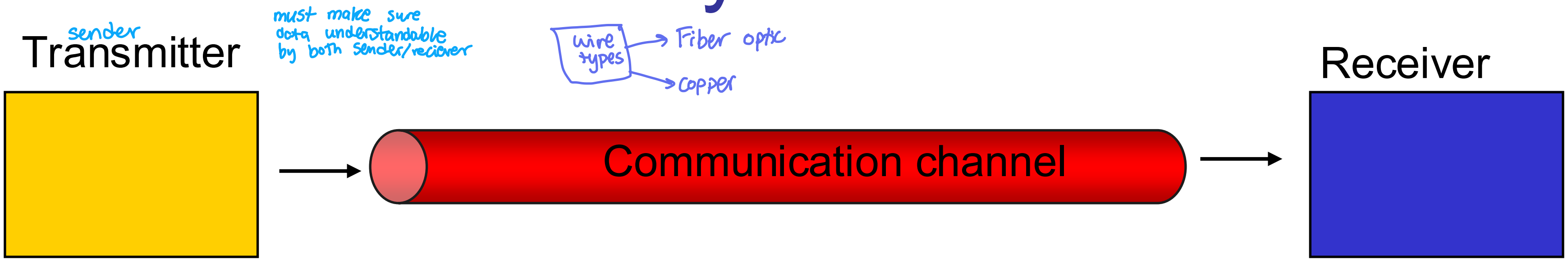
Electrical Signals Over Copper Cable

Cut down into smaller parts
0's & 1's look like pulses



Light Pulses Over Fiber-Optic Cable

A Transmission System



process through which I'm sending signals

Transmission: Communication of data by propagation and processing of signals through a **communication channel**

Signal: **Electromagnetic energy** that moves through the transmission medium and carries some information.

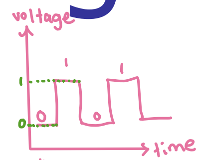
Transmitter

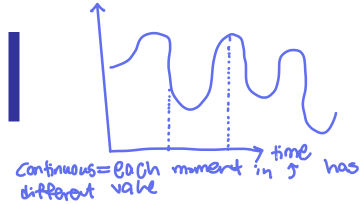
- Converts information into *signal* suitable for transmission
- **Injects energy** into communications medium or channel
  - Telephone converts voice into *electric current*
  - **NIC** converts bits into *electric current or pulses of light*

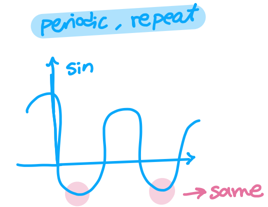
Receiver

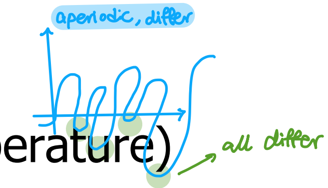
- **Receives energy** from medium
- Converts received signal into form suitable for delivery to user
  - Telephone converts current into *voice*
  - NIC converts *electric current or pulses of light* into *bits*

Analog and Digital



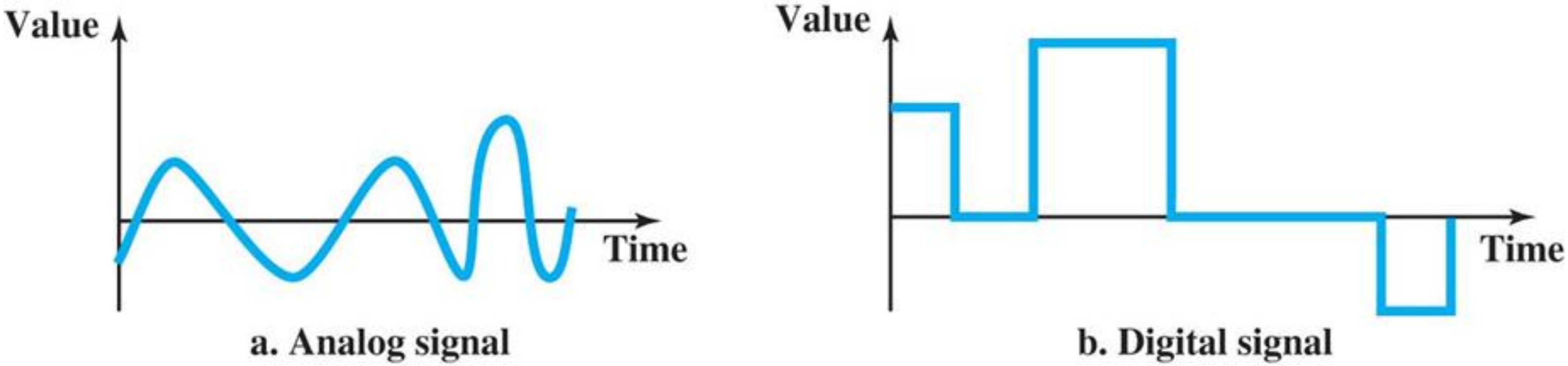




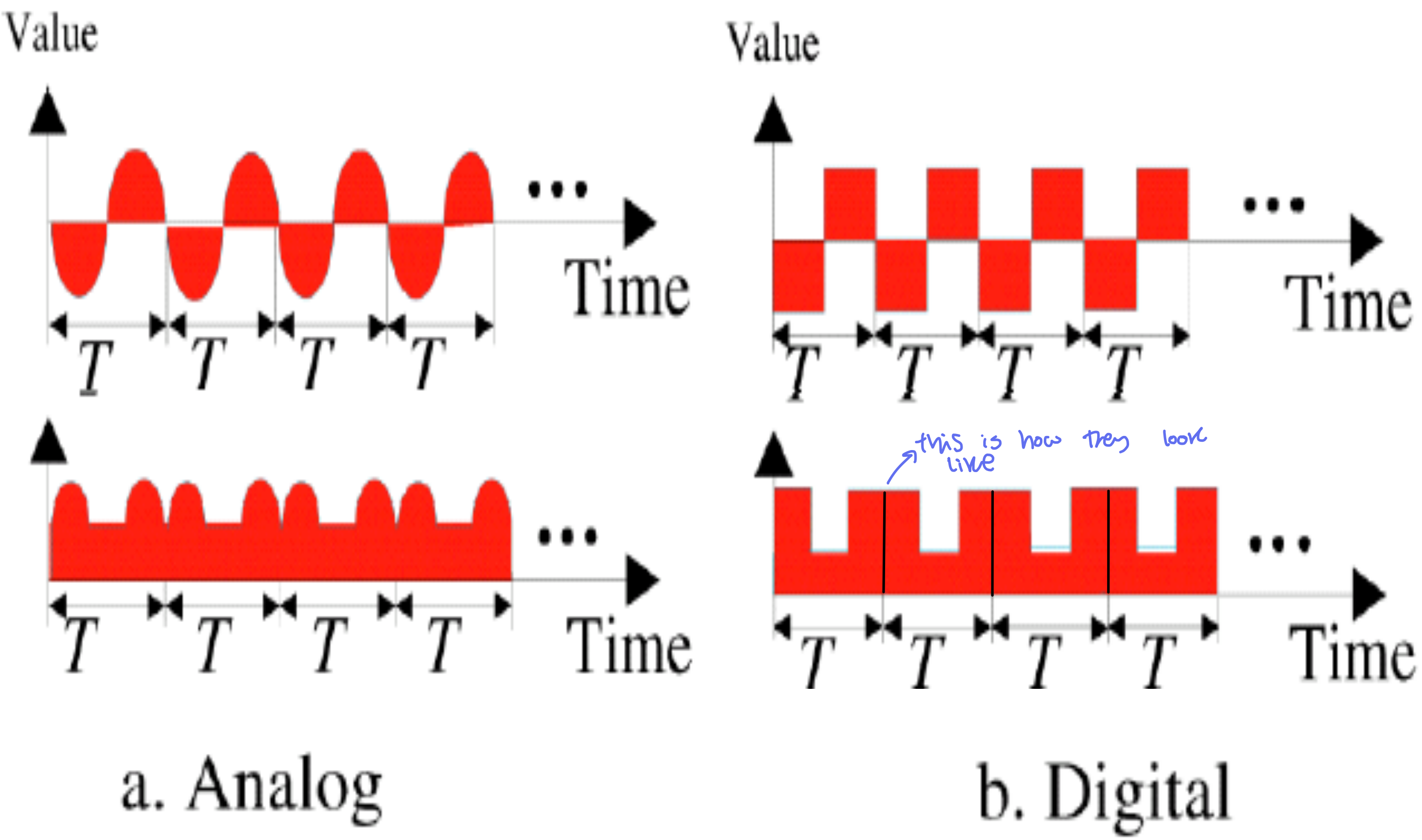


- Analog Data: **Continuous** value data (sound, light, temperature)
- Digital Data: **Discrete** value (text, integers, symbols)
- Analog Signals: **Continuously** varying **electromagnetic wave**
  - have an **infinite number** of values over a **period of time**
- Digital Signals: Series of voltage pulses (square wave)
  - have only a **limited number** of values over a **period of time**.
  - Maintains a constant level then changes to another constant level
- Signals are classified into:
  - Periodic Signals: Consists of **repeated patterns** over **identical** period of times (**cycles**)
  - Aperiodic Signals: change **without a pattern** that repeats over time

Figure 2.2 Comparison of analog and digital signals



Periodic analog and digital signals



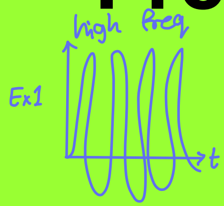
Note:

In data communication, we commonly use periodic analog signals and aperiodic digital signals.

different combo of each still exists

Note

Frequency is the rate of change with respect to time.



Change in a short span of time means high frequency.

Change over a long span of time means low frequency.

Note

Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

Hz sec

Example

The power we use at home has a frequency of 60 Hz. The period of this sine wave can be determined as follows:

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166 \text{ s} = 0.0166 \times 10^{3} \text{ ms} = 16.6 \text{ ms}$$

can immediately swo cuz correct formula

1 ms = 10^{-3} second

memorize them

Example

The period of a signal is 100 ms. What is its frequency in kilohertz?

$100\,ms \times \frac{10^{-3}\,s}{1\,ms} = 0.1\,s = T$

mostly MCQ or Fill in the blank

$f = \frac{1}{T} = 10\,Hz$

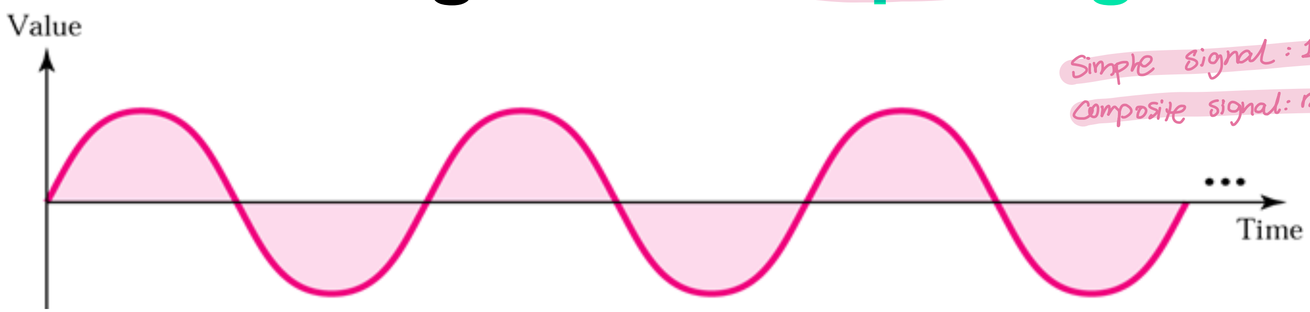
$10\,Hz \times \frac{10^{-3}\,kHz}{1\,Hz} \rightarrow 0.01\,kHz$

Solution

First we change 100 ms to seconds, and then we calculate the frequency from the period (1 Hz = 10^{-3} kHz).

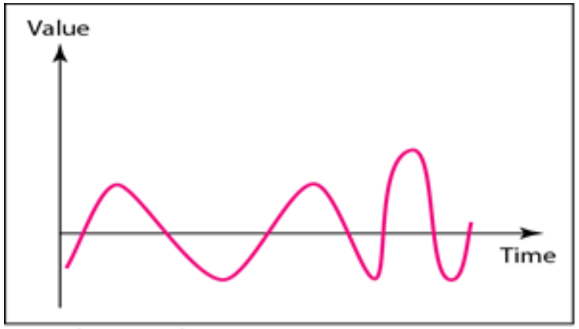
$$f = \frac{1}{T} = \frac{1}{10^{-1}}\ \text{Hz} = 10\ \text{Hz} = 10 \times 10^{-3}\ \text{kHz} = 10^{-2}\ \text{kHz}$$

Signals that have just one frequency are called simple signals, for example, the sine signal is simple signal

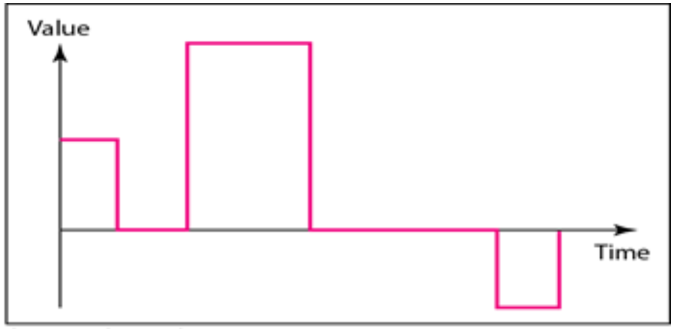


Simple signal : 1 freq
Composite signal: multiple freq

Signals that are composed of multiple frequencies are called composite signals



a. Analog signal



b. Digital signal

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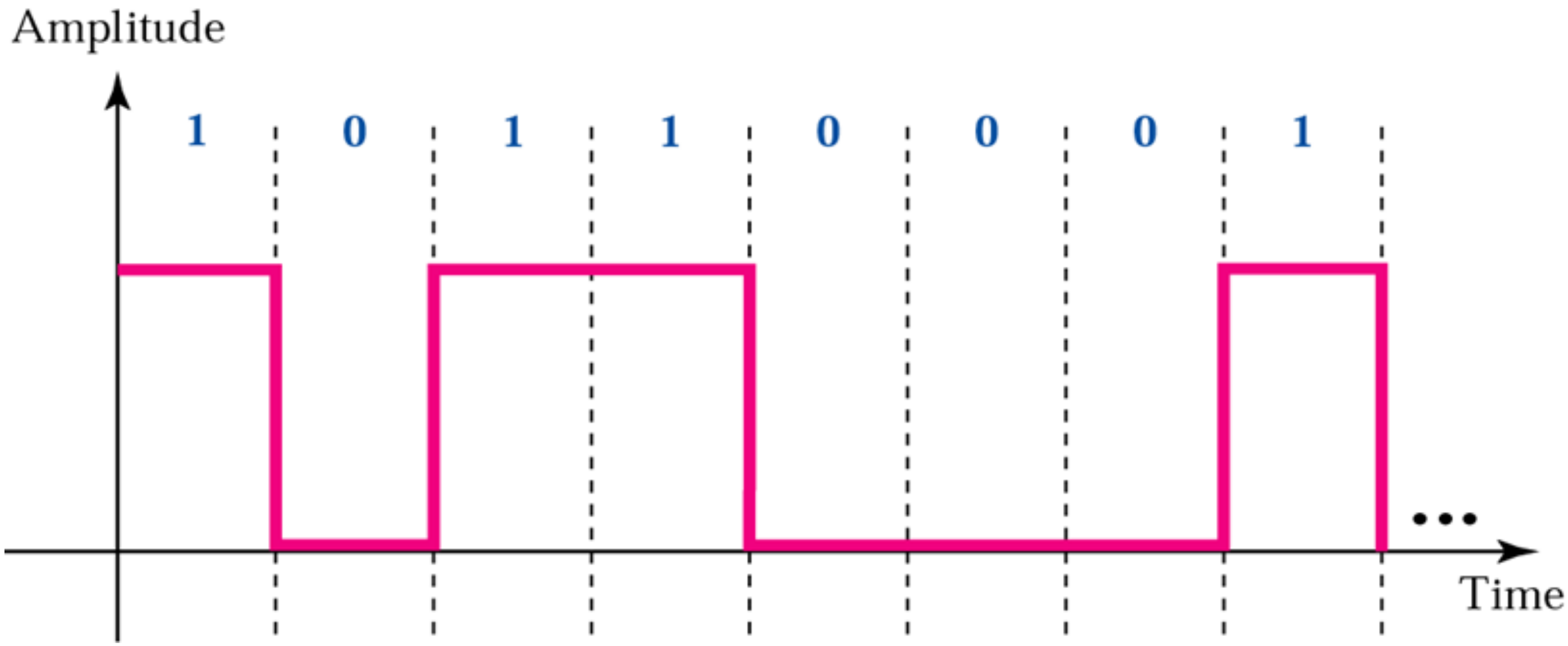
Digital Signals

1 = Positive voltage > 0

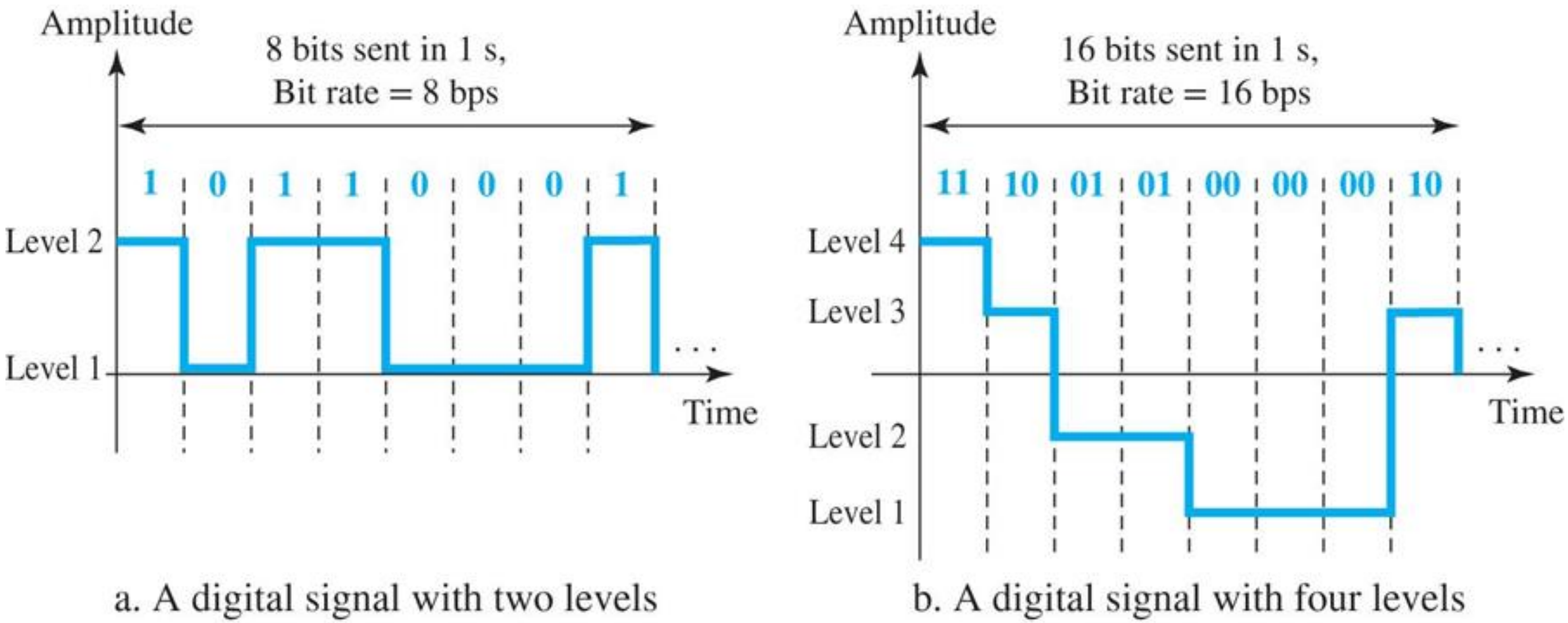
0 = Zero voltage



Most Digital Signals are <u>Aperiodic</u> □ Frequency is not appropriate

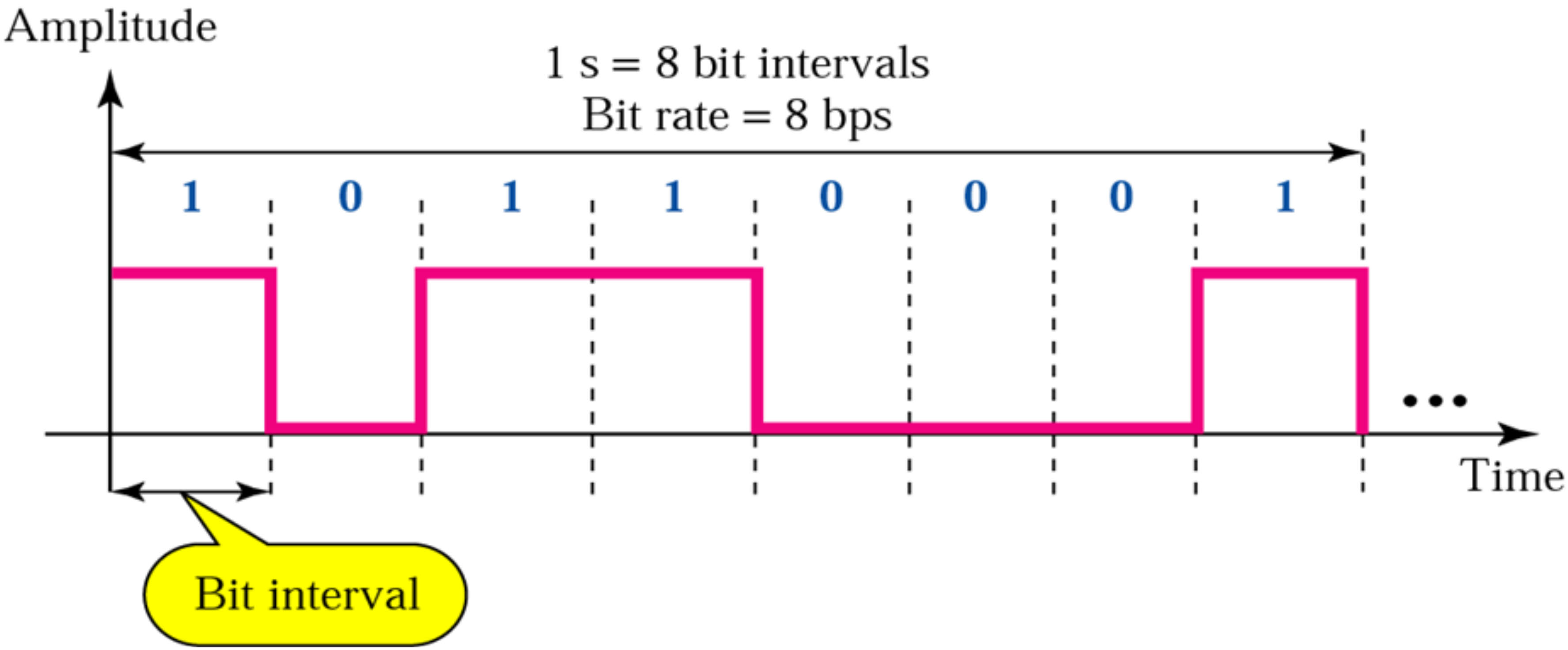
Figure 2.5 Two digital signals, one with two and one with four bit-levels

0 1 : in this example
2^{input} = levels



- Access the text alternative for slide images.

Figure ***Bit rate and bit interval***



Bit Interval (digital signal period): **The time required to send (represent) one single bit (time units)** unit: seconds

Bit Rate (digital bandwidth) = Transmission speed = Link Capacity: **Number of bits sent per second (bps)** $\frac{\text{bits}}{\text{second}}$: bps

Bit interval equation = $\frac{1}{\text{bit rate}}$

Bit rate = $\frac{1}{\text{bit interval}}$

Example

A digital signal has a bit rate of 2000 bps. What is the duration of each bit (bit interval)

unified units:
bps
s

Solution

The bit interval is the inverse of the bit rate.

Bit interval = 1/ 2000 s = 0.000500 s
= 0.000500 x 10^6 μs = 500 μs

Bit interval = $\frac{1}{2000\ s}$ = 0.000500 s

① Ex:

A communication Link transmits data at a bit rate of 5 Mbps. What is the duration of each bit in microseconds (μs)?

① Conversion

Bit rate = 5 Mbps $\times \frac{1000000}{1\ \text{Mbps}}$ = 5,000,000 bps

② Formula

Bit interval = $\frac{1}{\text{bit rate}} = 2\times10^{-7}\text{s} \times \frac{1\ \mu\text{s}}{10^{-6}\text{s}} = 0.2\ \mu\text{s}$

③ Final conversion

$10^6\ \mu\text{s} = 1\text{s}$

Dr Solution

Bit Interval = $\frac{1}{\text{bit rate}}$

$= \frac{1}{5\times10^6\ \text{bps}} = 0.2\times10^{-6}\ \text{s}$

$= 0.2\ \mu\text{s}$

Conversion of Bits Per Second

Data Transfer Rate Unit	Conversion
Bits per second (bps)	1 bps = 1 bps
Kilobits per second (Kbps)	1 Kbps = 1,000 bps
Megabits per second (Mbps)	1 Mbps = 1,000,000 bps
Gigabits per second (Gbps)	1 Gbps = 1,000,000,000 bps
Terabits per second (Tbps)	1 Tbps = 1,000,000,000,000 bps
Bytes per second (Bps)	1 Bps = 8 bps
Kilobytes per second (KBps)	1 KBps = 8,000 bps
Megabytes per second (MBps)	1 MBps = 8,000,000 bps
Gigabytes per second (GBps)	1 GBps = 8,000,000,000 bps
Terabytes per second (TBps)	1 TBps = 8,000,000,000,000 bps

②

A sensor network sends readings at 400 bps.

a) Find the bit interval in seconds

b) Express it in milliseconds

ms

μs

① Substitution

Bit interval = $\frac{1}{\text{Bit rate}} = \frac{1}{400\ \text{bps}} = 0.0025\text{s}$

② Conversion 1s = 1000 ms

$0.0025\text{s} \times \frac{1000\text{ms}}{1\text{s}} = 2.5\text{ms}$

Mon 5 Jan

All types of data types can be transmitted ① Text ② Photo ③ Video ④ Audio

Faster, easier, affordable, secure, ↳ if encrypted

Advantages of Digital Transmission

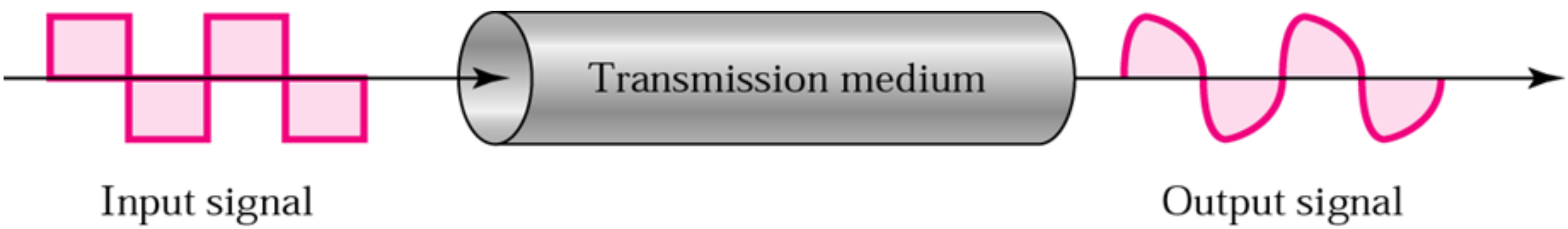
- Low cost technology $$
- Longer distances using repeaters
- Security & Privacy
  - Encryption
- Noise can be easily removed
- Cheaper and easier digital Multiplexing (Combining data from different sources into one link) Combo
- Allows processing of both analog data (voice, video) and digital data by the computer

Signal corruption

- No transmission medium can pass all the signal frequencies safely

Blocking:
1. Internet
2. Traffic
3. Hackers

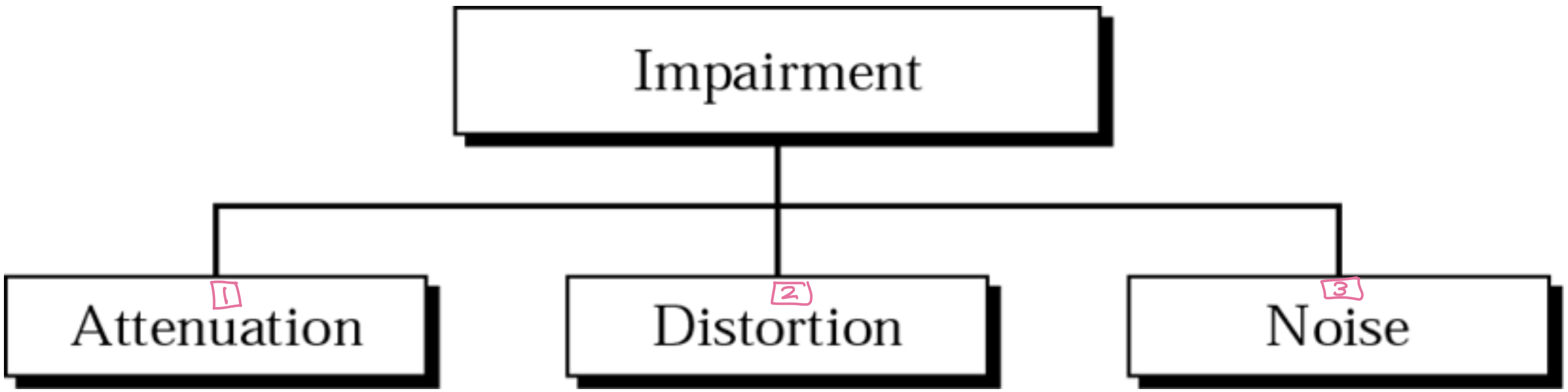
- A medium may
  - Pass some frequencies → some things effecting my pulses
    - device burn out
    - surrounding wires
  - Block others
  - Weaken others



Transmission Impairments

Impairments: Factors that make the received signal different from the transmitted one

must know:
① definition
② types
③ recover from



Attenuation

loss of energy due to resisting medium

pulses get less with distance

Amplifier: device (has it's own power) taking signals & amplifies it to continue

Distortion

- Signal changes shape
- causes diff bits to overlap

0→1, 1→0 → causing message to change

Noise

signal stopped in middle

combine both transmitted and noise in reciever want to find a way to remove noise while keeping transmitted

① Thermal: random motion of electrons, create extra signal

② Induced: depend on actual surrounding objects that produce noises

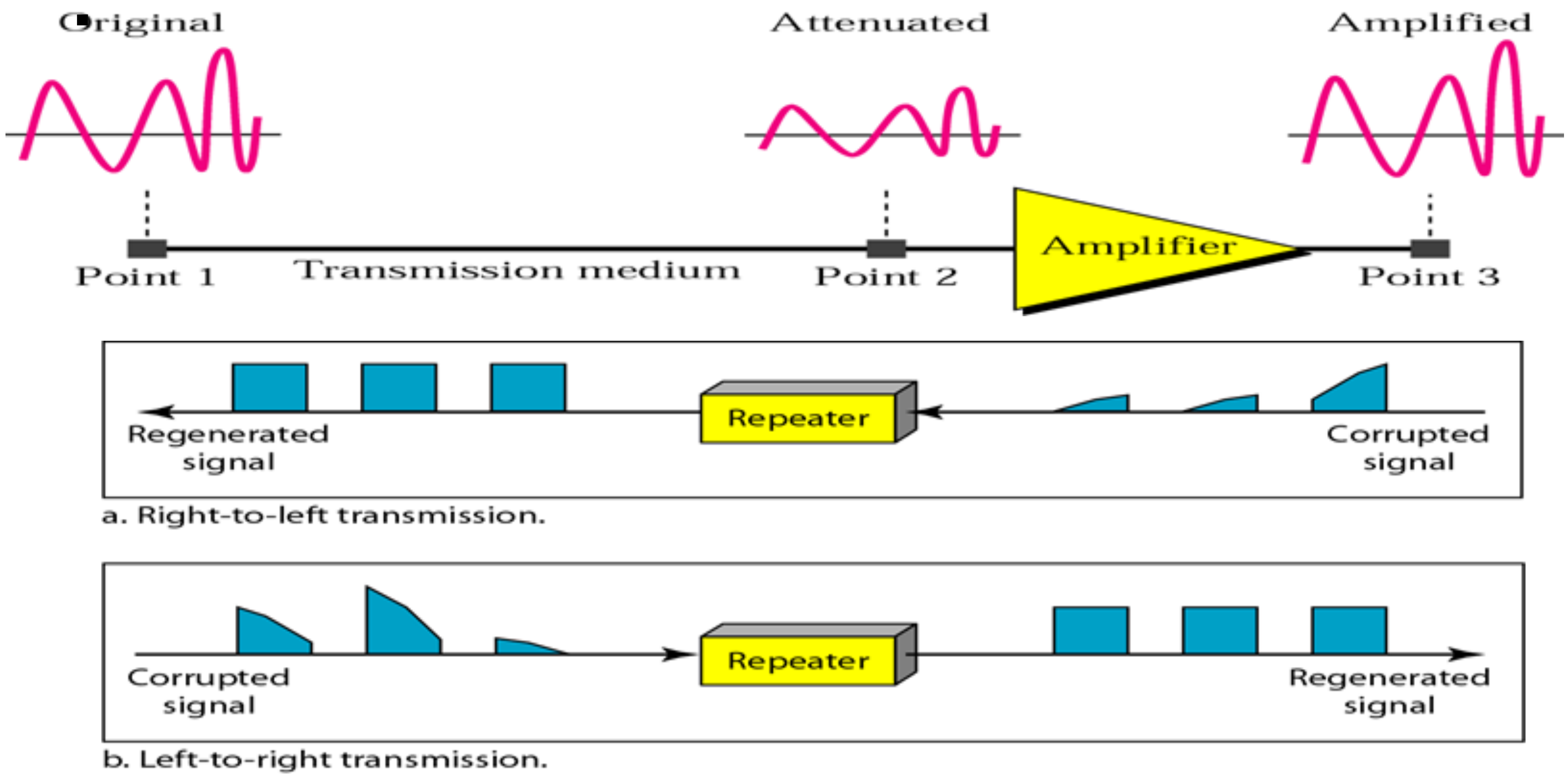
③ Crosstalk: Two wires

④ Impulse: anamolies happening around me spike, explosion…

- power lines

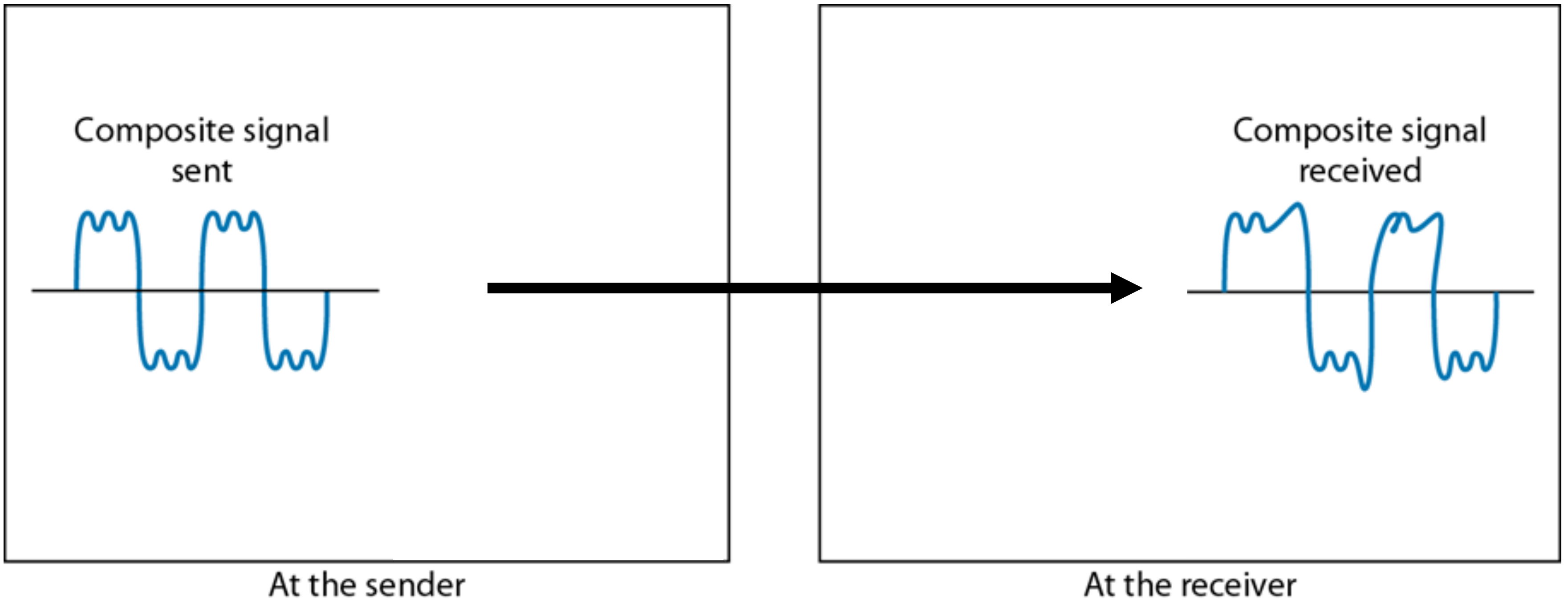
Attenuation

- Attenuation: **Loss of energy** due to **resisting the medium** (Signal strength falls off with distance)
- Increases with signal frequency
- Ex. A wire carrying electrical signal becomes warm after some time
- Amplifiers (analog signals) and repeaters (digital signals) are used to handle attenuation

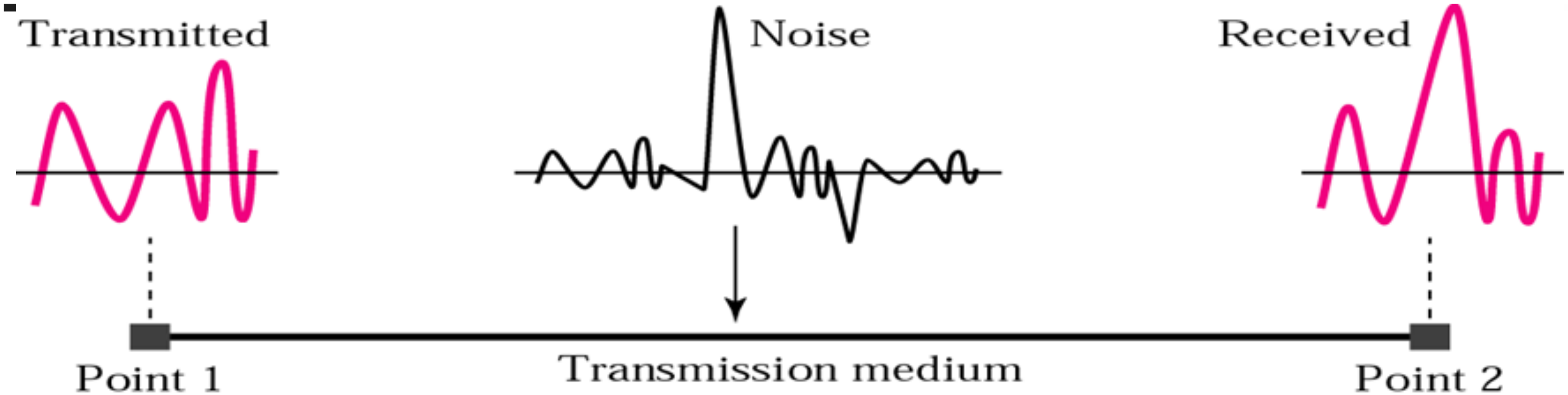


Distortion

- Distortion : **Signal changes in shape**
- Distortion will cause different bits to overlap
-



Noise



- **Thermal Noise** due to **random motion of electrons** in a wire which will create an **extra signal**
- **Induced Noise:** caused by motors and electrical equipments.
- **crosstalk noise** : Two wires beside each others (hearing another conversation in the background while talking with the phone)
- **Impulse noise:** irregular pulses or noise spikes of short duration and high amplitude
  - caused by **power lines or lightning**
  - **Very critical** in case of **digital signals** (primary source of error in digital data communication)

PERFORMANCE

Other Physical layer definitions:

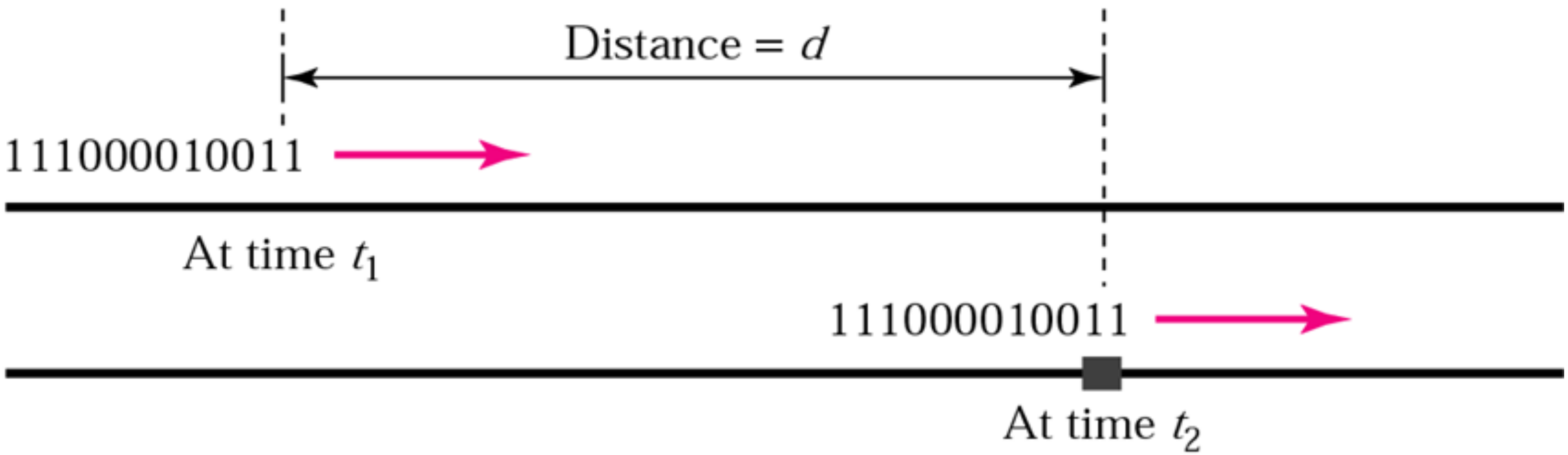
- **Propagation time**= time required for a bit to move between two nodes. (s)
  - Propagation time = **distance of the link (between the two nodes) / Propagation speed**
- **Propagation speed** : Speed of light in the medium.
- Depends on the medium
  - Light travels at $3x10^8$ m/s Vacuum (free space), lower in the air and much lower in a cable (2/3 in vacuum)

Because resistance
speeds

- vaccum → $3x10^8 \frac{m}{s}$
- air →
- cable

Propagation Time

$$\text{Propagation time} = t_2 - t_1 = d/\text{Propagation speed}$$



Other Physical layer definitions – Transmission Time

- **Transmission time** = The time it takes the sender to transmit (put) all the bits of a frame into the link (from NIC to Medium)

  - $$Transmission\,Time(\text{bps}) = \frac{\textbf{Length of frame (message) in bits}}{\textbf{bandwidth}}$$ → transmission speed

  - **Queuing Time** = Time needed for each intermediate device to hold the message before it can be processed.

- **Latency (delay): Total message delivery time = Transmission time + Propagation time + processing time+ queuing time**

Example

What are the propagation time and the transmission time for a 2.5-kbyte message (an e-mail) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4×10^8 m/s.

length/size = 2.5 kbyte × $\frac{1000 \text{ byte}}{1 \text{ kbyte}}$ = 2500 bytes × $\frac{8 \text{ bit}}{1 \text{ byte}}$ = 20000

bandwidth = 1 Gbps × $\frac{1000000000 \text{ bps}}{1 \text{ Gbps}}$ = 1000000000 bps

Solution

distance = 12000 km × $\frac{1000 \text{ m}}{1 \text{ km}}$ = 12000000 m

speed = 2.4×10^8 $\frac{m}{s}$

We can calculate the propagation and transmission time as shown on the next slide:

propagation time = $\frac{12000000}{2.4 \times 10^8}$ = 0.05 s

transmission time = $\frac{\text{length}}{\text{bandwidth}}$ = $\frac{2000 \text{ bit}}{1000000000 \text{ bps}}$ = 2×10^{-6} s

NOTES:

1. (length size) × 8 = bits
2. conversion factors MUST be memorized
3. From unit, should know given

Example (continued)

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{2500 \times 8}{10^9} = 0.020 \text{ ms}$$

Note that in this case, because the message is short and the bandwidth is high, the dominant factor is the propagation time, not the transmission time. The transmission time can be ignored.

Example

What are the propagation time and the transmission time for a 5-Mbyte message (an image) if the bandwidth of the network is 1 Mbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at 2.4×10^8 m/s.

Solution

We can calculate the propagation and transmission times as shown on the next slide.

Example (continued)

$$\text{Propagation time} = \frac{12{,}000 \times 1000}{2.4 \times 10^8} = 50 \text{ ms}$$

$$\text{Transmission time} = \frac{5{,}000{,}000 \times 8}{10^6} = 40 \text{ s}$$

Note that in this case, because the message is very long and the bandwidth is not very high, the dominant factor is the transmission time, not the propagation time. The propagation time can be ignored.

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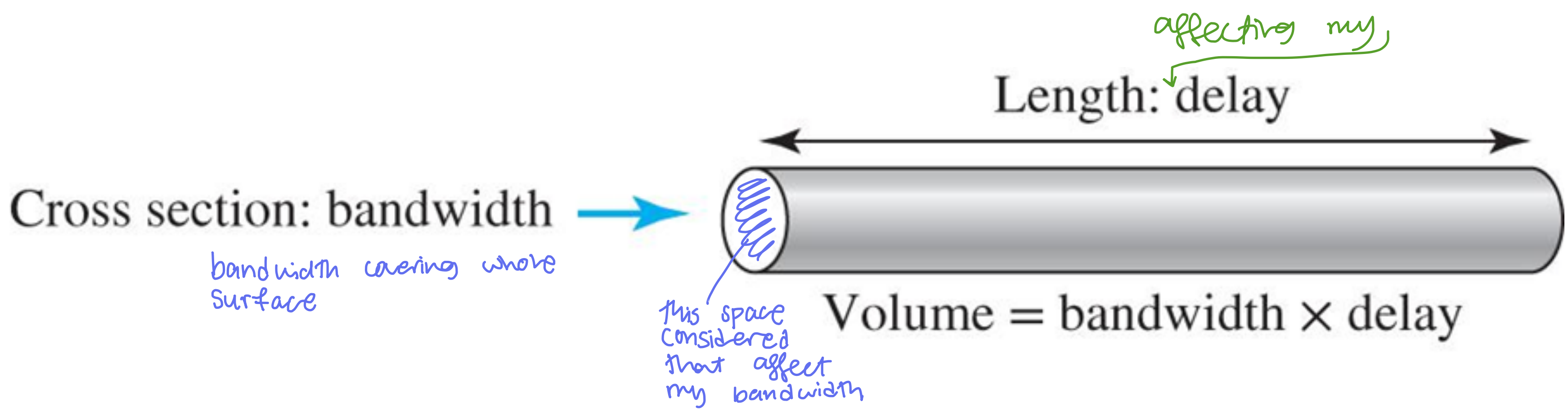
Figure 2.7 Bandwidth-delay product

Quiz 1: overview pt 1 & 2
physical pt 1 & 2

bandwidth-delay product = Length of the link in bits



Example

We can think about the link between two points as a pipe. The <u>cross section of the pipe represents the bandwidth</u>, and the <u>length of the pipe represents the delay</u>. We can say the <u>volume</u> of the pipe defines the <u>bandwidth-delay</u> product

Note

The bandwidth-delay product defines the number of bits that can fill the link.

Figure *Filling the link with bits for case 1*

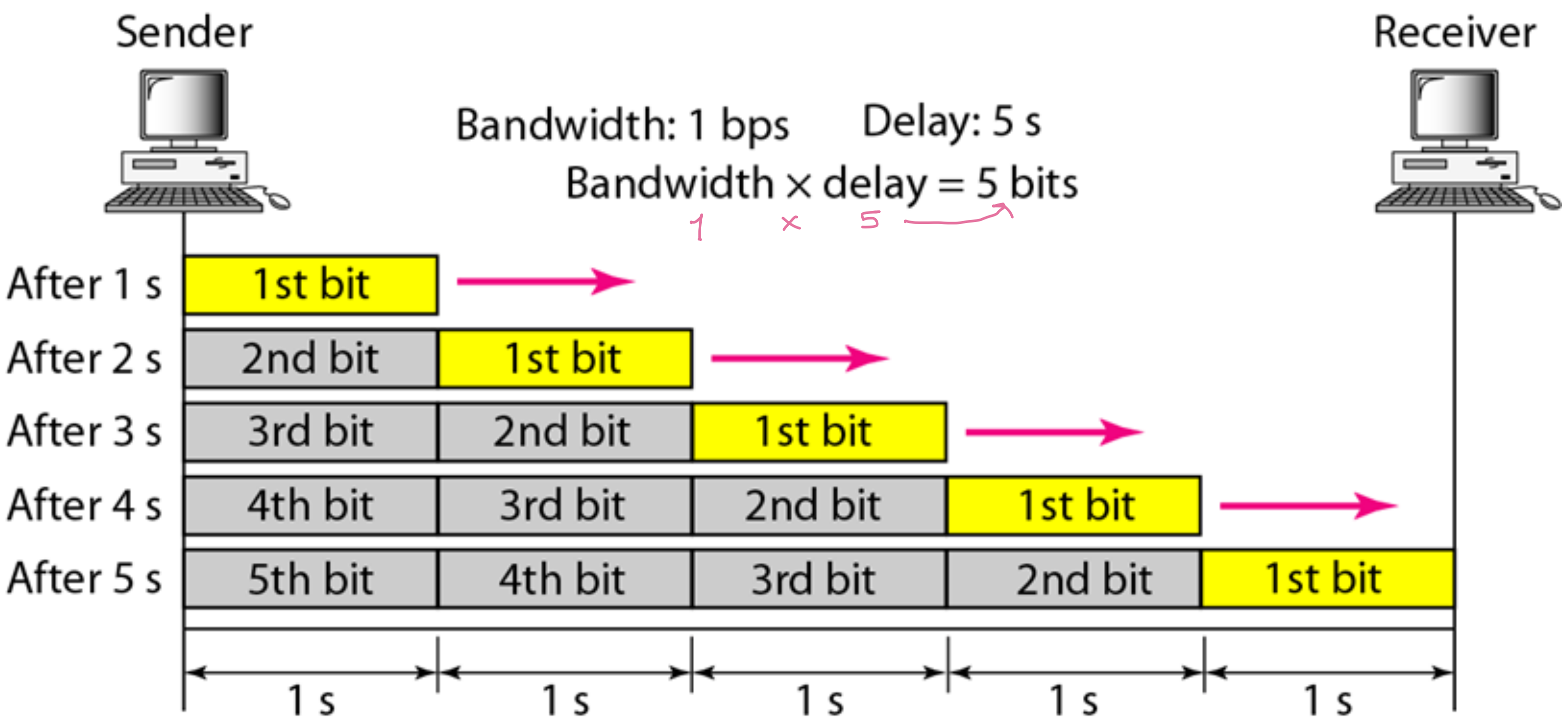
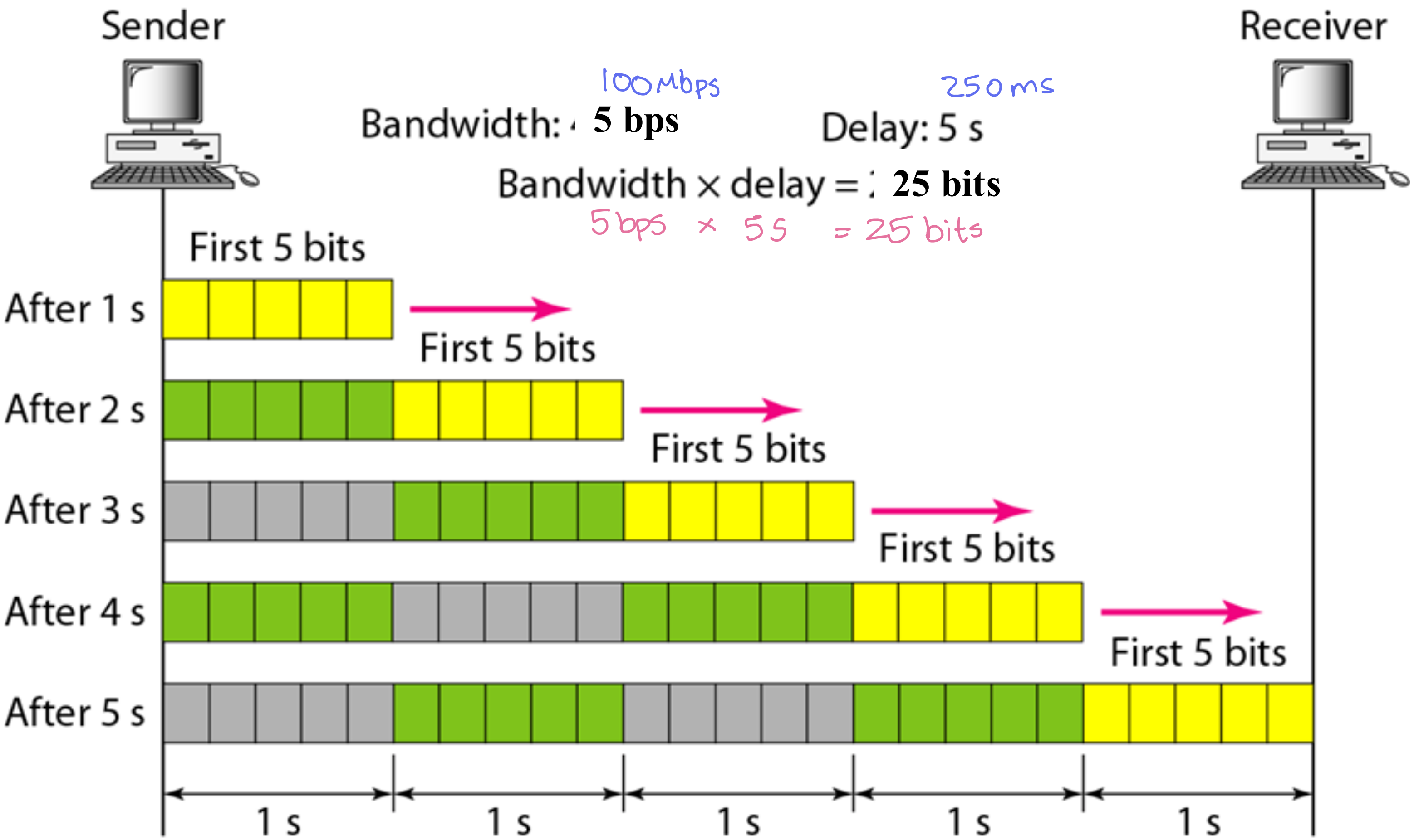
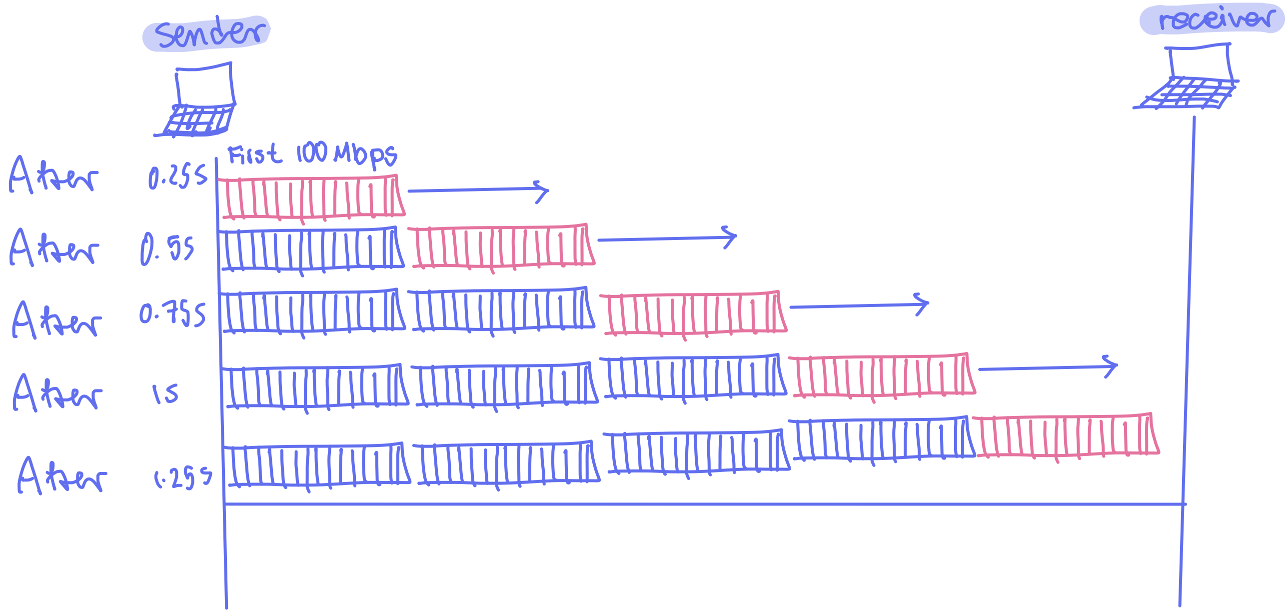


Figure *Filling the link with bits in case 2*



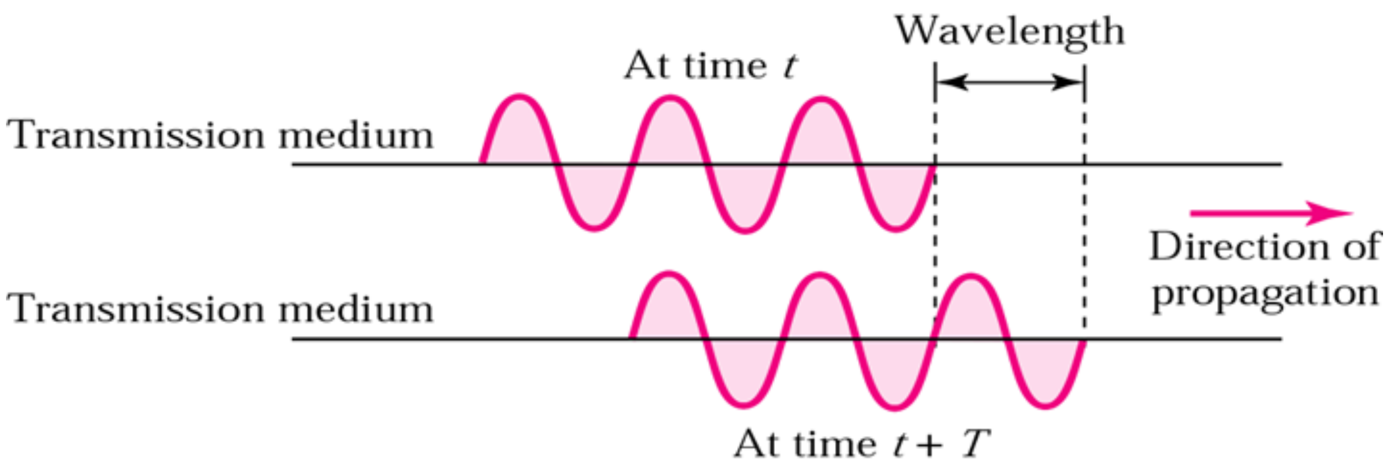

sender
receiver
First 100 Mbps
After 0.25s
After 0.5s
After 0.75s
After 1s
After 1.25s

Other Physical layer definitions - Wavelength

- **Wavelength:** the distance a **simple** signal can travel in one period (or the distance occupied by one cycle)

100 Mbps →

50 ms



- Depends on both the signal frequency and the medium
- Wavelength = Propagation speed x Period
  = Propagation speed / frequency

$\frac{3\times10^8 \frac{m}{s}}{5000000000} = 0.06 Hz$ | $\frac{2\times10^8 \frac{m}{s}}{193000000000000} = 1.036\times10^{-5} Hz$