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Physical Layer

Presented by Tran Thanh Dien

Contents

- Present core components of a data transmission network
- Identify issues related to a computer based data transmission network
- Introduce methods of digitization
- Present characteristics of communication channel and cable features
- Introduction line coding methods

Outcome

- List the issues related to a computer-based data transmission network
- Describe different digitization methods
- Differentiate and calculate parameters of a channel such as Bandwidth, Baud rate, Data rate, Bruits, Channel Capacity, Traffic
- Encoding data using different line coding methods

Functions of Physical Layer

- Responsible for transmission and reception of data bits through communication channel
- The foundation for building communication networks
- The physical characteristics of electrical or optical signaling techniques
- Bit representation: encode bits into electrical or optical signal
- Transmission rate: Number of bits sent each second

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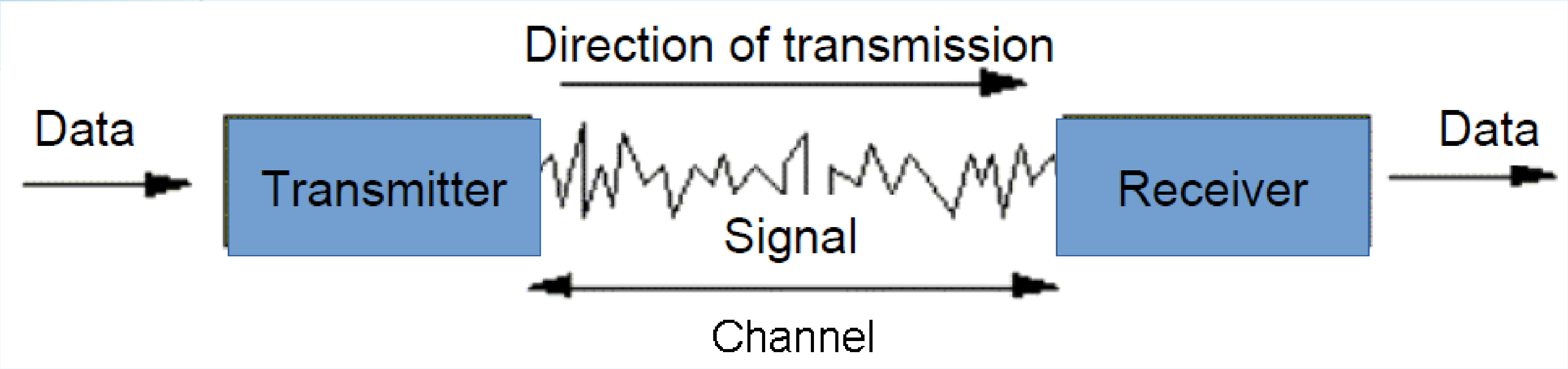
- Synchronizing the sender and receiver clocks (bit rate)
- Transmission mode: Simplex, half-duplex, full duplex
- Line configuration: connect devices to the media (P2P, multipoint,…)
- Topology: How devices are connected (star, ring, bus, mesh topology)

A Simple data Communication model



Issues related to data communication systems:

- Data and Signal
- How to digitize information
- Types of channel can be used for data transmission
- Connection schema of communication devices
- Methods for transmitting raw bit from hosts to hosts

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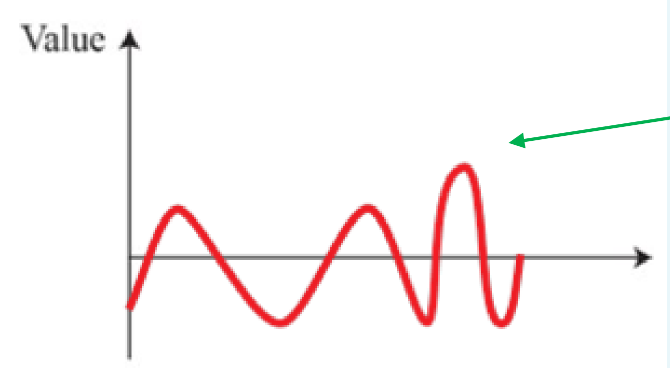
Data and Signals

Data

- Data: A set of recorded facts, numbers, or events.
- Data is meaningless until it is given relevance
- Data are propagated from one point to another by means of electrical signals
- Data can be analog or digital.
  - Analog data takes on continue values, e.g., voice, video
  - Digital data takes on discrete values, e.g., integers, ASCII text

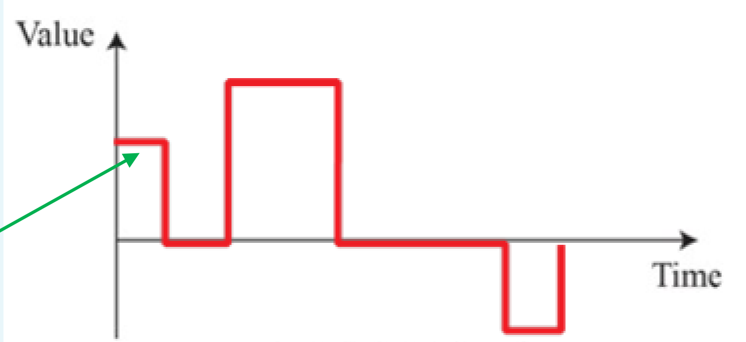
Signals

- Signal: gesture, action, sound used to convey information or instructions.
- It is the means used to transmit data.
- Signal can be analog or digital:



a. Analog signal

An analog signal has infinitely many levels of intensity over a period of time



b. Digital signal

A digital signal has limited number of defined values

Signals

- Analog signal: changes continuously.
- Digital signal: having discrete set of values, e.g., sequence of voltage pulses transmitted over a wire medium.
- Digital data can be represented by analog signals using a modem (modulator/demodulator).
- Analog data can be represented by digital signals using a codec (coder-decoder).

Four combinations of data and signals

Data	Signal	Encoding or Conversion Technique	Common Devices	Common Systems
Analog	Analog	AM and FM	Radio tuner TV tuner	Telephone; AM and FM radio; Broadcast TV; Cable TV
Digital	Digital	NRZ-L; NRZI; Manchester; 4B/5B	Digital encoder	Local area networks Telephone systems
Digital	(Discrete) Analog	Amplitude/Frequency/Phase shift keying	Modem	DSL; Cable modems; Digital Broadcast TV
Analog	Digital	Pulse code and Delta modulation	Codec	Telephone systems; Music systems

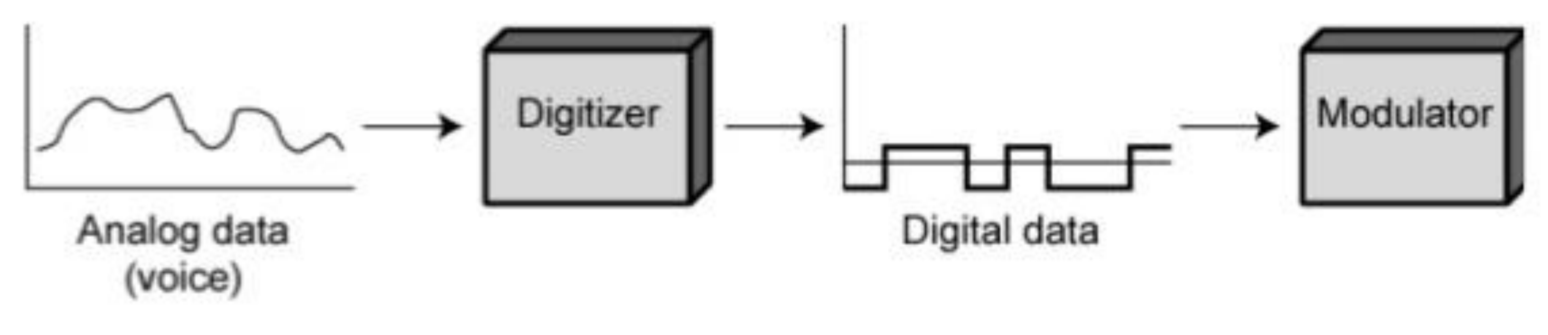
Digital Signals

- Digital signaling is:
  - Cheaper
  - Less susceptible to noise interference
  - Suffers more attenuation.

Digitization

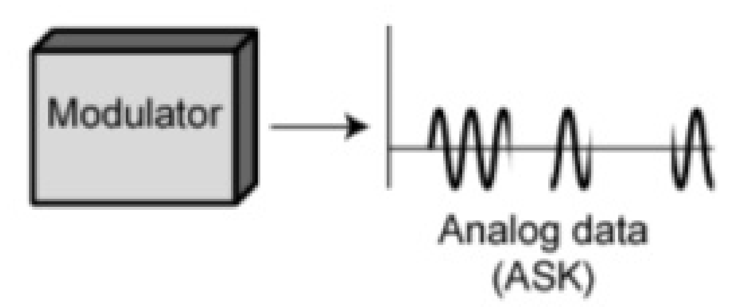
Digitization

- Conversion of analog data into digital data



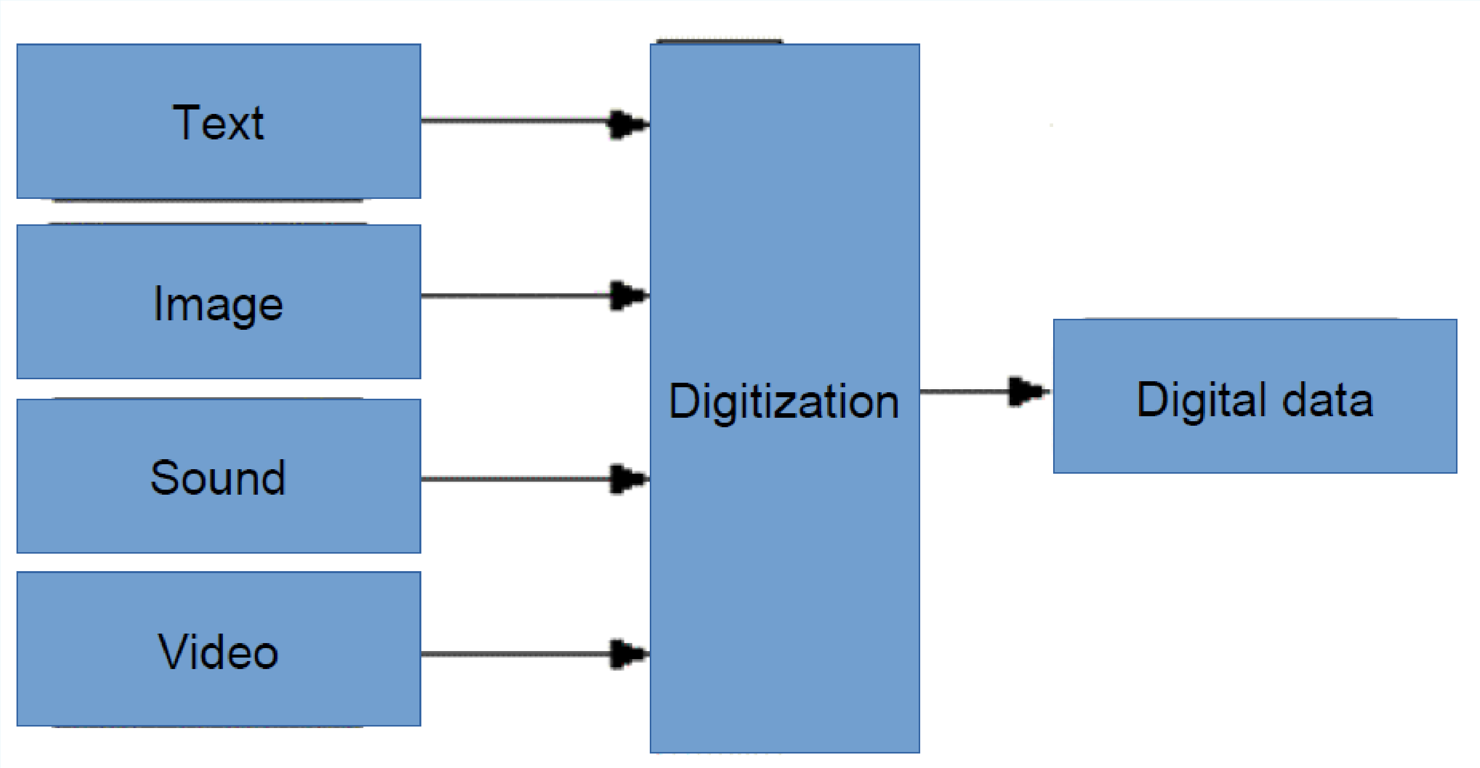
- Digital data can be transmitted using digital signaling technique (e.g., RZ, NRZI,…)

- Digital data can be represented by analog signal.

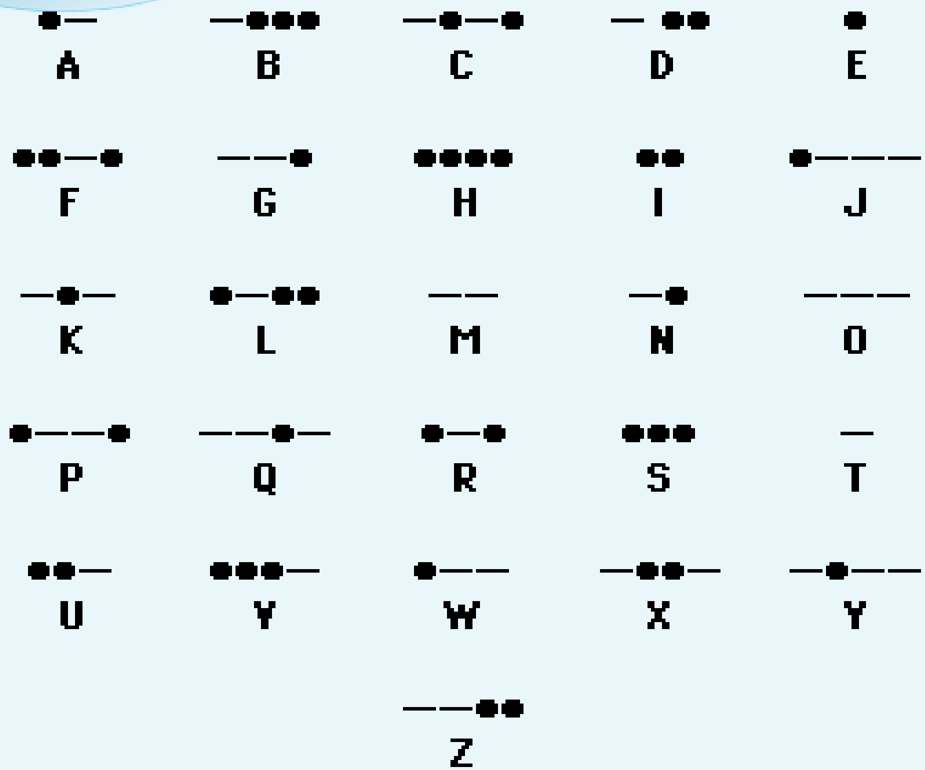


Digitalization

- Digitization model



Digitization of Text



Morse Code

poids forts

poids faibles

	000	001	010	011	100	101	110	111
0000	NUL	DLE	SP	0	@	P	\	p
0001	SOH	DC1	!	1	A	Q	a	q
0010	STX	DC2	"	2	B	R	b	r
0011	ETX	DC3	#	3	C	S	c	s
0100	EOT	DC4	$	4	D	T	d	t
0101	ENQ	NAK	%	5	E	U	e	u
0110	ACK	SYN	&	6	F	V	f	v
0111	BEL	ETB	,	7	G	W	g	w
1000	BS	CAN	(	8	H	X	h	x
1001	HT	EM	)	9	I	Y	i	y
1010	LF	SUB	*	:	J	Z	j	z
1011	VT	ESC	+	;	K	[	k	{
1100	FF	FS	'	<	L	Ç	l	ù
1101	CR	GS	-	=	M	]	m	}
1110	SO	RS	.	>	N	↑	n	≈
1111	SI	US	/	?	O	<--	o	DEL

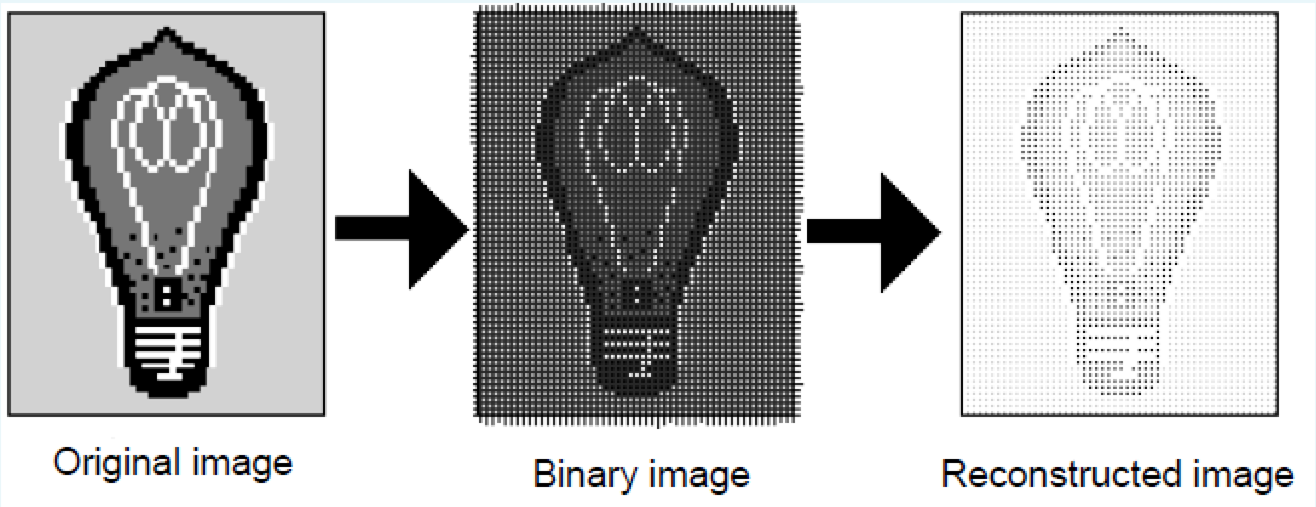
code ASCII

Digitization of Text

- **8 bits code:**
  - ASCII - American Standard Code for Informatics Interchange
  - Mã EBCDIC - Extended Binary-Coded Decimal Interchange Code
  - Cannot represent symbols other than those found in the English language
- **6 bits code: Unicode**
  - Provides a unique coding value for every character in every language

Digitization of images

- An image consists of number of lines
- Each line consists of number of pixels
- Example: An image of resolution 640x480 has 480 lines and each line has 640 pixels

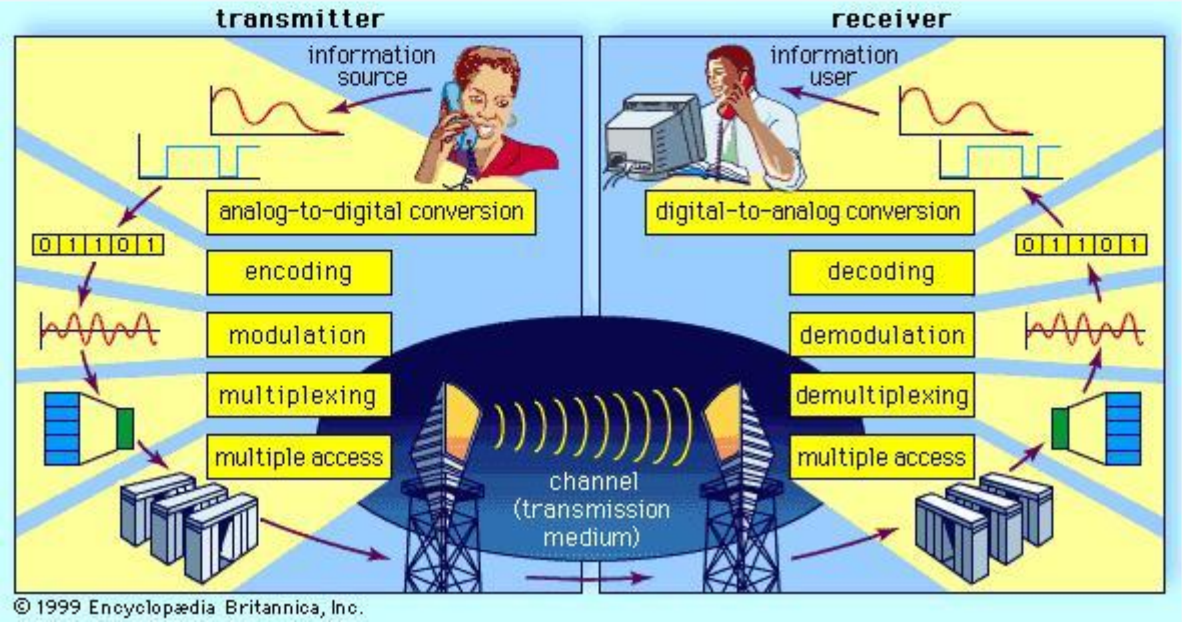


Digitization of images

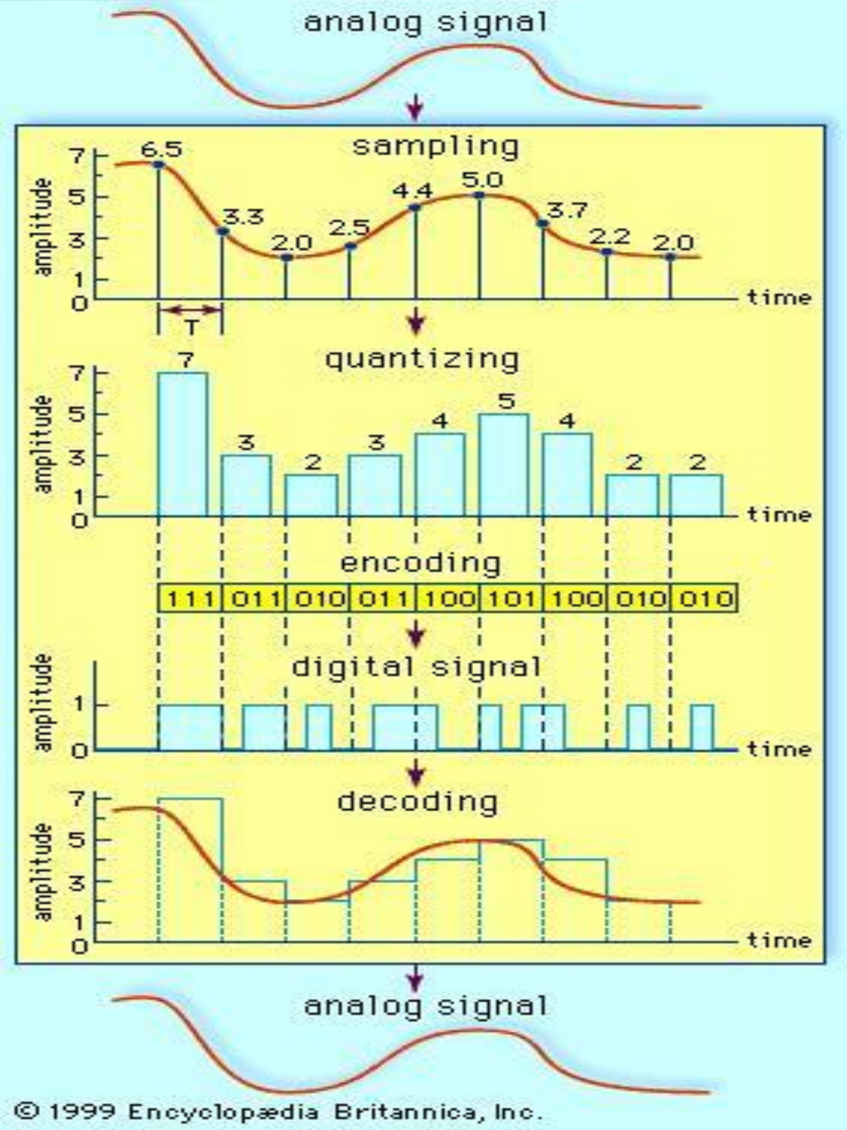
- Black & White images : 0: Black, 1: White
- Images for 256 gray level : 8 bits / pixel
- Color images: 1 pixel = aR + bG +cB
- The size of color image is large => need methods to reduce image size: Compression (GIF, JPEG, PNG,…)

Digitization of sound and movie

- Most voice, radio, and television communication are analog data (signals)
- Analog data should be converted to digital



Digitization of sound and movie



- **Sampling**: measuring the amplitude of the analog waveform at equally spaced discrete instants of time
- **Quantization:** each sampled amplitude must be converted to one of a finite number of possible values, or levels.
- **Bit mapping:** Mapping levels into a binary sequence and then store or transmit them.

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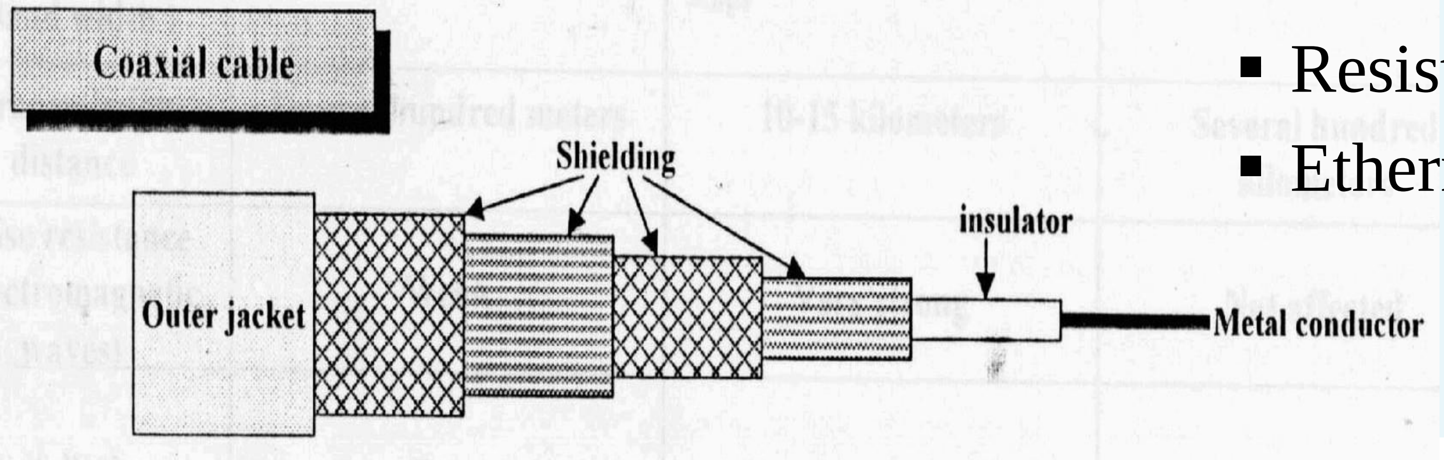
Communication Channels

Wired communication media

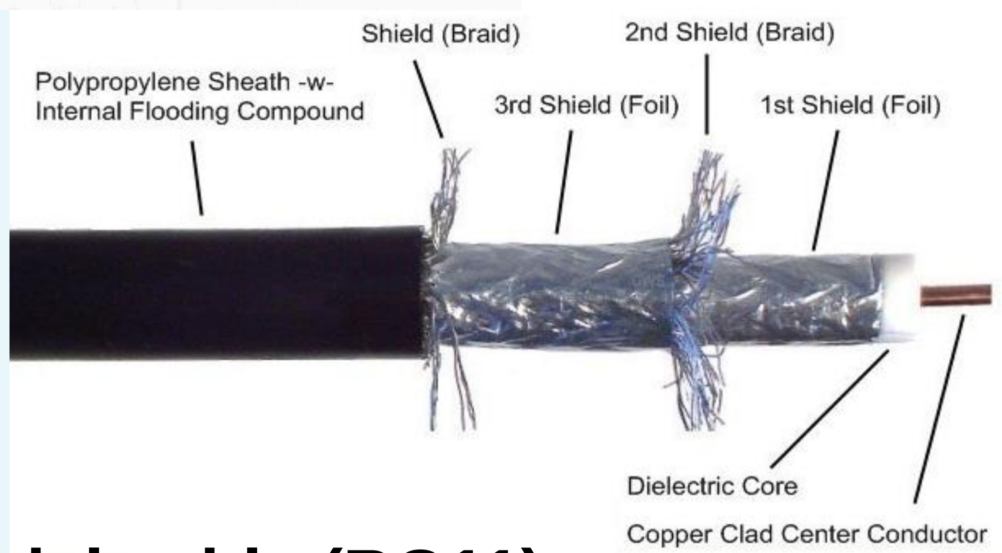
- **3 popular cable:**
  - Twisted pair cable
  - Coax cable
  - Fiber optic cable
- **Factors for choosing cable:**
  - **Price**
  - **Network diameter**
  - **Number of hosts in network**
  - **Requirement of bit rate**
  - **Requirement of bandwidth**

Coax cable



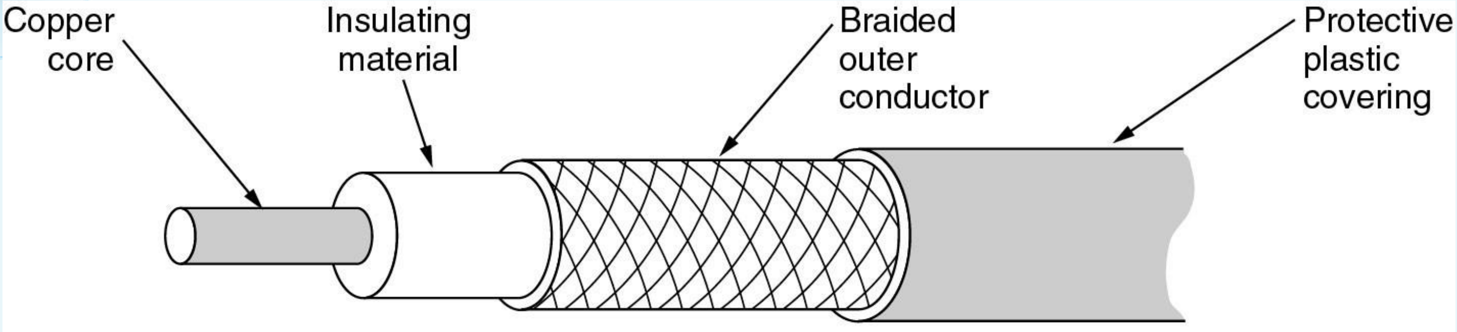
- Resistence: 50 Ω
- Ethernet 10-BASE5

- Connnector: AUI, BNC, T
- Length: 500 m
- Speed: 10Mbps



Thick coaxial cable (RG11)

Coax cable



- **Resistence: 50 Ω**
- **Ethernet 10-BASE2**
- **Connector: AUI, BNC, T**
- **Length: 185 m**
- **Speed: 10Mbps**

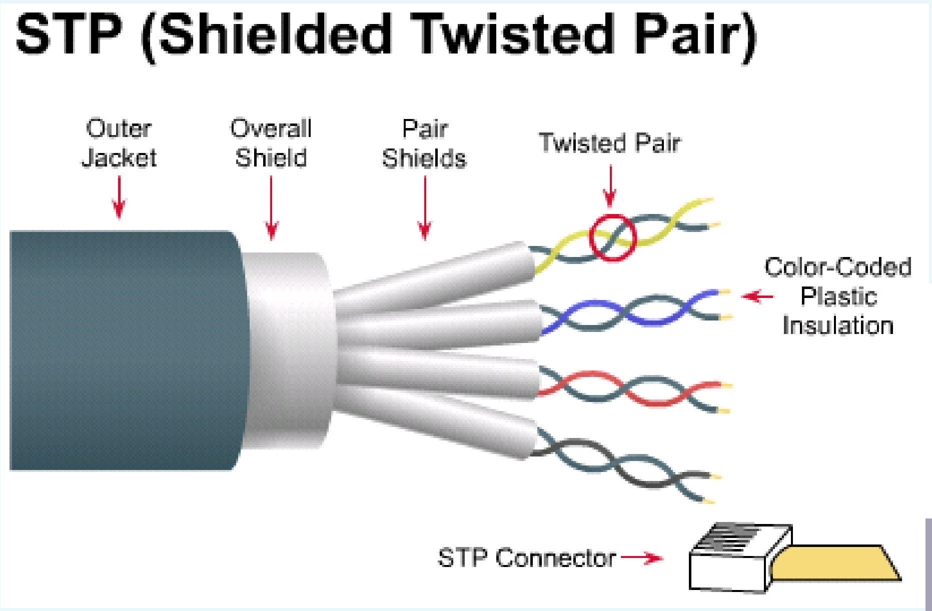
Thin coaxial cable (RG58)

AUI (15-pin)

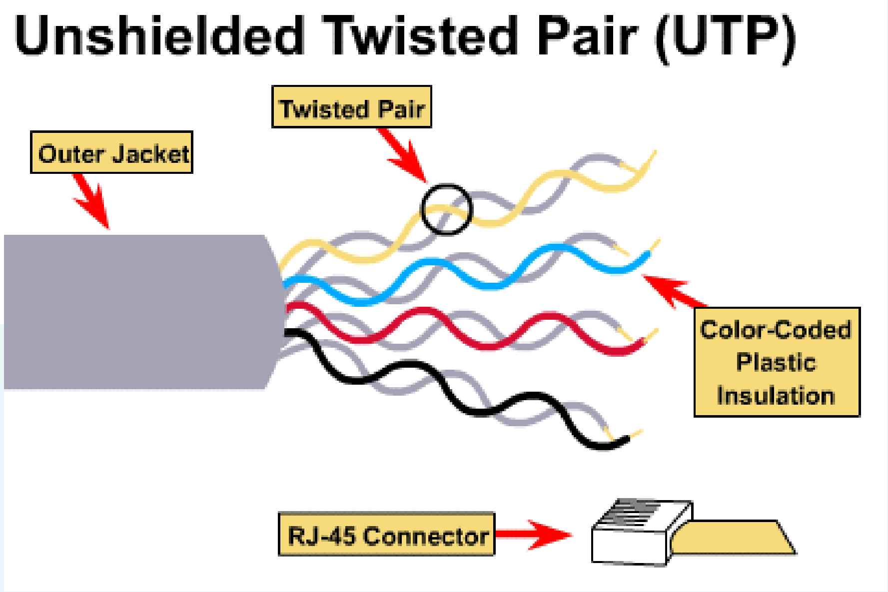
T-Connector

BNC

Twisted pair cable



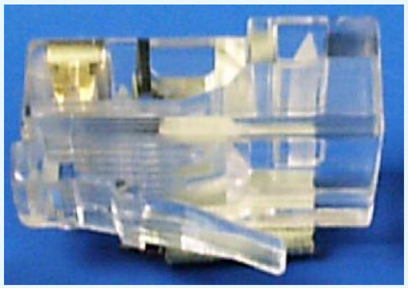
Mã length: 100m

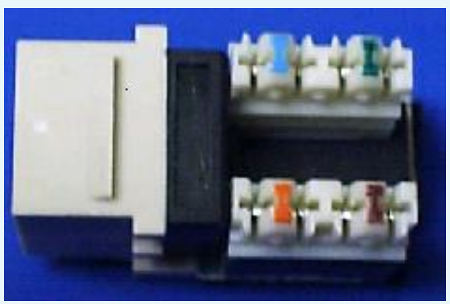


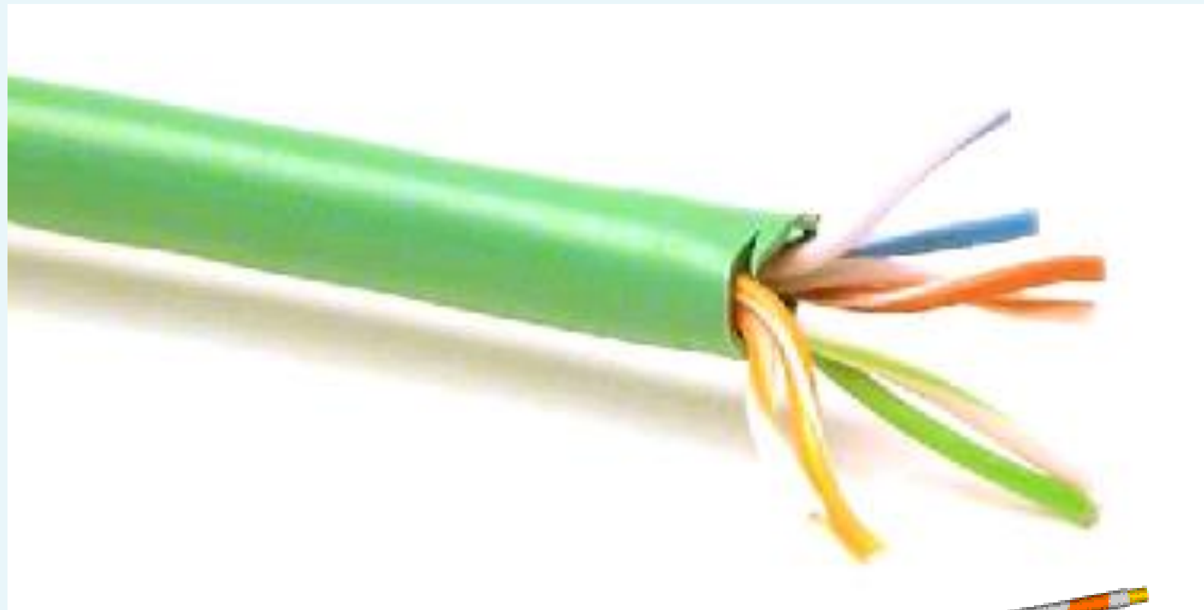
Twisted pair cable

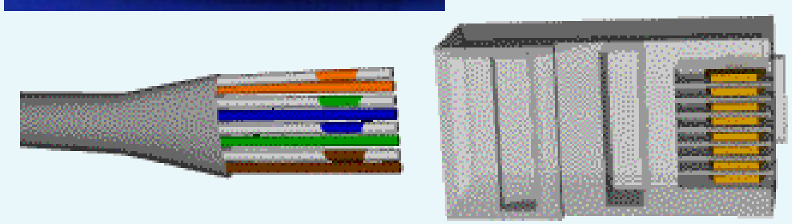
UTP Categories - Copper Cable				
UTP Category	**Data Rate**	**Max. Length**	**Cable Type**	**Application**
CAT1	Up to 1Mbps	-	Twisted Pair	Old Telephone Cable
CAT2	Up to 4Mbps	-	Twisted Pair	Token Ring Networks
CAT3	Up to 10Mbps	100m	Twisted Pair	Token Rink & 10BASE-T Ethernet
CAT4	Up to 16Mbps	100m	Twisted Pair	Token Ring Networks
CAT5	Up to 100Mbps	100m	Twisted Pair	Ethernet, FastEthernet, Token Ring
CAT5e	Up to 1 Gbps	100m	Twisted Pair	Ethernet, FastEthernet, Gigabit Ethernet
CAT6	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT6a	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (55 meters)
CAT7	Up to 10Gbps	100m	Twisted Pair	GigabitEthernet, 10G Ethernet (100 meters)

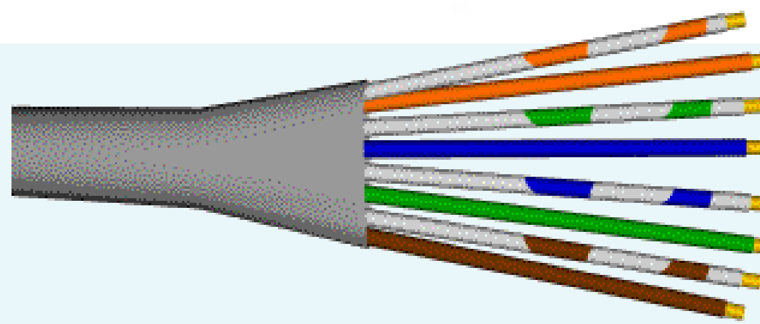
Twisted pair cable



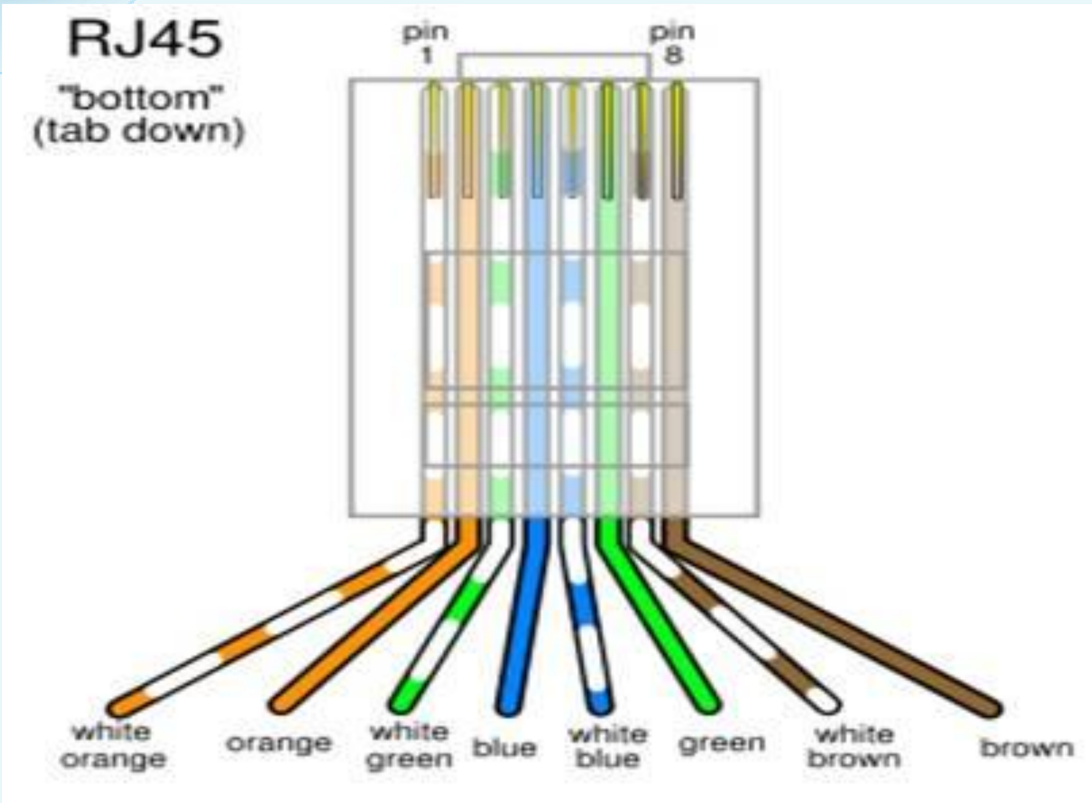


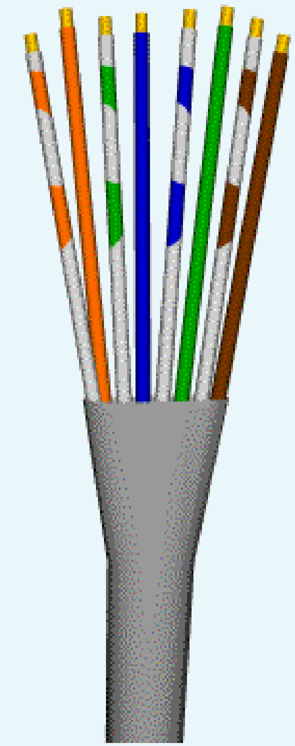


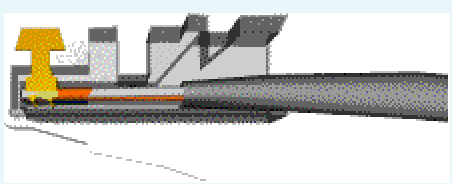


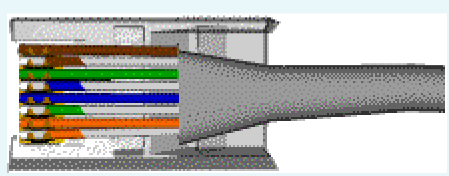


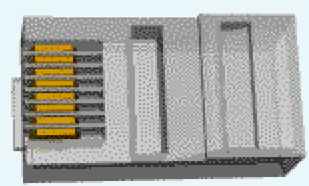
EIA/TIA-568B Ethernet Cable Wiring

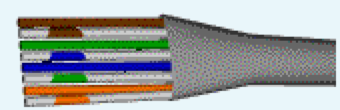




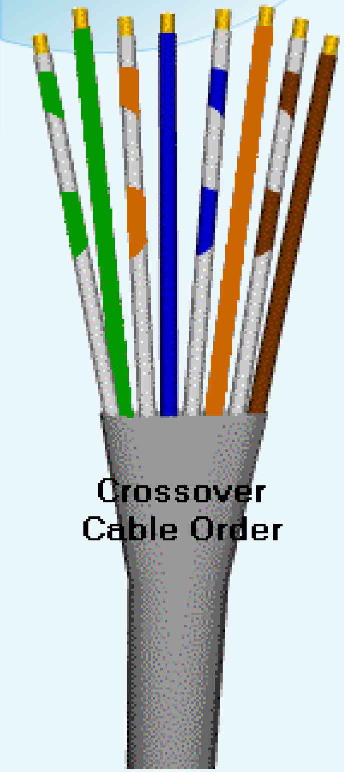


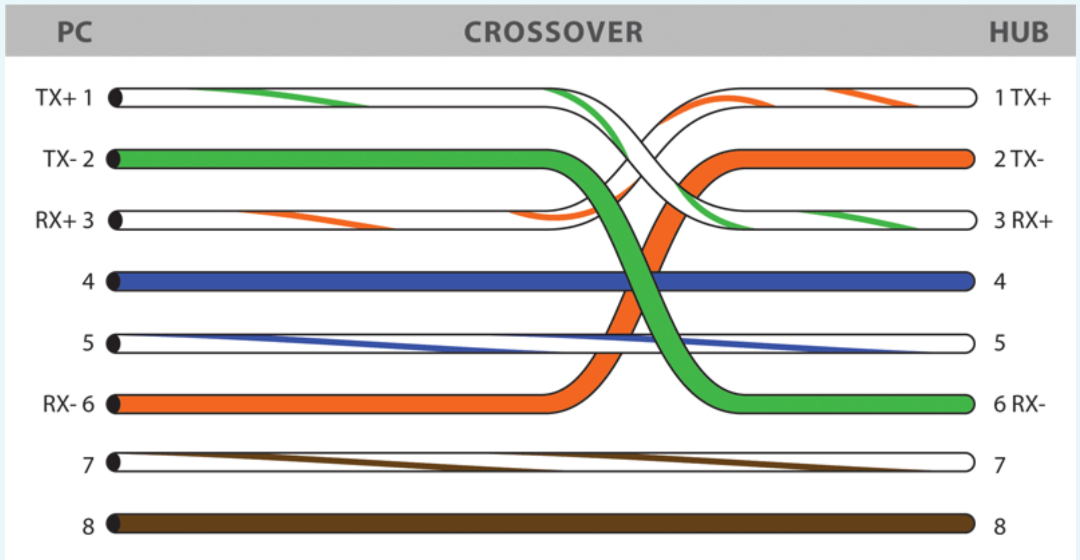


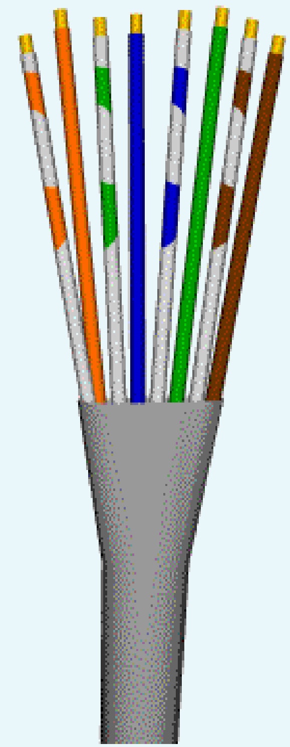




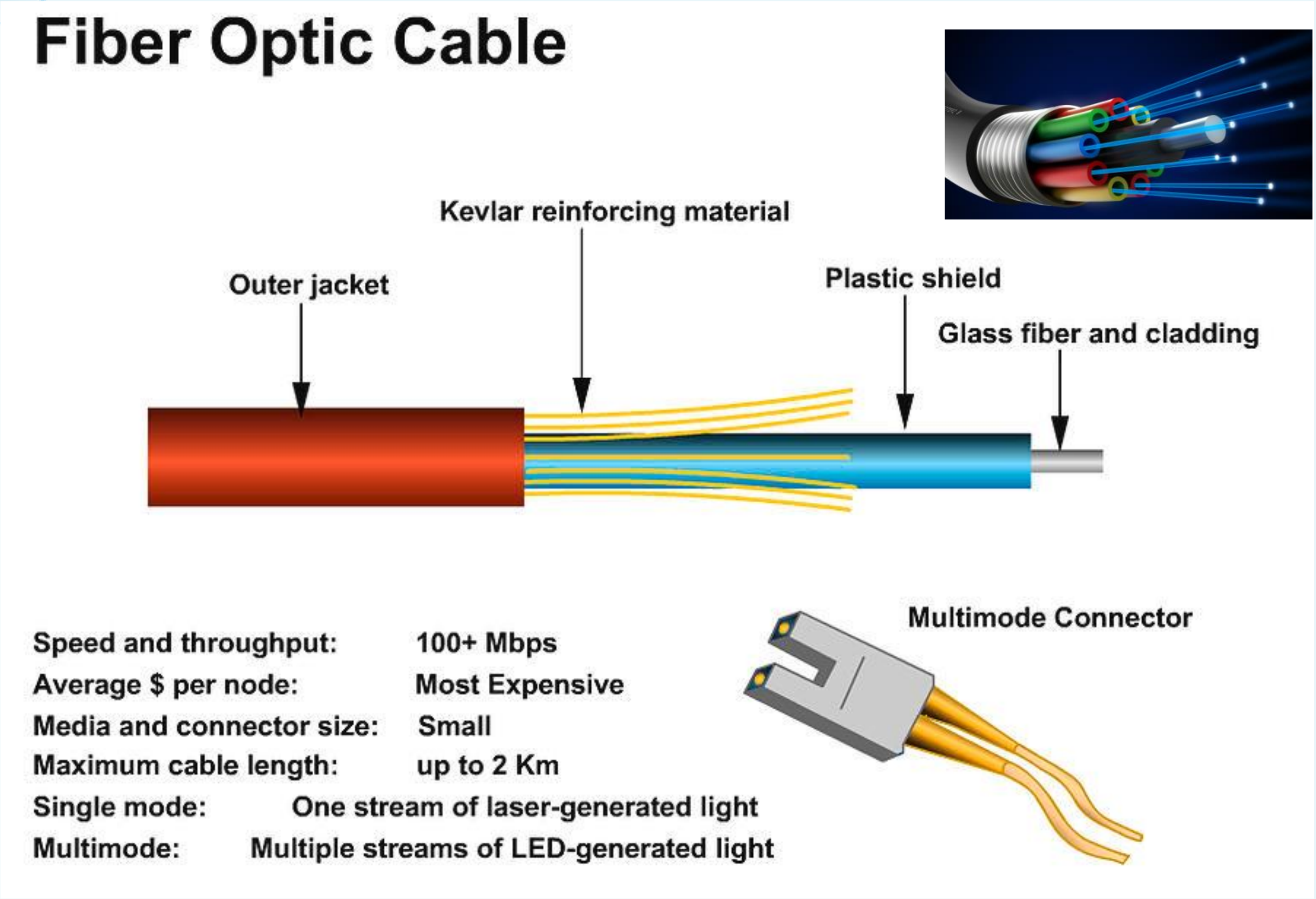
Cách bấm dây UTP
Theo chuẩn EIA/TIA-568B (Bấm chéo)



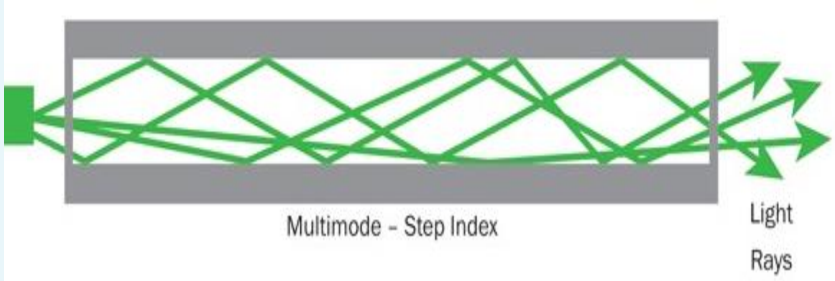




Fiber optic cable



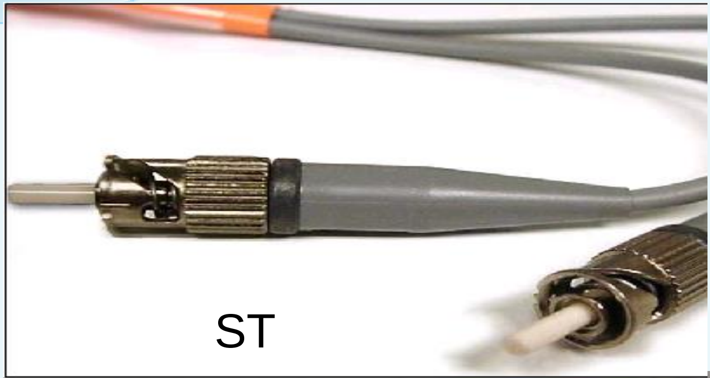
Fiber optic cable

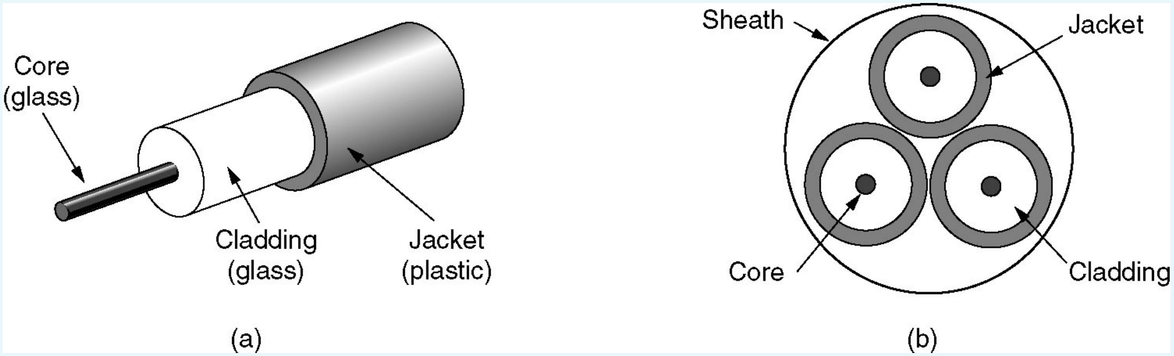


Single-Mode	Multimode
• Small core • Less dispersion • Carry a single ray of light, usually generated from a laser. • Employ for long distance applications (100Km) • Uses as Backbone and distances of several thousands meters.	• Larger core than single mode cable. • Allows greater dispersion and therefore, loss of signal. • Used for shorter distance application, but shorter than single-mode (up to 2Km) • It uses LED source that generates differtes angles along cable. • Often uses in LANs or small distances such as campus networks.

Dr Ajay N Phirke

Fiber optic cable



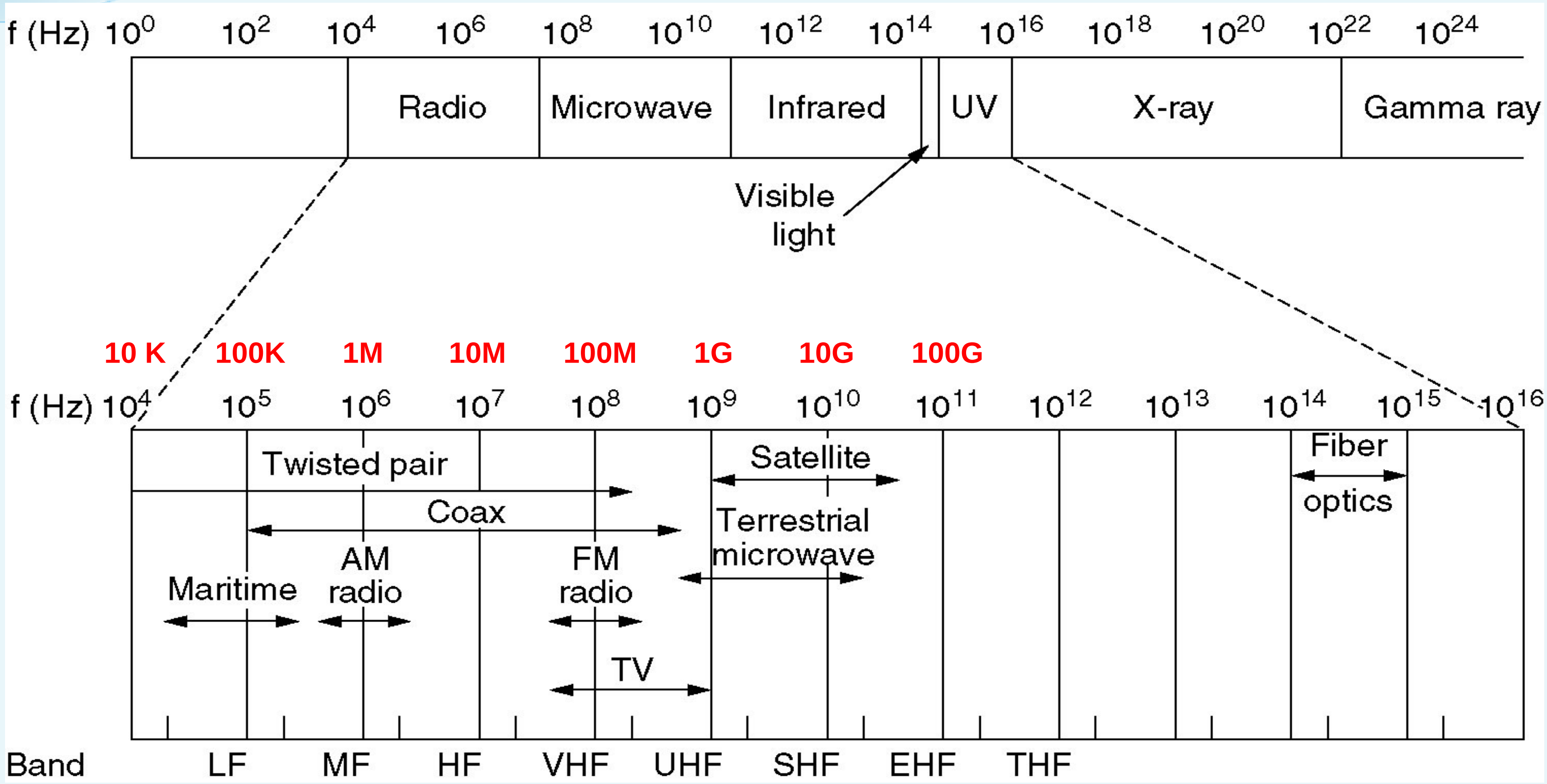


Wireless communication media

- Using electromagnetics as the means to transfer data
- 3 important parameters of wireless signal
  - c : Speed of light
  - f: Frequency of wave
  - λ:Length of wave

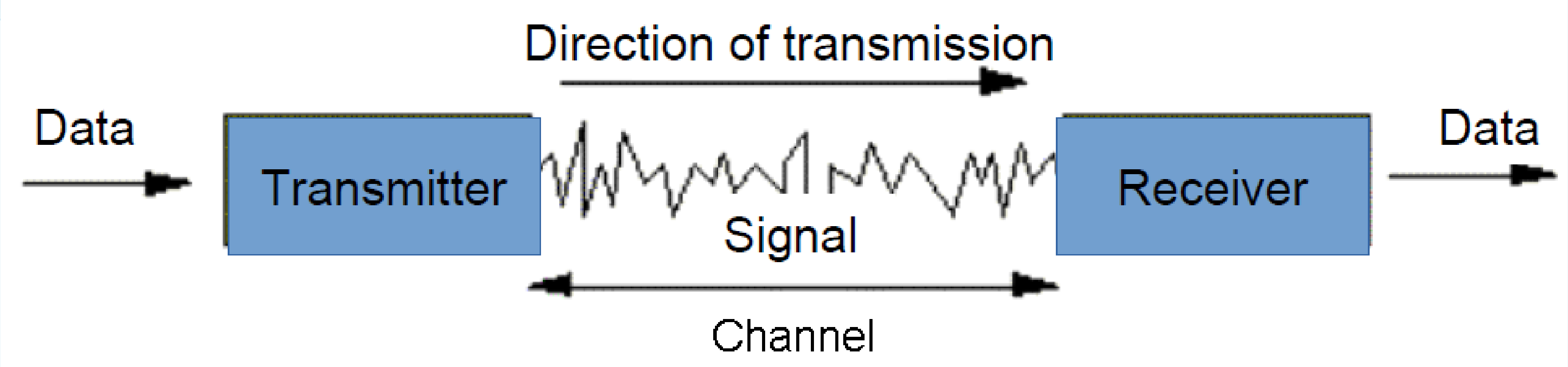
  => $c = \lambda f$

Wireless communication media



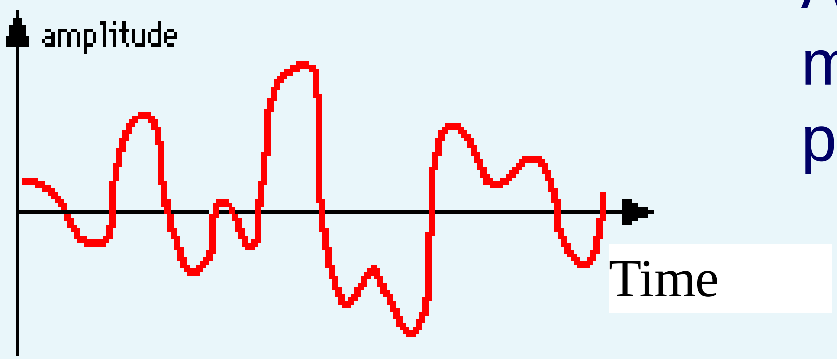
Characteristics of Communication Chanel

Analog and Digital Signal

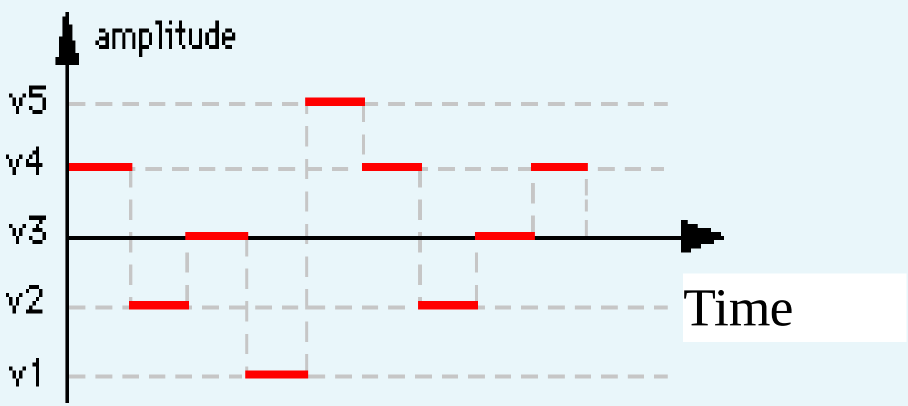


•Data (bits 0, 1) are transmitted from one device to another using analog signals or digital signals.

Tín hiệu tuần tự & Tín hiệu số



An analog signal has infinitely many levels of intensity over a period of time



A digital signal has limited number of defined values

Sine wave

- Most fundamental form of periodic analog signal
- Not declined or ended after a period of time and can be produced easily
- Mathematically Sine Wave signal described by the formula:

$$s(t) = A\sin(2\pi ft + \phi)$$

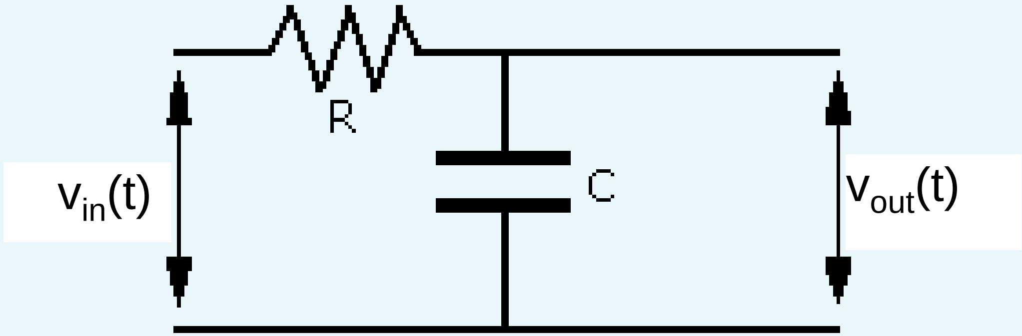
  - peak amplitude (A) – absolute value of signal's highest intensity – unit: volts [V]
  - frequency (f) – number of periods in one second – unit: hertz [Hz] = [1/s] – inverse of period (T)
  - phase (φ) – absolute position of the waveform relative to an arbitrary origin – unit: degrees [º] or radians [rad]

Sine wave

- **According to Fourier Analysis**: Any composite signal can be represented as a combination of simple waves with different frequencies, phases, and amplitudes.
- A periodic signal can be represented by a series of sine waves with discrete frequencies.
- Any aperiodic signal can be represented as a combination of simple waves with continue frequencies.

A Simple communication channel

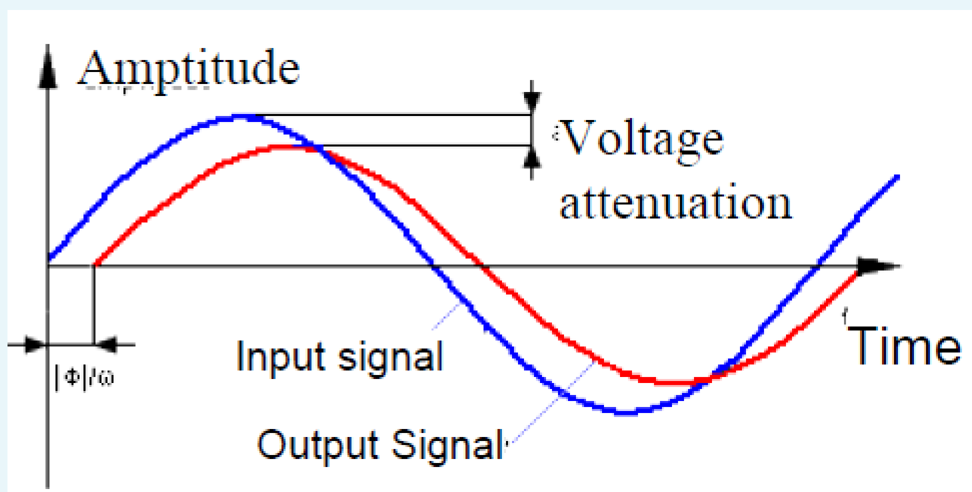
- A Simple communication channel



- $v_{in}(t) = \mathbf{V}_{in} \sin wt$
  - $\mathbf{V}_{in}$: Amplitude of voltage at input
  - w: Radian Frenquency; f = w/2pi : Frequency;
  - T = 2pi/w = 1/f : Period.
- $v_{out}(t) = V_{out} \sin (wt + F)$
  - $\mathbf{V}_{out}$: Amplitude of voltage at Output
  - F : Phase .

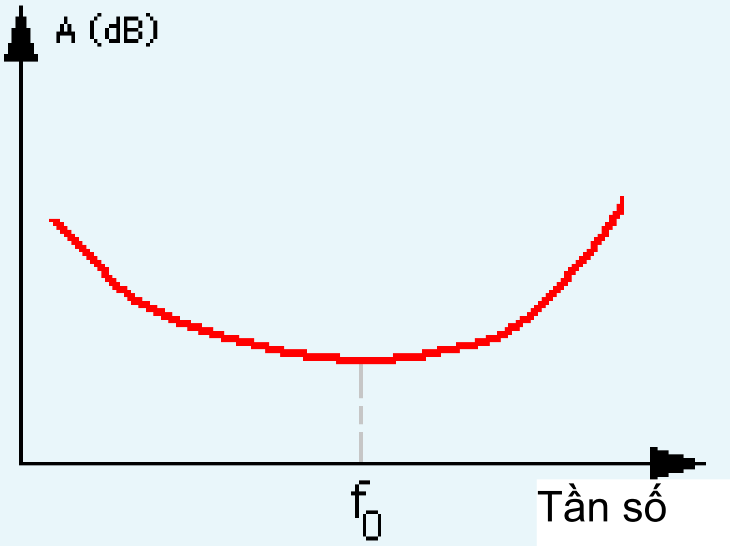
Characteristics of communication channel

- According to Electromagnetism law, in simple cases:
  - $Vout/Vin = (1 + R^2C^2w^2)^{-1/2}$
  - $F = atan(-RCw$



Loss of signal

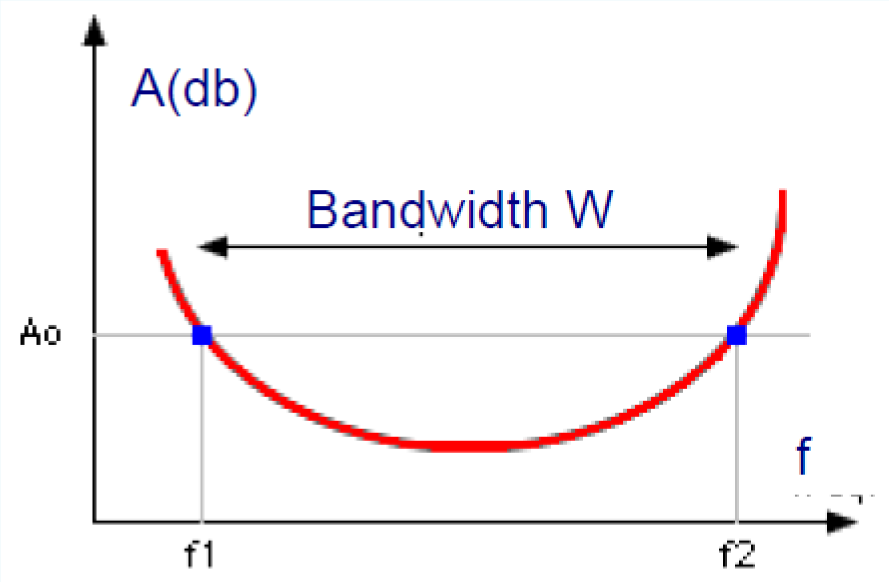
- Loss of signal = Pin/Pout
- Calculated in decibel:
- A(w) = 10 log10(Pin/Pout)



- The nearer to f_0 the frequency of the signal is , the less the loss of signal is

Bandwidth

- A0: Threshold of hearing
  - Sine waves which frequencies are lower than f1 or grater than f2 are considered as lost
  - Sine waves which frequencies are between f1 and f2 can be received at output
  - Range of frequencies from f1 to f2 is called bandwidth of a physical channel.



Example: Bandwidth of a telephone channel is about 3100 Hz because frequencies of voice that people can hear are in range from 300 Hz to 3400 Hz

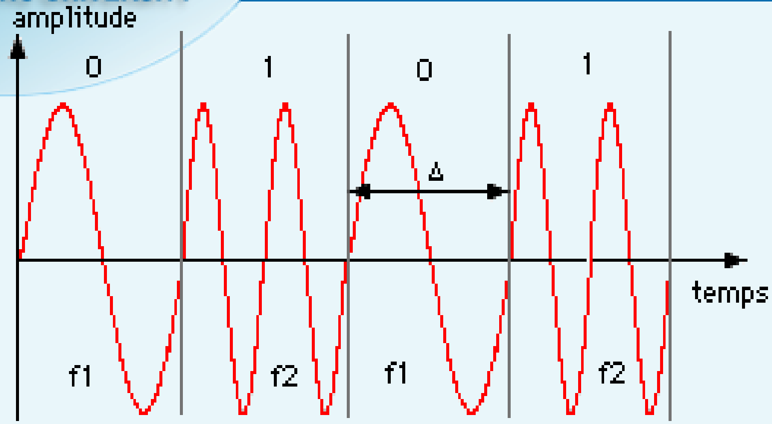
Baud rate and Data rate

- Baud rate R: the number of distinct symbol changes made to the transmission medium in a second
  - $R = 1/t$ (bauds),
  - t: length of signal
- Data rate/bit rate D: the number of bet can be transmitted in a second
  - Each signal carries n bit
  - $D = nR$ (bits/s)
- Example: Given a transmission systems

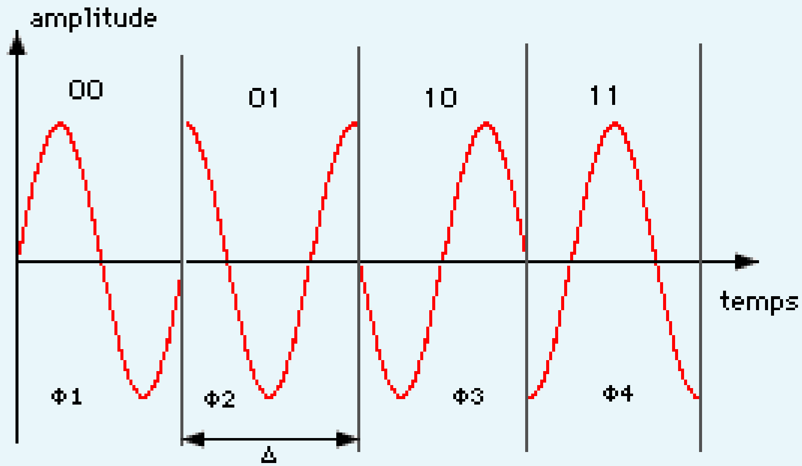
  R = 1200 bauds và D = 1200 bits/s.

  → each signal carriers only one bit

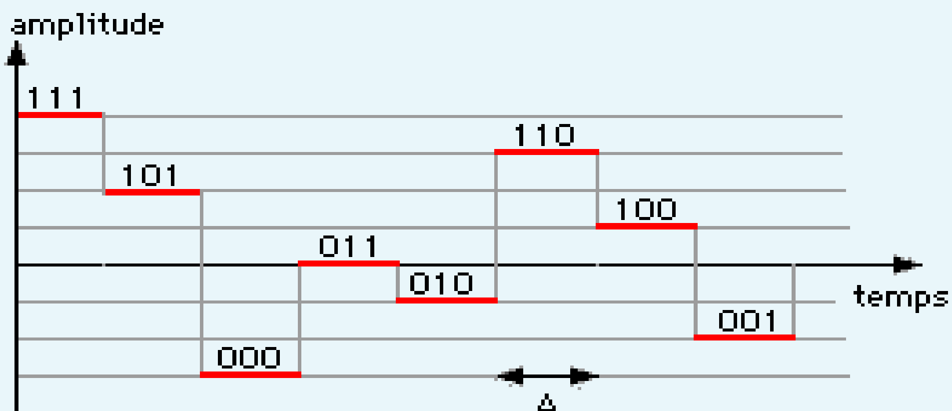
Example of baud rate & data rate



R = 1/Δ **D = R**



R = 1/ Δ **D = 2R**



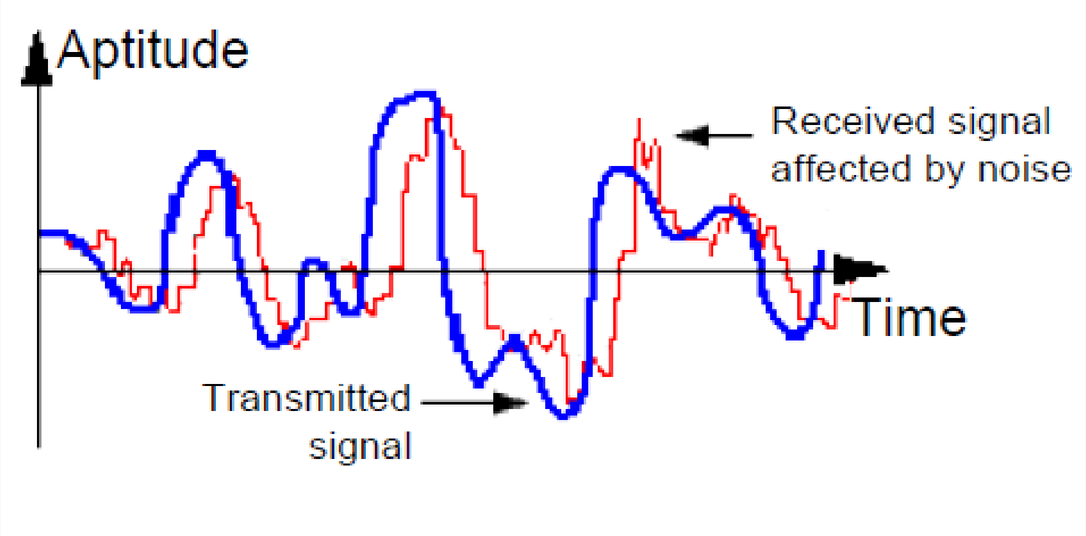
R = 1/ Δ **D =3 R**

Increase data rate

- D = n R
- To increase D:
  - Increase n (number of bits carried by one signal): limited by noise.
  - Or increase R(baud rate): limited by Rmax
- Nyquist (1928):
  - In theory: Rmax = 2 W,
  - In practical Rmax = 1,25 W

Noise and channel capacity

- Three kinds of noise
  - Determined noise: depended on channel characteristics
  - Undetermined noise
  - Thermal noise: from the electron motion



Noise and channel capacity

- Rate between power of signal P_S and power of noise P_B is calculated in decibel

  $$S/B = 10\log10(P_S(Watt)/P_B(Watt))$$

- Shannon Theorem (1948) determined the maximum number of bits carried by a signal

$$n_{max} = \log_2 \sqrt{1 + \frac{P_S}{P_B}}$$

Channel capacity

- From Nyquist and Shannon:

$$C = D_{max} = R_{max} n_{max} = 2W \log_2 \sqrt{1 + \frac{P_S}{P_B}} = W \log_2 [1 + \frac{P_S}{P_B}]$$

- C is capacity of a channel, determines the maximum bit rate supported by a channel

Channel capacity

- Example : Telephone channel
  - Bandwidth W = 3100 Hz
  - Rate signal/noise S/B = 20 dB.
  - What is channel capacity C = ?

We have:

$$C = D_{max} = R_{max} n_{max} = 2W \log_2 \sqrt{1+\frac{P_S}{P_B}} = W \log_2 [1+\frac{P_S}{P_B}]$$

S/B = $10\log_{10}(P_S/P_B)$

$\Rightarrow P_S/P_B = 10^{((S/B)/10)} = 10^{((20)/10)} = 10^2$

$\Rightarrow C = W \log_2(1+P_S/P_B) = 3100 * \log_2(1+100) =$ **20600 b/s**

Traffic

- Traffic is the amount of data moving across a network at a given point of time.
- Traffic presents efficiency of channel usage, a base for choosing a appropriate channel (bandwidth)
- A communication is session having average duration T(s)
- Nc is the average number of session per hour
- E is traffic density, used to measure the usage of channel in one second :

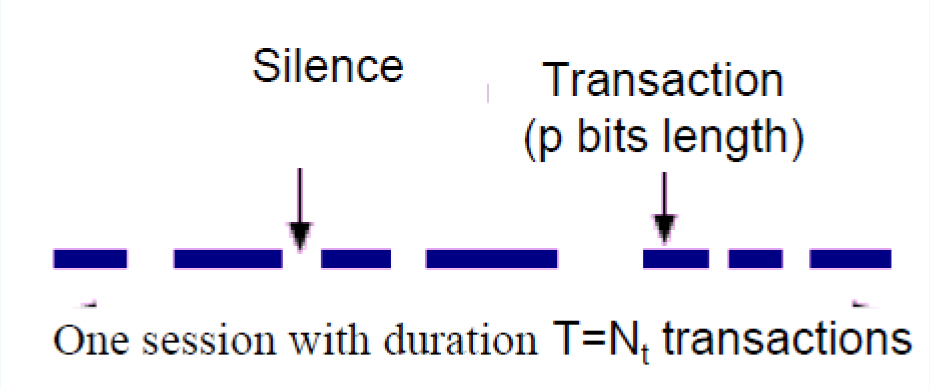
$$E = T\ Nc / 3600$$

Traffic

- A session is composed from many **transactions** having the average duration p bits, and separated by silences.
- Supposing that N_t is the average number of transactions per session.
- **D** is data bit of the channel, then the real data bit **d** in this situation is:

$$d = \frac{N_t p}{T}$$

Traffic



D is data bit of the channel, then the real data bit **d** in this situation is:

$$d = \frac{N_t p}{T}$$

Efficency of channel usage: $\theta = \frac{d}{D}$

Traffic

- Example: In scientific computing, a user connects to a remote Host via a channel with:

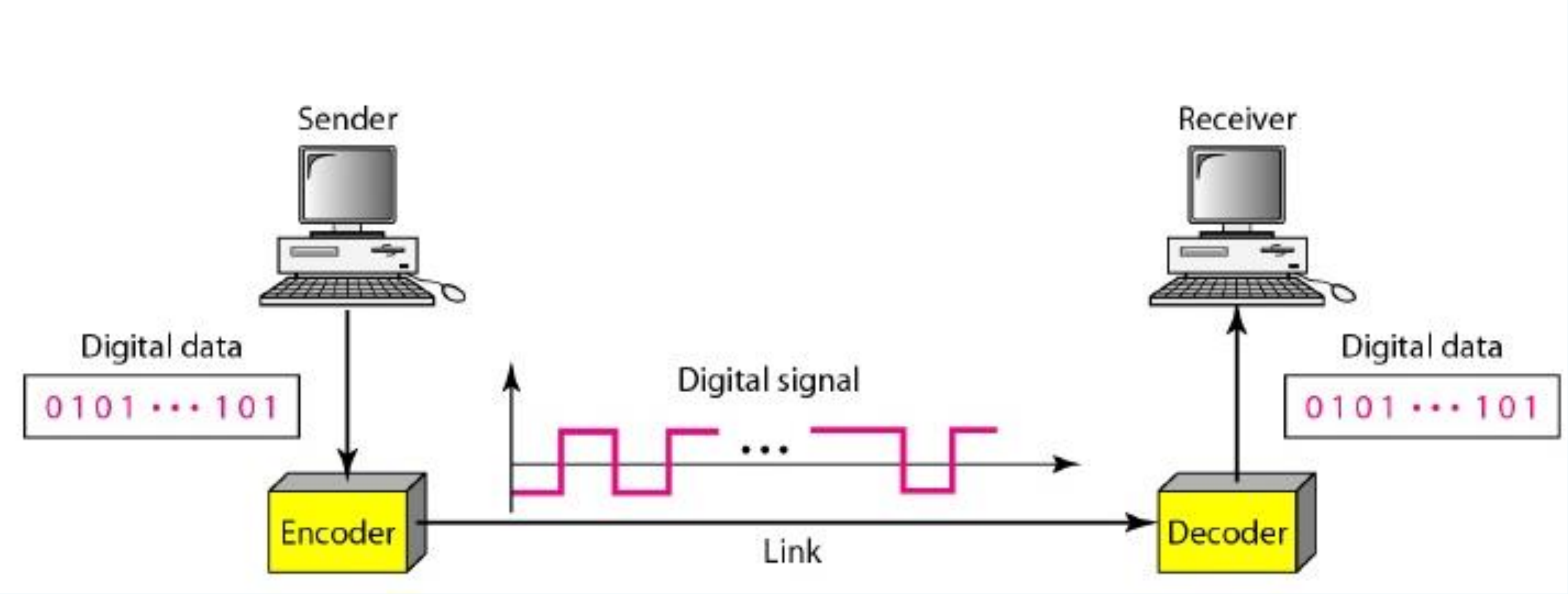
  p = 900 bits, Nt = 200, T = 2700 s, Nc =0.8, D = 1200 b/s.

Then,

- Traffic density of channel E (2700*0.8)/3600=0.6
- Efficiency of channel usage θ = 0.05
  - ✓d= (200*900)/2700 = 67
  - ✓θ = (67/1200) =0.06

Line Coding

What is Line Coding



Using signal (analog or digital) to transmit bits “0” and “1” over a communication channel

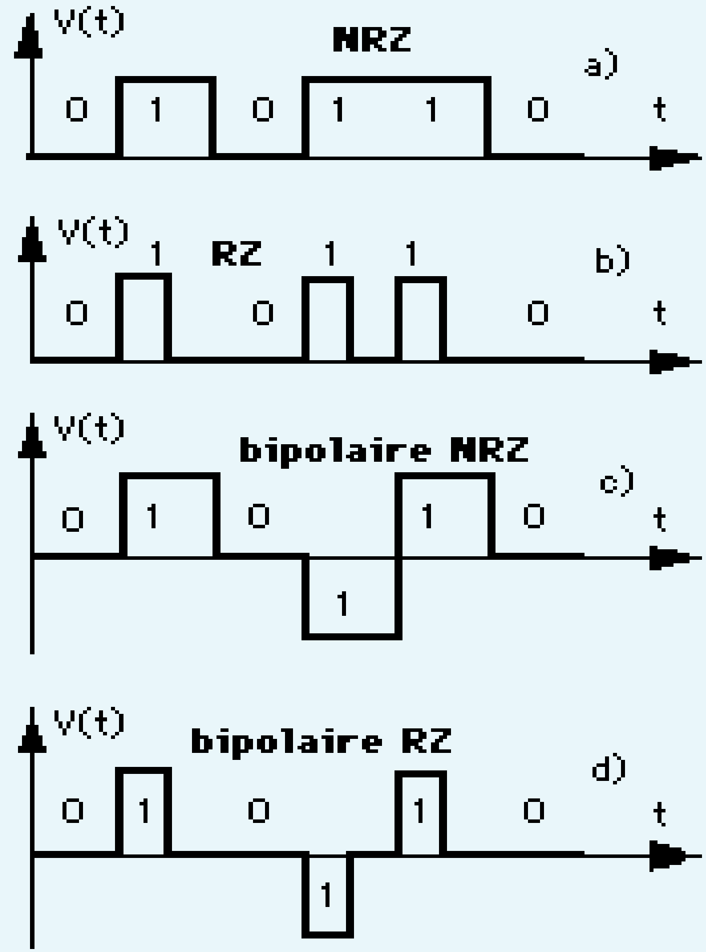
Line code using digital signal

a) NRZ : A zero voltage represents a bit 0, a positive voltage represents a bit "1“

b) RZ : A bit "1" is represented by a transition from voltage V0 to 0

c) Bipolar NRZ : A bit "1" is presented by a positive voltage, then a negative voltage repeatedly

d) Bipolar RZ : A bit “1” is represented by a transition from a non zero voltage to zero. First value of none zero voltage is positive, then a negative voltage repeatedly

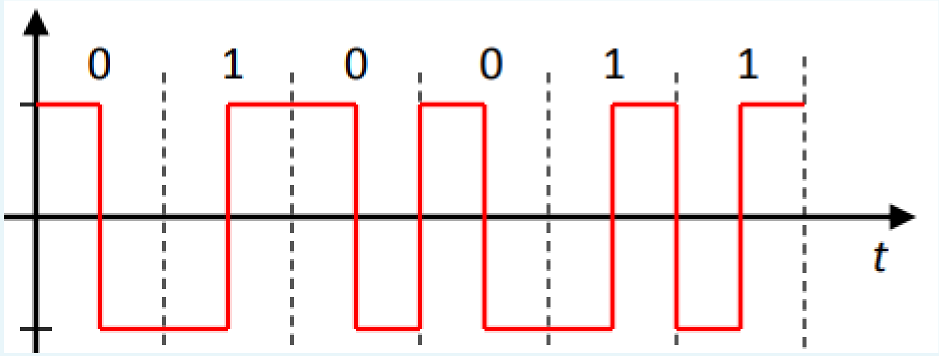


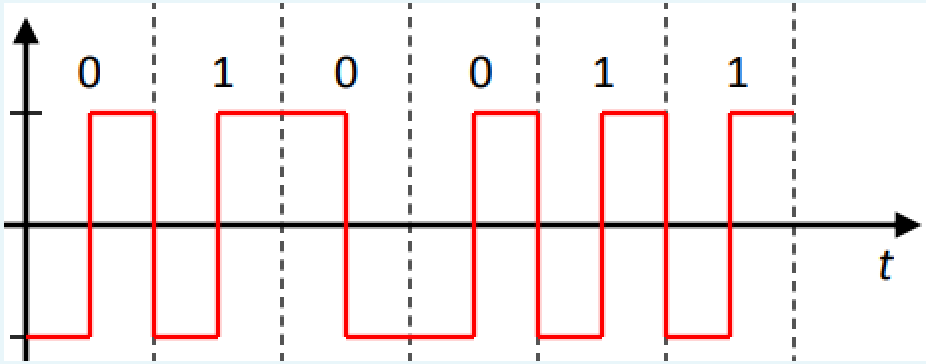
Line code using digital signal

Biphase:

- Manchester : A bit "0" is represented by a transition from high to low and a bit "1" is from low to high
- Differential Manchester: bit

1: → Forces transition at beginning; bit 0 → Do nothing





Line code using analog signal

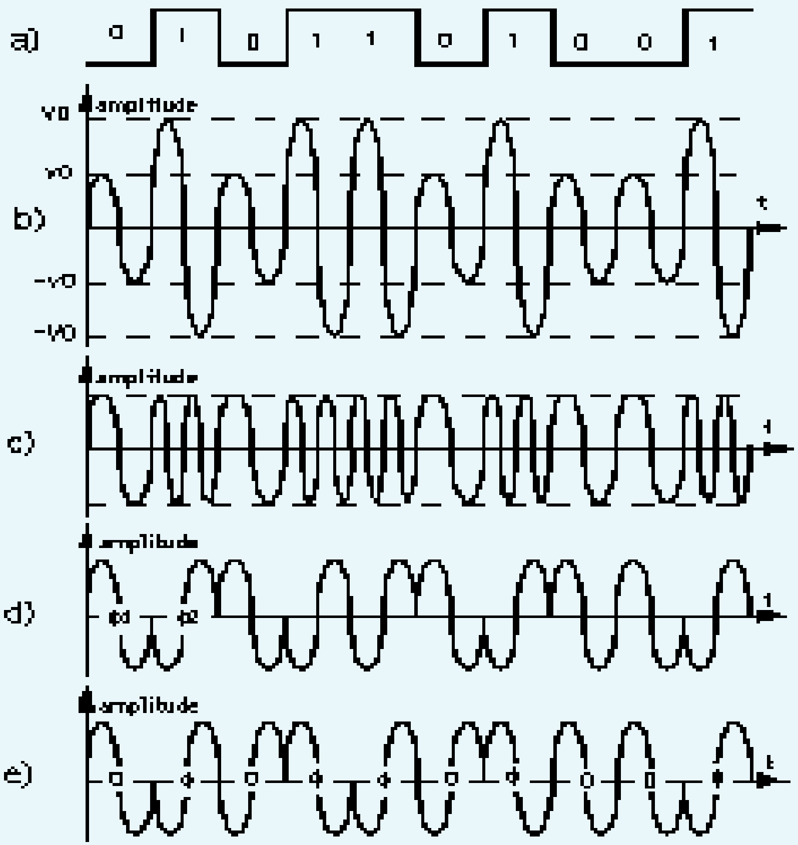
a) NRZ

b) Amplitude modulation

c) Frequency modulation

d) Phase modulation

e) Bi-phase modulation



Bài tập

1. Tính thời gian lan truyền của tín hiệu nếu khoảng cách giữa 2 thiết bị là 12,000km. Giả sử tốc độ lan truyền là 2.4×10^8m/s
2. Tính thời gian lan truyền và thời gian truyền một email 2,5KB nếu:
   – Băng thông của mạng là 1Gbps
   – Khoãng cách giữa người gởi và người nhận là 12,000km
   – Tín hiệu được truyền với tốc độ ánh sáng (2.4×10^8m/s)

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Bài tập

3. Tính thời gian lan truyền và thời gian truyền một một tập tin 5MB nếu:
   - Băng thông của mạng là 1Mbps
   - Khoãng cách giữa người gởi và người nhận là 12,000km
   - Tín hiệu được truyền với tốc độ ánh sáng ($2.4x10^8$m/s)