2nd year professional license

Physical Layer (Chapter 2)

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Data Representation (1)

- The purpose of a network is to transmit information from one computer to another.
- To do this, you must first decide on the type of coding of the data to be sent,
  - that is, its computer representation.
- This will be different depending on the type of data, because it can be:
  - sound data
  - text data
  - graphic data
  - video data …

Data Representation (2)

The representation of this data can be divided into two categories:

- A digital representation: that is to say the coding of the information in a set of binary values, i.e. a sequence of 0s and 1s
- An analog representation: that is to say that the data will be represented by the variation of a continuous physical quantity

Information coding

- Data networks originated from the digitalization of information.
  - The coding of information by 0s and 1s.
- Several standardized codes exist. The main codes are:
  - ASCII code,
  - EBCDIC code and
  - Telegraphic.

Concept of transmission

- Once the data is encoded, its bits must be transmitted over the network.
- The transmission of information depends on:
  - the medium: cable, air and optical fiber, which propagate respectively: electricity, electromagnetism and light waves,
  - the method, direct link called baseband, remote or modulated link called modulation..

Data transmission support

- For data transmission to take place, there must be a transmission line, also called a transmission path or channel, between the two machines.
- The transmission media can be:
  - material (wires, cables, etc.) or
  - immaterial (waves).

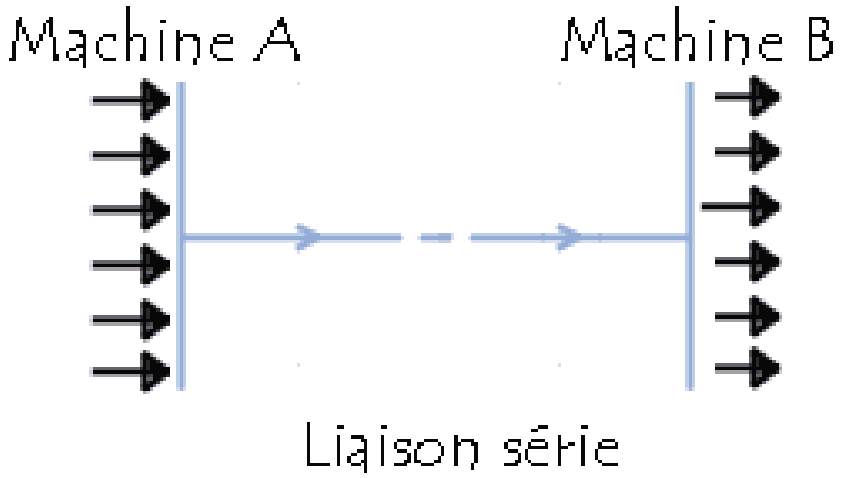
Data transmission on a channel

- The exchange of information between 2 terminal installations can be carried out:
  - in series or in parallel.
  - in synchronous or asynchronous mode.

Serial and parallel transmission (1)

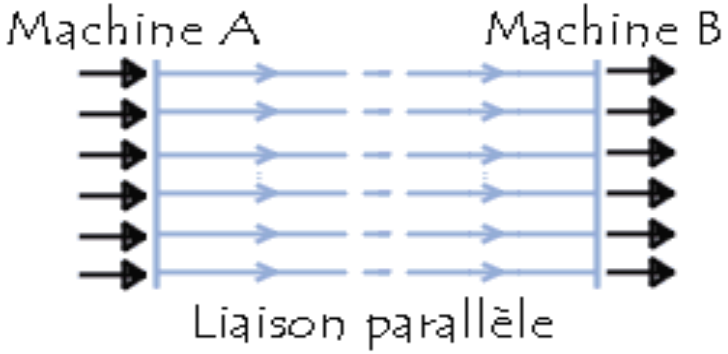
Bit transmission can be done in two ways:

- ***Serial transmission :***
  - Bits are transmitted sequentially one after the other on the same wire.
  - Serial transmission is used for long distances (greater than a few meters).



Serial and parallel transmission (2)

- ***Parallel transmission :***
  - Transmission of several bits simultaneously (8 or 16 bit microbus).
  - That is to say, the bits of the same character are transmitted at the same time on several different wires.
  - The parallel connection is faster, more expensive, more cumbersome (more wires), and very poor over long distances (the phase shift between the different signals on the same cable often leads to desynchronization).
  - This system is not generally used for networks but for example between a computer and a printer.



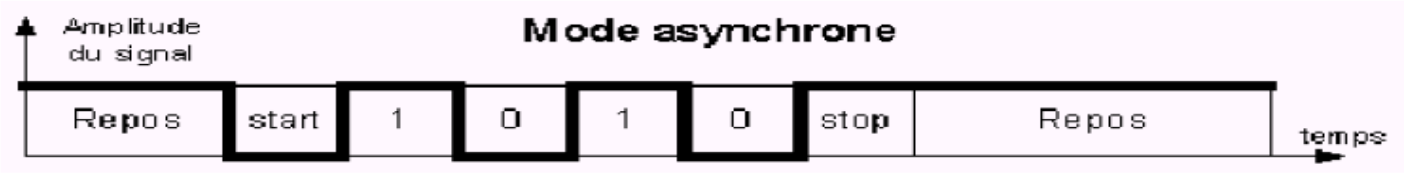
Synchronous or asynchronous transmission (1)

- The purpose of synchronization is to ensure that the receiver picks up the information at the times when the signal is significant.
- It is therefore essentially a question of time synchronization.
- Two ways of transmitting the signal so that it is correctly interpreted by the receiver.
  - In asynchronous mode
  - In synchronous mode

Synchronous or asynchronous transmission(2)

In asynchronous mode:

- This mode is used when the transmission is slow and irregular.
- The useful bits, i.e. those corresponding to the information to be sent, are preceded by bits announcing the start of the transmission (START BIT) and followed by bits announcing the end of the transmission (STOP BIT).
- The asynchronous mode requires sending the information character by character.
- The flow rate is low (300, 600, 1200 and 2400 b/s),The signals are transmitted at any time.
- No clock between the source and the destination.
- The clocks of the transmitter and the receiver have the same frequency



Synchronous or asynchronous transmission(3)

In synchronous mode:

- In general, bits can be transmitted at a constant rate, consistent with both the transmission medium capabilities and the receiver recovery capabilities.
- The useful bits are sent one after the other at each clock period without separation bits, and the receiver must evaluate these bits at the same rate and at the same times as the transmitter.
- The bit rate is higher (1200, 2400, 4800, 9600, 14400, 28800 and 33600 b/s).

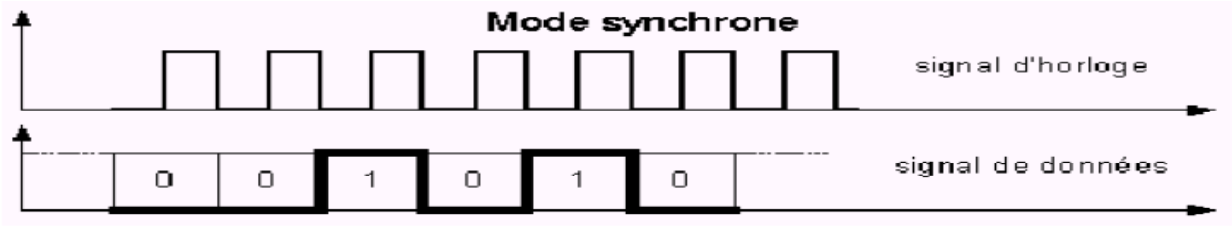
Synchronous or asynchronous transmission (4)

Synchronous mode

- We therefore no longer exchange bytes but blocks of information called FRAMES. These frames can have the following appearance:

délimiteur de début	@ source	@ destinat	données ...	contrôle cheksum	délimiteur de fin

- In synchronous transmission, the receiver receives, with the data, the synchronization clock which gives the rhythm of the bits.
- A special wire carries the clock signal.

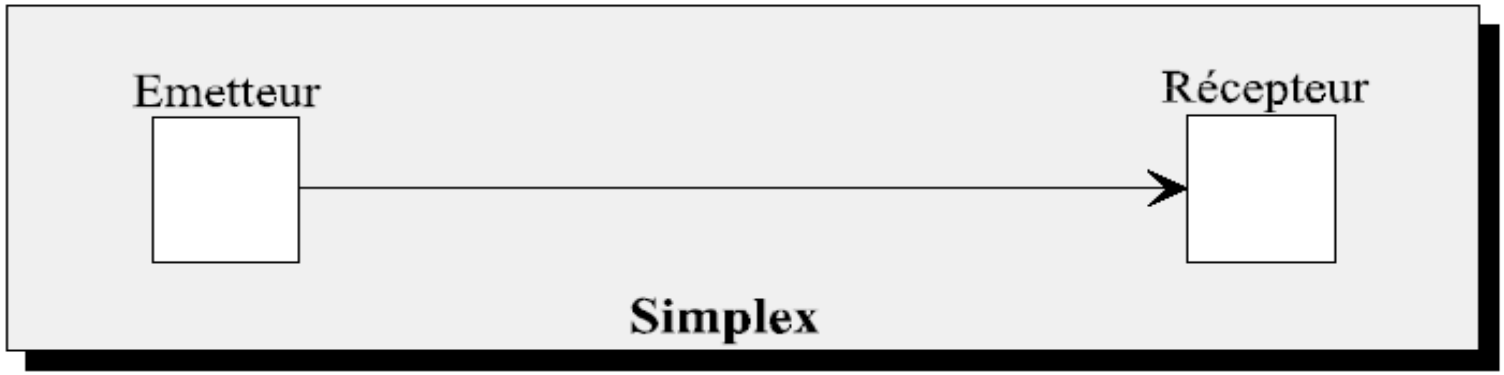


What are the types of transmission modes?

- **The transmission modes are of three major types:**
  - Simplex Transmission Mode.
  - Half Duplex Transmission Mode.
  - Full Duplex Transmission Mode.

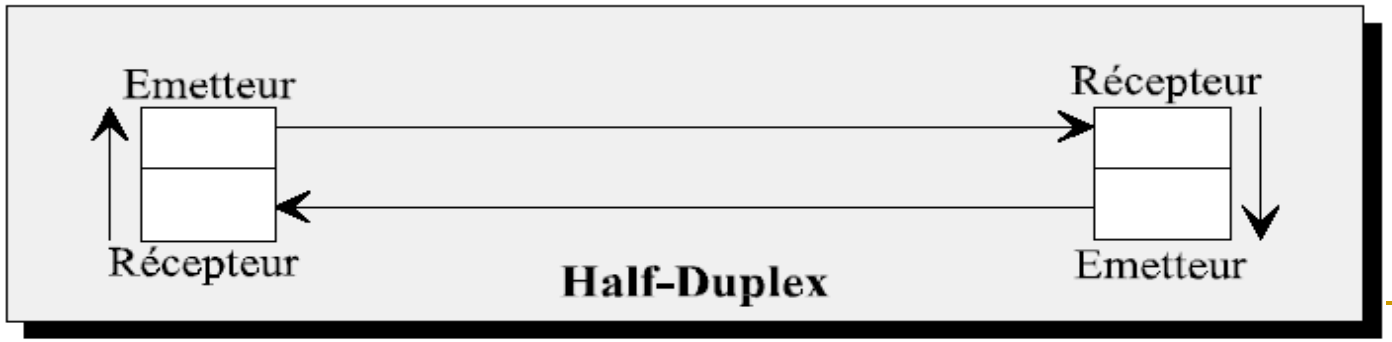
What are the types of transmission modes?

- ***Simplex Mode:***
  - Unilateral (one-way), meaning that information is always flows in the same direction.
  - Transmission can only be from the transmitter to the receiver.
  - The use of this mode is justified for systems where the receiver never needs to transmit, for example: radio, television.



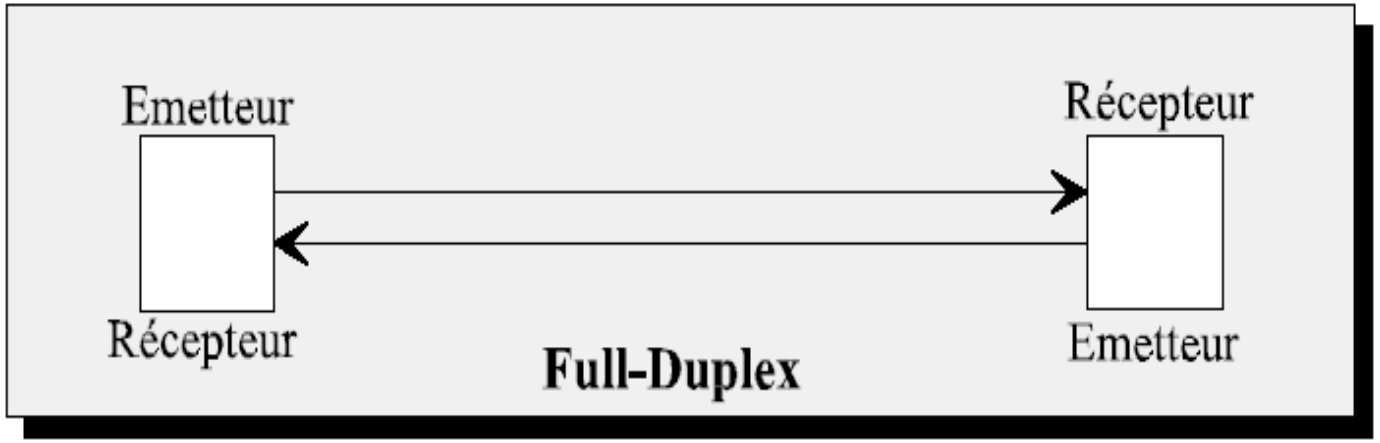
What are the types of transmission modes?

- ***Half-duplex (HDX) mode:***
  - Bilateral (bidirectional) alternating,
  - that is to say that the information is not always flows in the same direction, but that in turn, the transmitter can become receiver, and vice versa.
  - However, at a given moment, one cannot transmit and receive at the same time.
  - Example: communication between two talkie-walkies, in which one either speaks or listens



What are the types of transmission modes?

- Full Duplex (FDX) Mode:
  - Simultaneous bilateral (also bidirectional),
  - The transmission is done in both directions simultaneously.
  - Example: classic telephone communication, in which one either speaks or listens, but in which one can "interrupt the other's speech"



Concept of signal

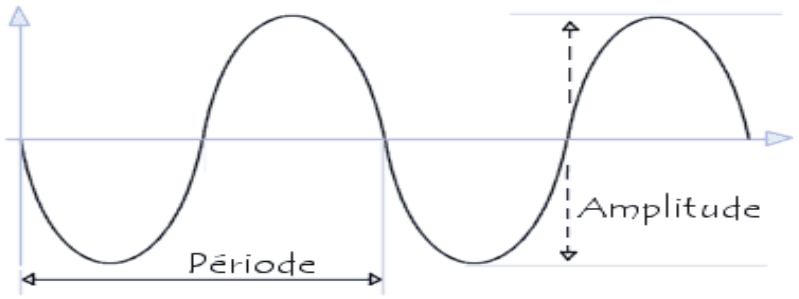
- Communication connects, through a channel, the source of information and the recipient,
- This using a signal or a series of signals.
- The signal is the vehicle of information.

Notions on electromagnetic waves (1)

- Data transmission on a physical medium is done by propagation of a vibratory phenomenon.
- This results in a wave signal depending on the physical quantity that is varied:
  - in the case of light it is a light wave
  - in the case of sound it is an acoustic wave
  - in the case of the voltage or intensity of an electric current it is an electric wave

Notions on electromagnetic waves (2)

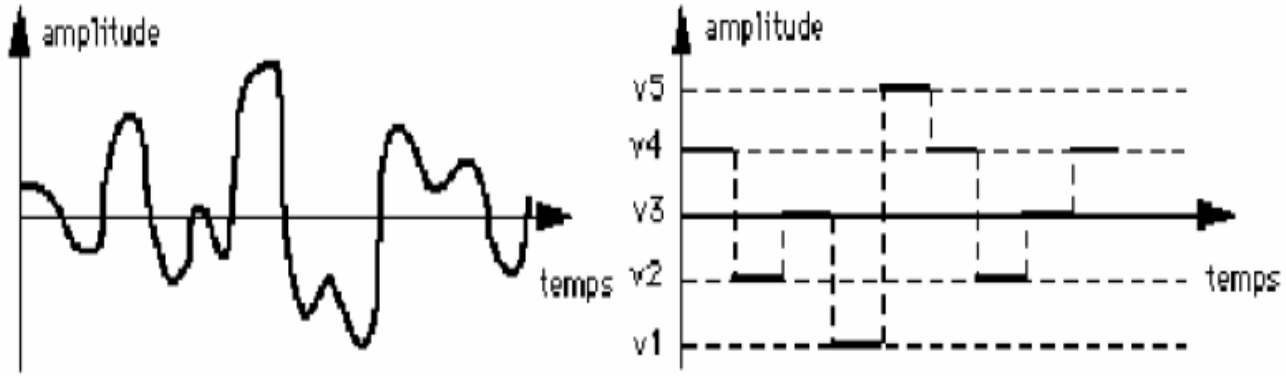
- Electromagnetic waves are characterized by their frequency, amplitude and phase (period).
- The signal is therefore the physical representation of information. The notion of time is inherent (inseparable) to the signal.
- In the simplest case a wave is expressed by a sinusoid
  - $y(t) = A \sin(2\Pi ft + \varphi)$; A: amplitude, f: frequency, φ : phase.



Analog/digital signal

Signals can be analog or digital.

- An analog signal can take an infinite number of values in a given interval (boundaries),
- while a digital signal can only take a finite number of values between two points.



Analog vs. Digital Message

- Message = data that the user wants to transmit
- Analog message
  - continuous time space, continuous value space
  - ex: voice, video.

- Digital message
  - discrete time space, discrete value space
  - ex: text, integers: 0 1 0 0 0 1 1 0 0 …

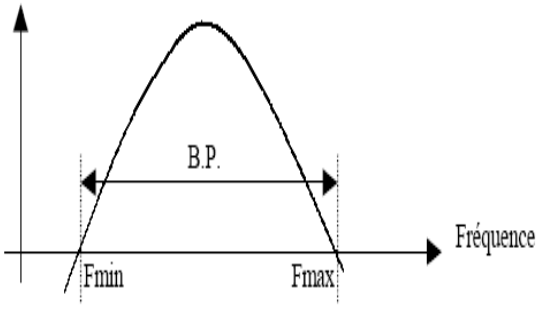
Analog vs. Digital Signal

- Signals are the physical representation of the message to be transmitted.
- They are generally in the form of an electrical quantity (voltage, current) which can then be converted into an electrical or electromagnetic wave for transmission
  - Analog signal: signal representing an analog message
  - Digital signal: signal resulting from the formatting of a digital message
  - It is in the form of a succession of waveforms that can take one of a finite set of possibilities used to encode the information

Characteristic of a transmission channel(1)

Bandwidth (Bande passante):

- The bandwidth of a channel is the frequency range over which the channel is capable of transmitting signals without their attenuation being too significant.
  - It is defined by: W = fmax – fmin
  - fmin is the lowest transmitted frequency
  - fmax is the highest.



- When we talk about a bandwidth, we indicate an interval width without specifying the limits of this interval.
- Example: telephone line bandwidth: 3100 Hz

Characteristic of a transmission channel(2)

Attenuation curve:

- Value of the attenuation ratio as a function of frequency.
- The attenuation ratio = $\frac{\text{Amplitude of the received signal}}{\text{Amplitude of the transmitted signal}}$

Channel capacity:

- The bandwidth directly determines the transmission capacity of a channel:

  C = 2 W (bauds)

Error rate:

- Probability of loss or alteration of information (1 bit).
- It can be measured by calculating for a significant time the ratio of the number of erroneous bits to the number of bits transmitted.

Characteristic of a transmission channel(3)

Bit rate (Débit binaire)

- The bit rate D is the number of bits transmitted per unit of time.
- Examples:
  - 64 Kbit/s or 100Mbit/s.
  - If the transmission time of a bit is 20ms, what is the bit rate?
  - → The bit rate is D= 1/20x0.001 = 50 bits/s.

Characteristic of a transmission channel(4)

modulation speed (Rapidité de modulation)

- A message is made up of a succession of signals (analog or digital) of equal duration Δ (elementary moment).
- The rate at which the signal is "put" on the line is defined by the modulation speed:
  - R = 1/ Δ (in bauds).
- The relationship between D and R can be expressed as follows:
  - $D = R \log_2 V$ in bits/s
  - V: The number of different values on the transmission line.

Characteristic of a transmission channel(5)

Remarks:

- In the case where we transport 1 bit by elementary moments we obtain: R = D
- The number of different significant states that a signal can take. is called the Valence
  - Valence $V = 2^n \rightarrow n = \log_2 V$
- A valence of value V allows the transport of n (bits) = $\log_2 V$ at each Baud.

Characteristic of a transmission channel(6)

- If each significant state represents n bits we can write that:
  - $D = n / t_e$ (t_e : the elementary time or bit time (bit duration)
  - $D = R . n$
  - $C = 2 n W$
  - $C = 2 W \log_{(2)} V$
- Shannon, in 1949, proved that the capacity of a transmission channel was not only limited by the bandwidth but also by the Signal/Noise ratio:
- Maximum capacity (maximum bit rate)
  - $C = W \log_2(1 + S / B)$

Characteristic of a transmission channel(7)

Noise:

- Noise is any signal received that, when interpreted by the receiver in the hope of extracting information, delivers incoherent information, of no interest to the recipient.
- Noise is expressed as follows:
  - S / B = 10 log10 (S / B)
  - S = signal power
  - B = noise power

Characteristic of a transmission channel(8)

Digital bandwidth (Bande passante numérique):

- For digital communications, it is expressed in bits per second (b/s).
- Bandwidth is the measurement of the amount of data that can flow from one place to another in a given period of time.
- The units of measurement used are: bits/s, Kbits/s, Mbits/s, etc.

Characteristic of a transmission channel(9)

- Throughput (le débit) is real bandwidth, measured
  - at a specific time of day
  - on given Internet routes,
  - when downloading a particular file.
- Throughput<= the maximum digital bandwidth of the media used.
- Factors affecting throughput:
  - the type of data transmitted,
  - the topology,
  - the number of users,
  - the user's computer,
  - the server computer,
  - power outages and other outages caused by weather.
  - The time of day…

Characteristic of a transmission channel(10)

- To calculate the data transfer time, here are 2 formulas:
  - Theoretical calculation: T = F/BP
  - Typical calculation: T = F/D
    - T = File transfer time (in seconds).
    - F = File size in bits.
    - BP = Maximum theoretical bandwidth of the link (in bits per second).
    - D = Actual throughput at the time of transfer (in bits per second).

Characteristic of a transmission channel(11)

- ***Propagation time T_p (Temps de propagation T_p):***
  - Is the time required for a signal to travel from one point to another on a medium. This time depends on:
    - The nature of the medium.
    - The distance.
    - The frequency of the signal.
- ***Transmission time T_t (Temps de transmission T_t):***
  - is the delay between the start and the end of the transmission of a message on a line.
  - It is therefore equal to the ratio between the length of the message and the flow rate of the line.
- ***Routing delay (Délai d'acheminement):***
  - The crossing time or routing delay on a channel is equal to the total time taken by a message to reach from one point to another,
  - it is therefore the sum of times Tp and T_t

Characteristic of a transmission channel(12)

- Example:
  - For a message of 100 bits transmitted at 2400 bit/s on a twisted pair of a length of 200 km with a propagation time of 10μs/km, we obtain:
    - T_t= 100/2400= 42 ms
    - T_p= 10 * 200 = 2 000 μs=2ms
  - In most cases the propagation time can be neglected compared to the transmission time.

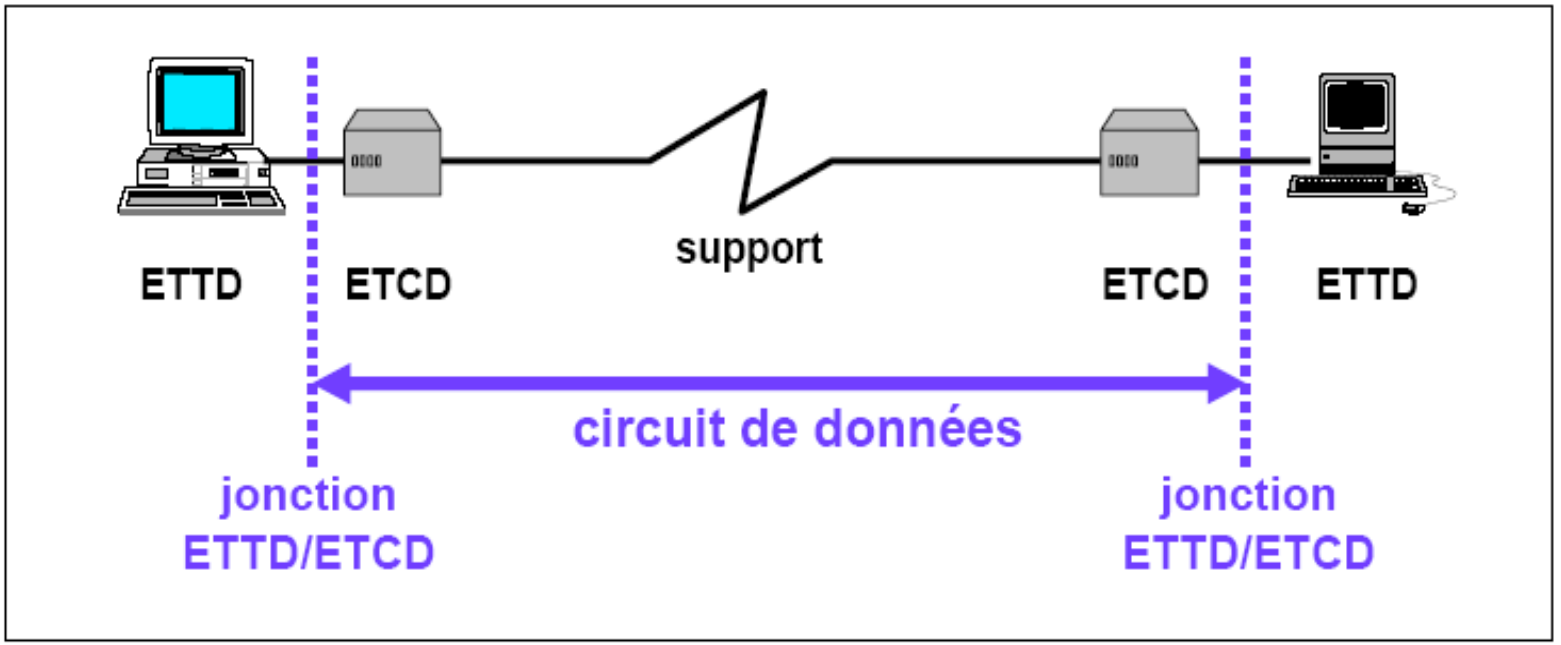
Exercice

We want to transfer a 320 KByte text le from one computer to another. Each character of the file is coded on 08 bits. The transmission is asynchronous with a Start bit, a Stop bit and a control bit on a line with a throughput of 9600bits/sec.

1. Calculate the durations T1 and T2 of transfer of this file such as:
   - duration T1 : without taking into account the Start, Stop and control bits.
   - duration T2 : taking into account the Start, Stop and Control bits.
   - **Calculate then Comment the Ratio R= (T2-T1)/T2**
2. Knowing that in the previous case the valence of the signal used was 2. Calculate the total transfer delay T3 if we switch to a valence of the signal equal to 16.

Computer communication system(1)

- The information to be transmitted is a sequence of bits and the elements making up the system are:



Computer communication system(2)

- **DTE** (Data Terminal Equipment or **ETTD:** Equipements Terminaux de Traitement de Données)
- The DTE:
  - integrates a communication controller,
  - it performs the processing on the data.
  - It can be a computer, a terminal, a printer or more generally any other equipment that does not connect directly to the transmission line.

Computer communication system(3)

- **DCE** (Data Communication Equipment or **ETCD:** Equipement Terminal de Circuit de Donnée)
- It allows bits to be transformed into signals.
- It has two essential functions:
  - Adaptation of the digital signal delivered by the DTE to the characteristics of the medium. Adaptation of the information consists of:
    - baseband coding/decoding (codec)
    - modulation/demodulation (modem)
  - Link management including establishment, maintenance and release of the line at each end.

Computer communication system(4)

- The junction constitutes the interface between DCE and DTE and allows the latter to control the data circuit.
- The data circuit is composed of all the (physical) means allowing the transport of a data signal

The different modes of transmission

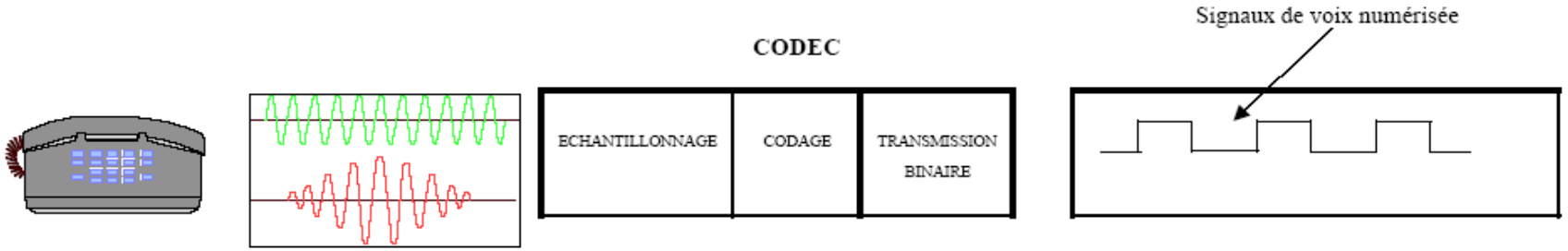
- There are two techniques depending on the limits of the transmission channel:
  - Transcoding the initial signal into a digital signal that meets the constraints imposed by the medium;
    - This is called digital or baseband transmission.
  - Modulation/demodulation of a carrier wave;
    - This is called analog transmission.

Baseband or digital transmission

- This technique is based on the transmission of information in its digital form, that is to say without any other modification than:
  - A possible amplification intended to avoid weakening phenomena (les phénomènes d'affaiblissement).
  - A codification intended to ensure good transmission

Baseband transmission (1)

- Digital or numerical transmission consists of transmitting bits in the form of square electrical pulses having a precise duration and amplitude.
- It is therefore a question of matching a digital signal for the "0" and another digital signal for the "1".



Principe d'un codec

Baseband transmission (2)

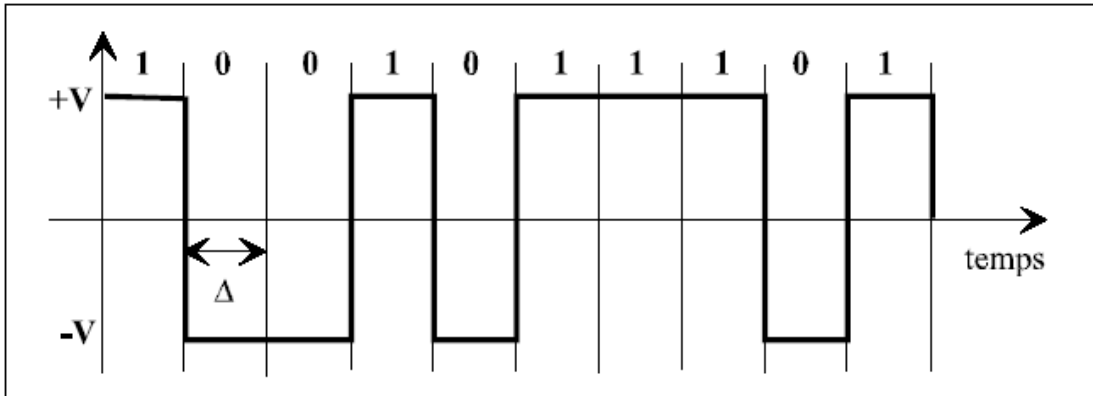
- ***Advantage:***
  - This form is the one that offers the best protection against parasitic electrical signals of any kind.
  - The identification of the information, a bit, consists of detecting a positive or negative pulse.
- **Major disadvantage:**
  - It requires a very large bandwidth, and
  - It is used in short distances (local networks)

Main encodings

- For the transmission to be optimal, it is necessary that the signal be coded in such a way as to facilitate its transmission on the physical medium.
- For this, there are different coding systems that can be classified into two categories:
  - Two-level coding:
    - the signal can take only a strictly negative or strictly positive value (-X or +X, X representing a value of the physical quantity allowing the signal to be transported)
  - Three-level coding:
    - the signal can take a strictly negative, zero or strictly positive value (-X, 0 or +X)

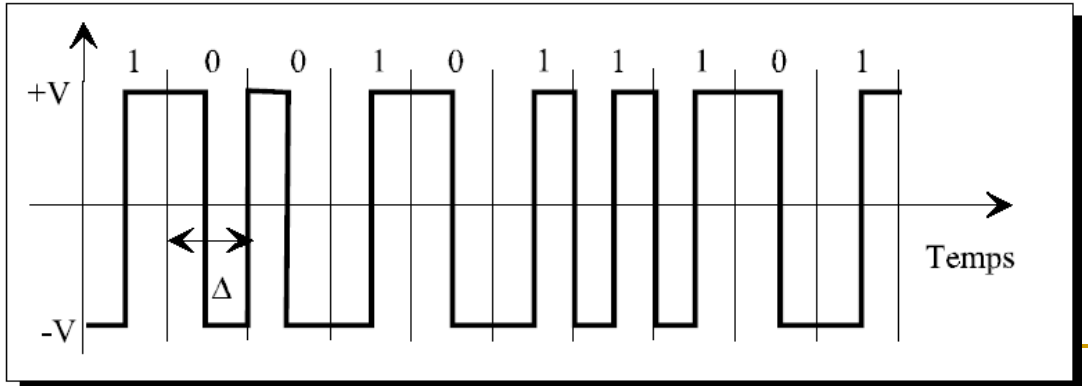
The NRZ code (No Return to Zero)

- This is the first and simplest coding system.
  - The '0' levels are coded by a voltage -V,
  - The '1' levels are coded by a voltage +V
- In this way we have a bipolar coding in which the signal is never zero.
  - Consequently, the receiver can determine the presence or absence of a signal.
- But the presence of a direct current during a sequence of 0 or 1 can interfere with the synchronization between transmitter and receiver



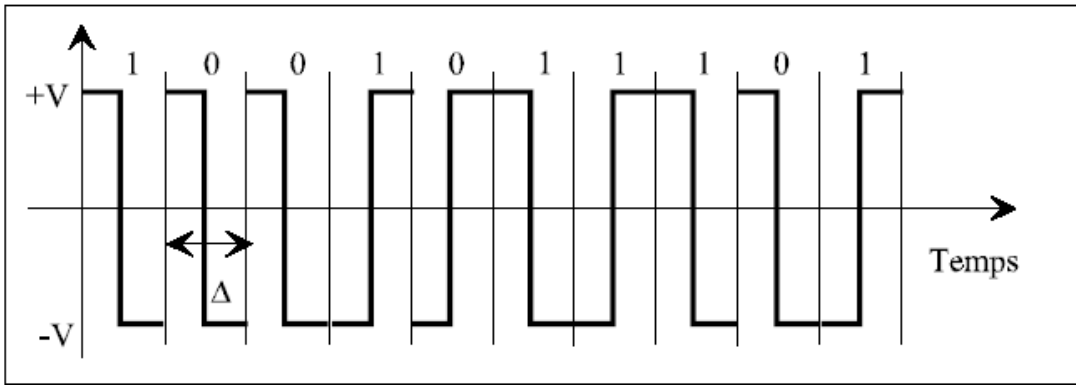
The Manchester code or two-phase code

- Introduces a transition in the middle of each interval.
- It actually consists of doing an exclusive OR (XOR) between the signal and the clock signal
  - Hence a systematic transition in the middle of each bit of the binary signal
- Advantages:
  - the non-zero crossing, making it possible for the receiver to detect a signal
  - at least one transition per interval



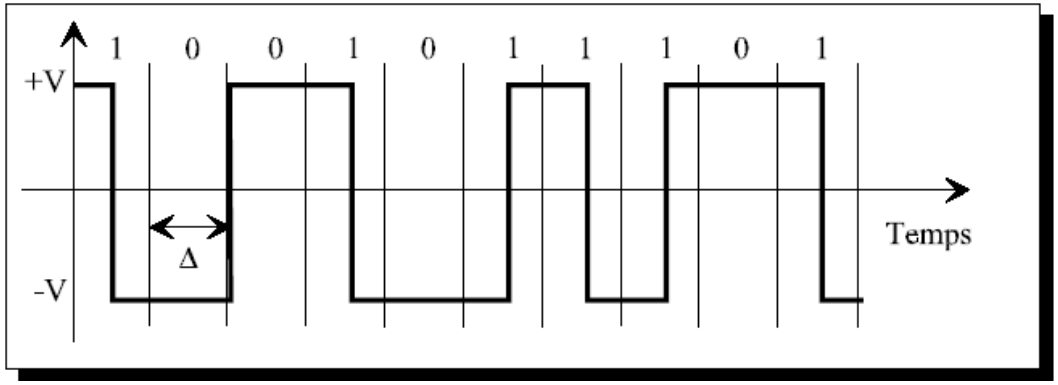
The Differential Manchester Code

- The logic level '0' of the elementary moment t copies the signal of the elementary moment t-1.
- The logic level '1' of the elementary moment t inverts the signal of the elementary moment t-1.



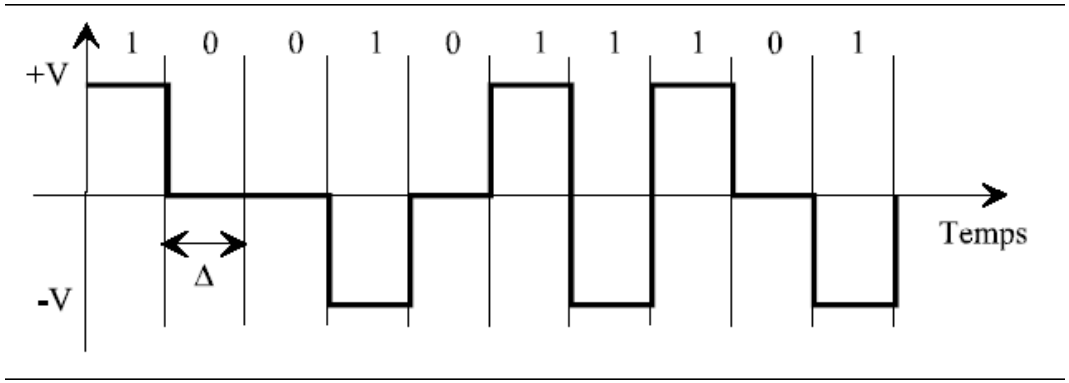
Miller Code or Delay Mode

- It is close to Manchester coding,
- a transition in the middle of the interval when the bit is 1,
- No transition in the middle of the bit for a 0.
- A transition at the end of the bit for a 0 if the next bit is also 0



Simple bipolar coding

- This is a three-level coding.
- It therefore offers three states of the quantity transported on the physical medium:
  - The value 0 when the bit is at 0
  - Alternatively V and -V when the bit is at 1



Modulation/demodulation

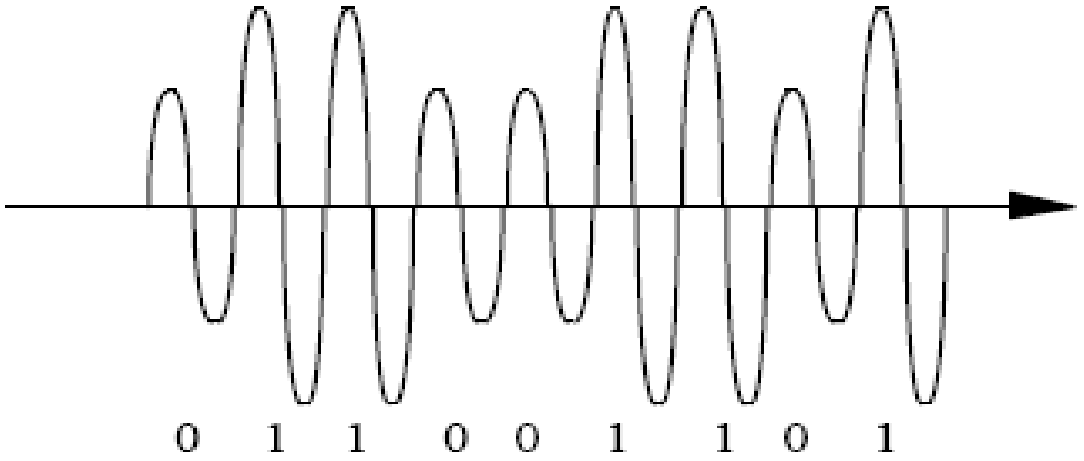
- ***Analog transmission:*** Analog transmission consists of using a simple signal, called a carrier wave, of which one or more parameters are modified, which are the ***amplitude***, the ***frequency*** and the ***phase***.
- ***Modulation:*** Defining a modulation is defining the set of elementary signals from which the transmitted signals will be chosen.
- Modulation is transforming a binary signal into an analog signal.

Types of modulation

- Modulation consists of using a sinusoidal "carrier" wave: $A \sin(2\pi f_0 t + \phi)$
- There are three main types of modulation:
  - Amplitude modulation (modification of A),
  - Phase modulation (modification of ϕ),
  - Frequency modulation (modification of f_0).

Amplitude Modulation
Amplitude Shift Keying (ASK)

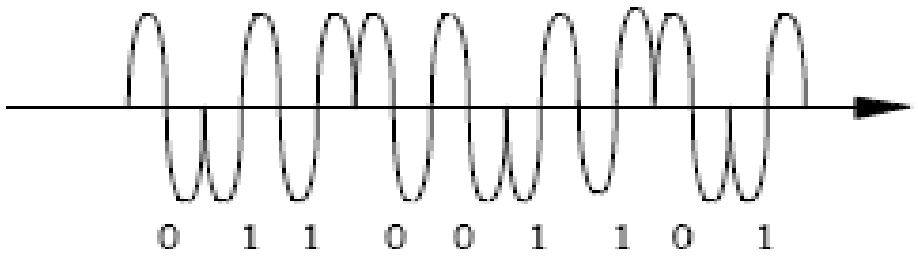
- Amplitude modulation associates a different amplitude with each symbol (or signal element) to be coded
- ex: $A = A_0$ for 0, and $A = 2\ A_0$ for 1



Phase Modulation

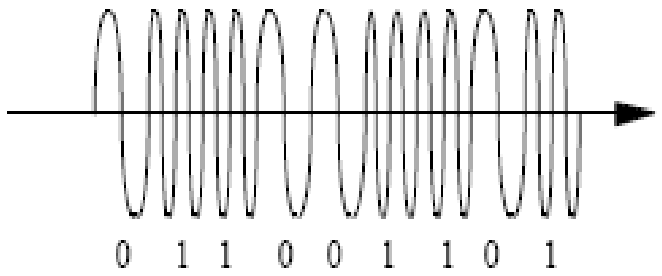
Phase Shift Keying (PSK)

- Phase modulation associates a different phase with each symbol to be coded
- ex: $\phi = 0$ for 0, and $\phi = \pi$ for 1



Frequency modulation
Frequency Shift Keying (FSK)

- Frequency modulation associates a different frequency with each symbol to be coded
- ex: f = f0 - Δf for 0, and f = f0 + Δf for 1



Modems

- This acronym comes from MOdulator-DEModulator, equipment capable of transmitting and receiving digital data on telephone lines or on specialized links.
- It is the equipment that performs the transformation of the binary digital signal into a modulated carrier wave and (vice versa) "Modulation and demodulation“
- It is a translator between 2 computers.
- The modem is a device allowing you to connect to the Internet via an access provider

Modem Types(1)

The external modem:

- It has the advantage of being portable, so it can be easily transported from one machine to another.
- It connects to a serial port.
- Its power is supplied by a power outlet
- The telephone cord plugs into a standard telephone socket.
- There will therefore be 3 more cables behind the computer.

Modem Types(2)

The internal modem:

- This is an ISA or PCI type card to be inserted into a slot on your computer.
- Only the connection to a PSTN (Public Switched Telephone Network) socket is necessary,
  - because it is the computer that takes charge of the power supply of the card.

Modem/fax

- Faxes are graphic images.
- When you receive a fax, you cannot transfer it to your word processor,
  - unless you have a character recognition program (OCR).

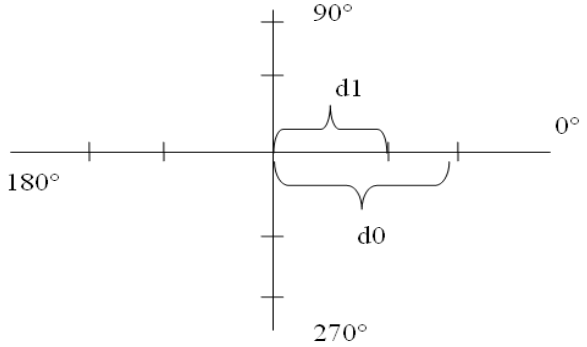
New techniques for modems

- In order to improve bit rates, research undertaken on modems has led to the definition of new techniques that match more than one bit per modulation action.
- It is therefore a question of combining phase and amplitude modulation
- This defines what is called a spatial diagram that shows the different possible combinations of modulations (phase and amplitudes: hybrid)

Spatial diagram(1)

Example:

- The 4 segments correspond to the 4 phases
- The amplitude is measured by the distance from the origin
- We have 4 phases (0, 90°, 180°, 270°) and 2 amplitudes for each phase
  - 8 possible combinations = 2^3
- This modem allows to make 3 bits per action of the modulation



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1

Spatial diagram(2)

Example of phase and amplitude modulation:

- Modulation implemented in a V29 modem used at 7200 bit/s.
- In this example,
  - each of the eight phase states are encoded on 3 bits;
  - two amplitude values (relative values 3 and √2) are used

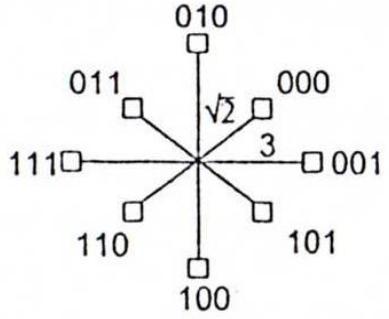
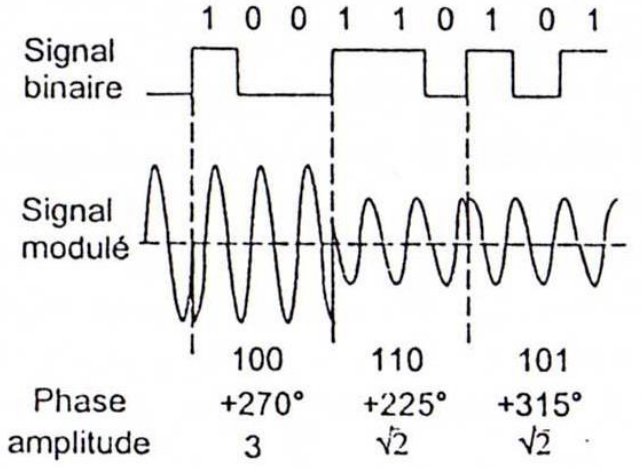
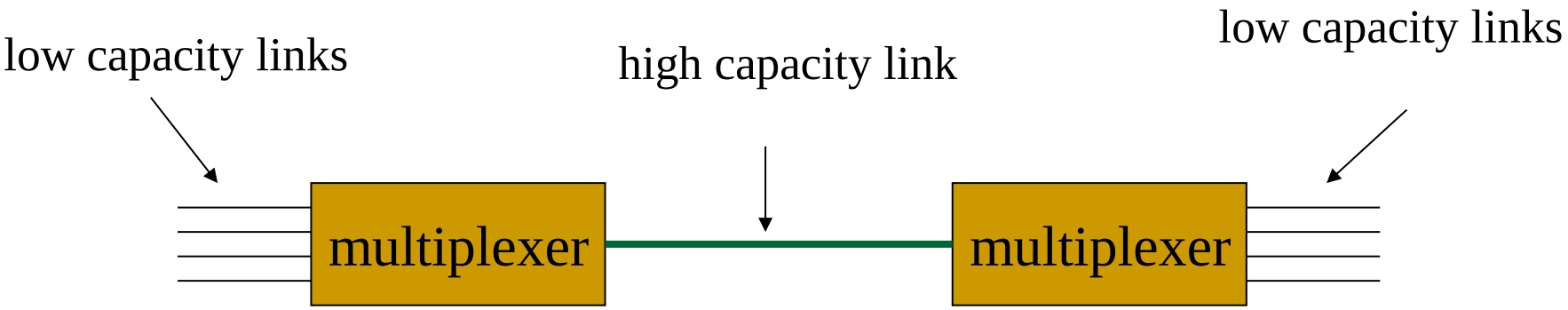


Diagramme spatial



Multiplexing

- Objective: Optimize the use of transmission channels
  - simultaneous transit of maximum information
- Principle:
  - Transmit on a single link (high speed), communications from several transmitters and receivers
  - Share the same communication channel.

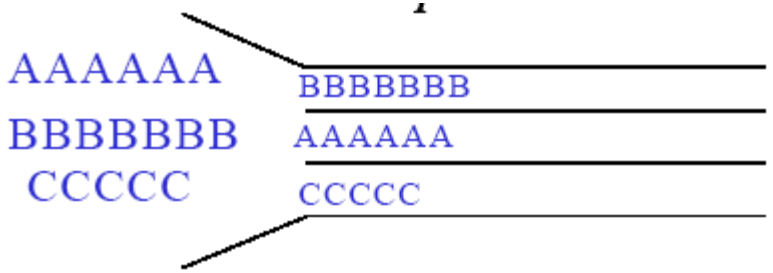


Types of multiplexing

- High-speed line sharing can be done by a technique of:
  - Frequency Division Multiplexing(FDM)
  - Time Division Multiplexing(TDM)

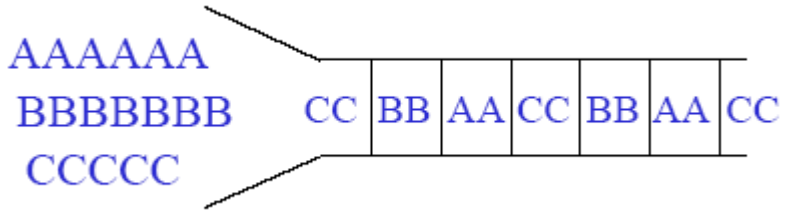
Frequency or spatial multiplexing

- The channel bandwidth is divided into sub-bands (channels) using modulation and filtering techniques
- each message corresponds to a frequency sub-band;
- a multiplexer mixes the different messages
- a demultiplexer, at the arrival, separates the messages using frequency filtering,
- This type of multiplexing is used:
  - for the transmission of analog signals,
  - by cable or radio,
  - for applications such as telephone, radio or television.



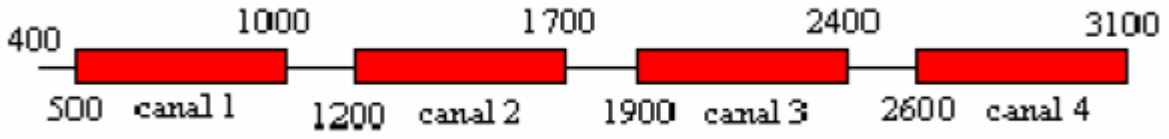
Time division multiplexing

- The multiplexer is nothing more than a packet mixer,
- the demultiplexer is a packet sorter
- The bandwidth of the high-speed line is periodically assigned to each low-speed line during constant time intervals (TI).
- This type of multiplexing is used:
  - for the transmission of digital signals,
  - Considering the possibility of transmitting 1 bit or 1 character per TI.



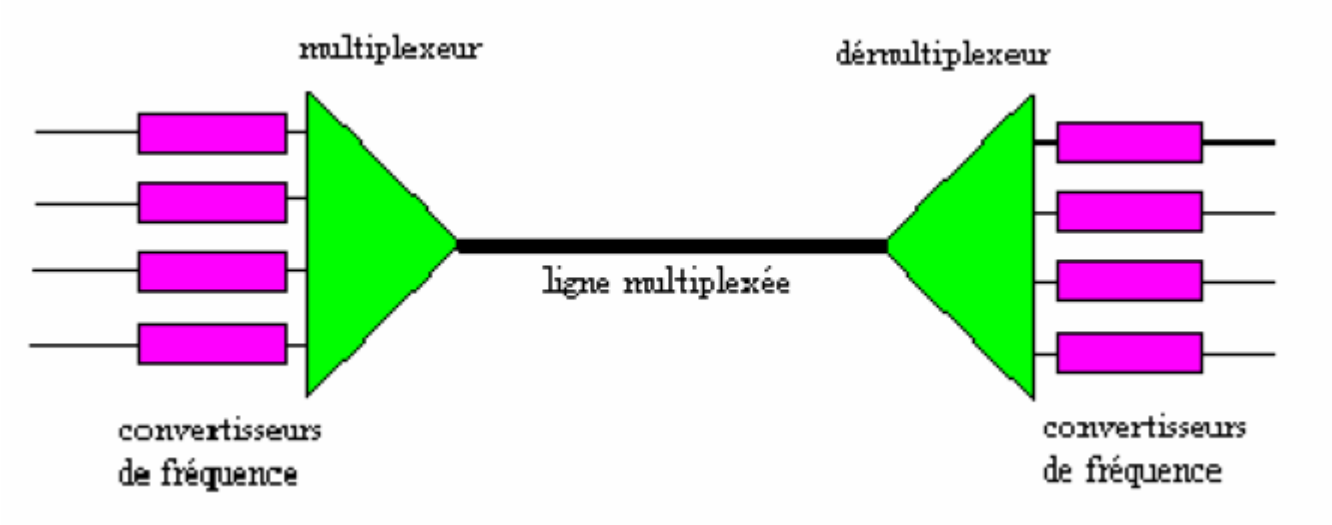
Example: Frequency multiplexing (1)

- 4 analog information trains are multiplexed on a telephone line with a bandwidth of 400 - 3100 Hz.
- The bandwidth of each train is 500 Hz.
- The multiplexing process:
  - Knowing that we have 4 channels to define on the 400-3100 Hz range,
  - we can divide it as follows:



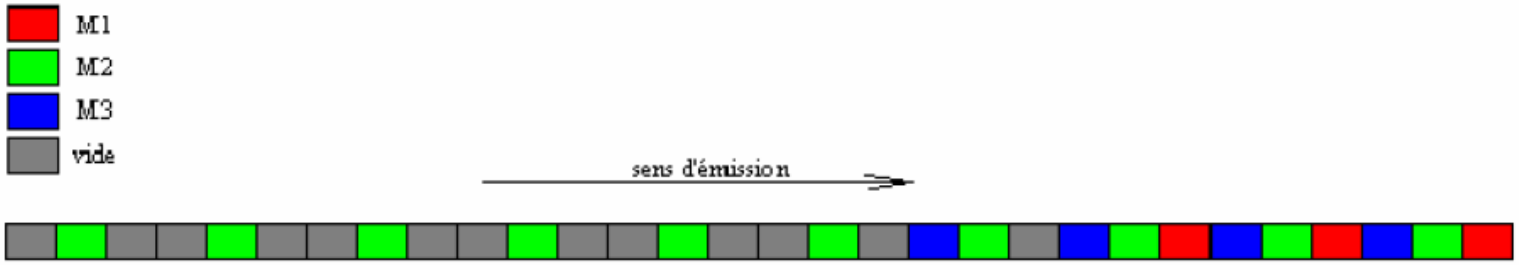
Example: Frequency multiplexing (2)

- The four information trains are each assigned to a channel,
- the multiplexer mixes the frequencies;
- the demultiplexer, using filters, allows the separation of four trains.



Example: Time Division Multiplexing

- 3 lines are multiplexed on a packet-switched link of length 1200 bits.
- Each line carries messages of respective lengths: 3600 bits, 12000 bits and 4800 bits.
- The throughput of the switched link is 4800 bits/s.
- the multiplexing process:
  - The three messages M1, M2, M3 correspond respectively to 3, 10, 4 packets.
  - Multiplexing corresponds to the interleaving of packets:
  - The throughput per message is the throughput of the link divided by three, i.e. 1600 bits/s.



Asyncronous Time Division Multiplexing (ATDM) Statistical Multiplexing

- Assign high speed channel only to low speed channels that
  - actually have something to transmit

Transmission media(1)

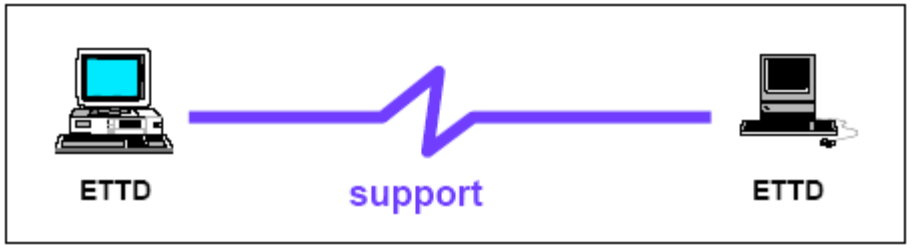
- Problematic

- **DTE** (Data Terminal Equipment) or ETTD (Equipement Terminal de Traitement de Données)

Transmission media(2)

How to choose a cable?

- There are several criteria, including:
  - How many devices must be connected to the support?
  - What communication protocol do you use?
  - What length of cable is required?
  - What transmission speed do you want to achieve?
  - In what environment will the cable be located?



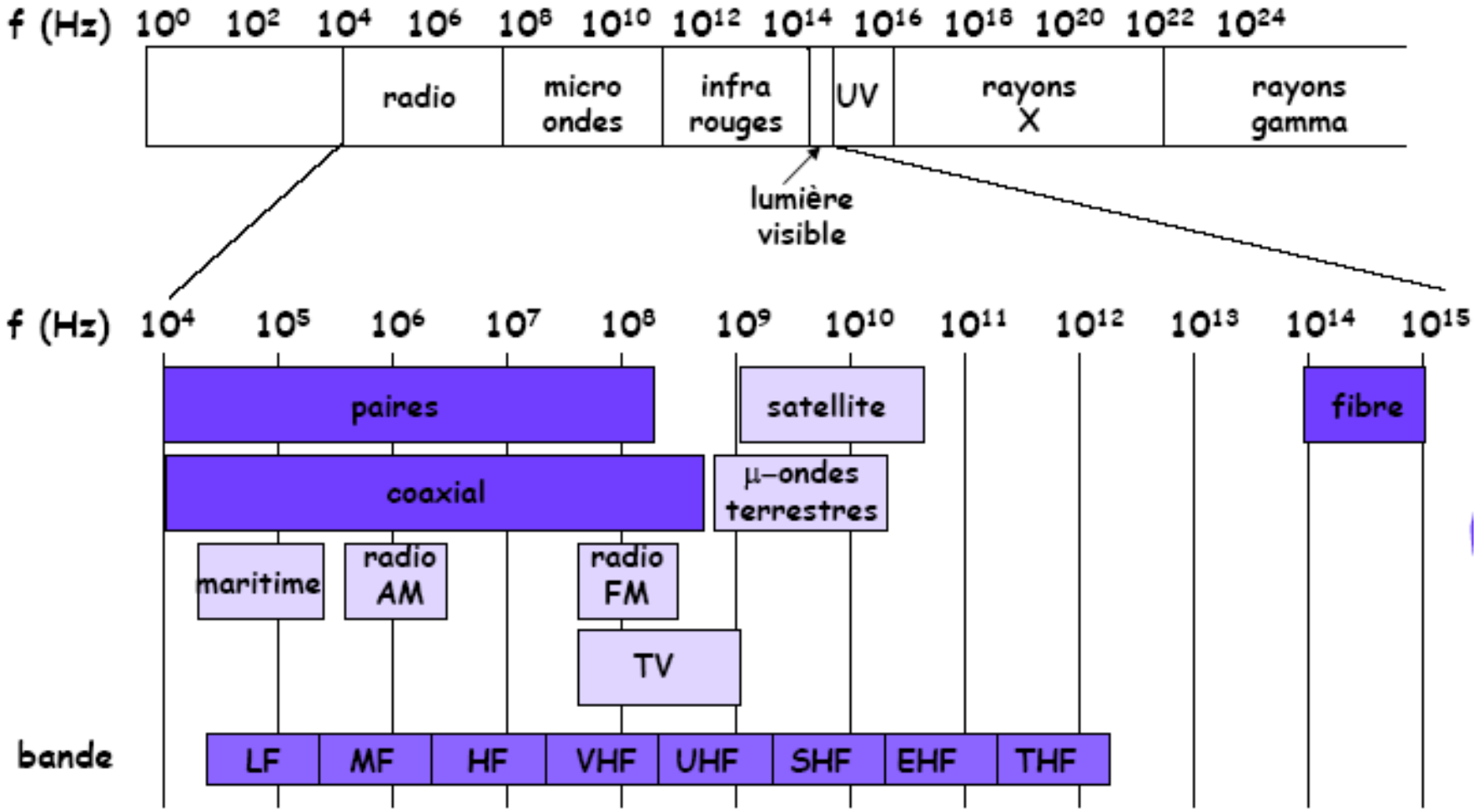
Transmission media (3)

- Many media are used in data transmission:
- Media with physical guide:
  - Cables,
  - Fibers
- Media without physical guide:
  - Radio waves,
  - Light waves

Cable Features

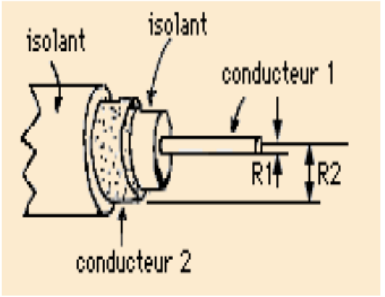
- Cables are characterized by:
  - the attenuation of the signal
  - its bandwidth (maximum frequency of the signal in Hertz, or flow rate in bits/s)
  - its error rate (the medium, depending on its quality, is itself a source of error)
  - its ease of connection to the equipment

The Electromagnetic Spectrum and Its Use



Coaxial cable (1)

- Two cylindrical conductors of the same axis separated by an insulator, the whole being protected by a plastic sheath
- 2 Kinds of cable:
  - Cable 75 Ω, known as "broadband"
    - used for analog transmission : it's television
  - 50 Ω cable, called "baseband"
    - generally used to transmit digital signals.
    - It allows a bandwidth of a few hundred MHz and speeds of up to 2Gbit/s.



Coaxial cable (2)

The connectors

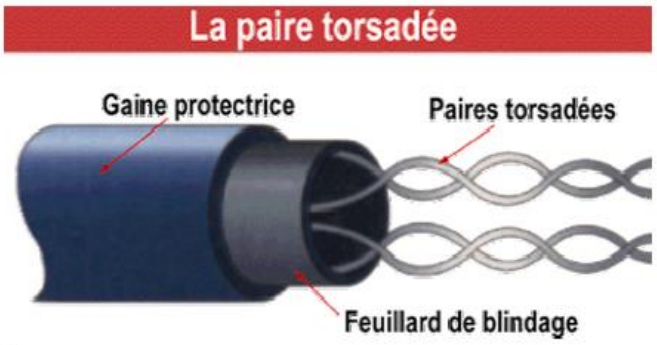
- “thick” (diameters of 2.6/9.5):
  - most common connector: the vampire plug
- “thin” (diameters of 1.2/4.4):
  - connector: the T plug

Coaxial cable (3)

- Advantages
  - Better transmission quality
  - Higher throughput
  - Easy handling (weight, flexibility)
- Disadvantage
  - Higher cost compared to twisted pair

Twisted pairs (1)

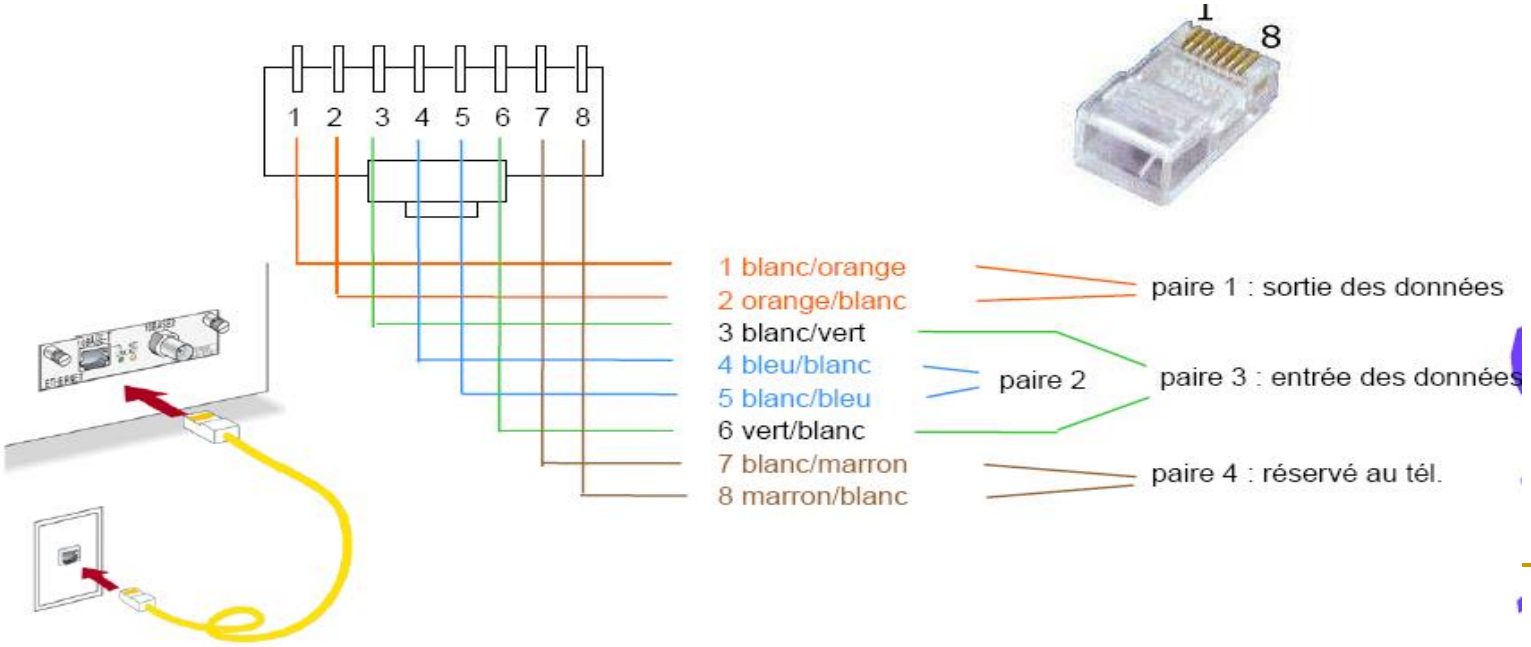
- One pair = one communication link
- 2, 4 or 8 pairs in the same sheath = one cable
- Analog (telephone) or digital (LAN)
- Bandwidth of some 100 kHz
  - 30 kbit/s in analog (5-6 km)
  - 100 Mbit/s in digital (100 m)



Twisted pairs(2)

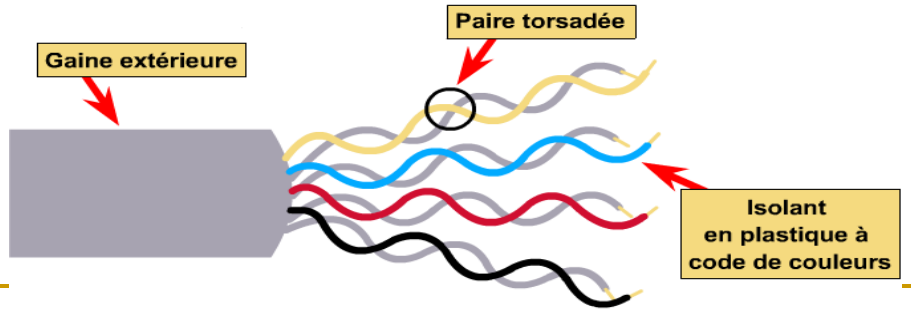
The connection:

- The RJ45 socket
- Similar to the RJ11 socket of the telephone, larger and with 8 pins (instead of 4)



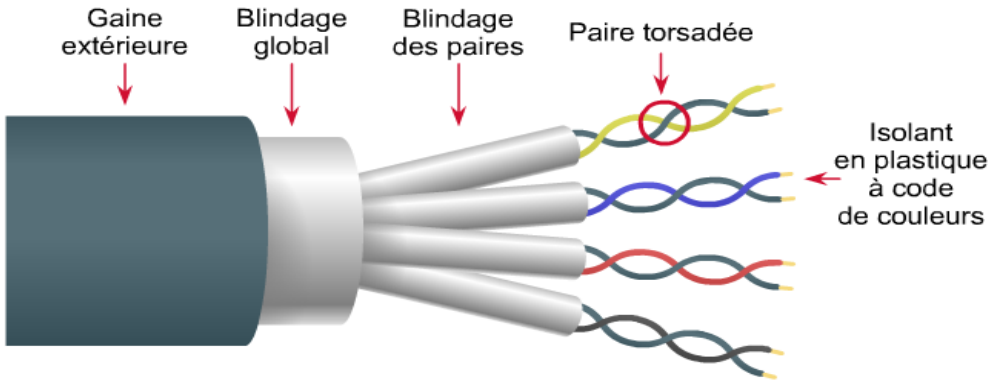
Unshielded Twisted Pair Cable (or UTP cable)

- It is a four-pair wire media used in a large number of networks.
- Each of the 8 copper wires in the cable is protected by an insulating material.
- Advantages:
  - It is easier to install than other types of network media.
  - It costs less per meter than other types of LAN cables.
  - Its size is its main advantage.
    - Due to its small diameter, it is possible to accommodate more unshielded twisted pair cables in a conduit than other types of cable.
  - Today, unshielded twisted pair cable is considered the fastest copper media.
- Disadvantage:
  - It is more susceptible to electrical noise and interference



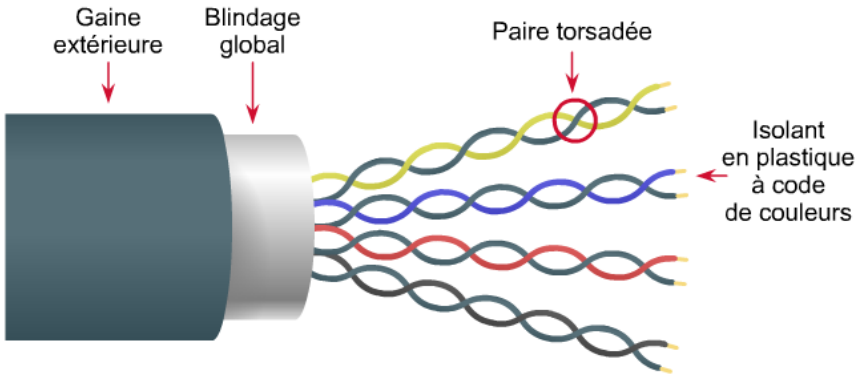
Shielded twisted pair cable

- Each pair of wires is wrapped in a metal foil and the four pairs are themselves wrapped in a metal foil.
- A shielded twisted pair cable reduces electrical noise
  - inside the cable (pair-to-pair coupling) as well as
  - outside the cable (electromagnetic interference, ...).
- Shielded twisted pair cable shares most of the advantages and disadvantages of unshielded twisted pair cable.
- It provides greater protection against all types of external interference,
- but it is more expensive and more difficult to install than unshielded twisted pair cable.



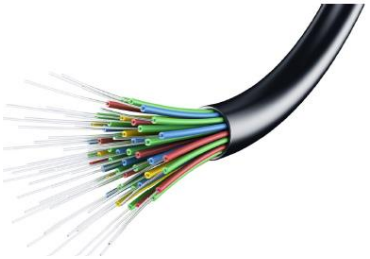
Hybrid twisted pair

- A new type of hybrid cable combines an unshielded twisted pair and a shielded twisted pair.
- The shielded twisted pair is wrapped in metal foil. It is usually a 100 ohm or 120 ohm cable.



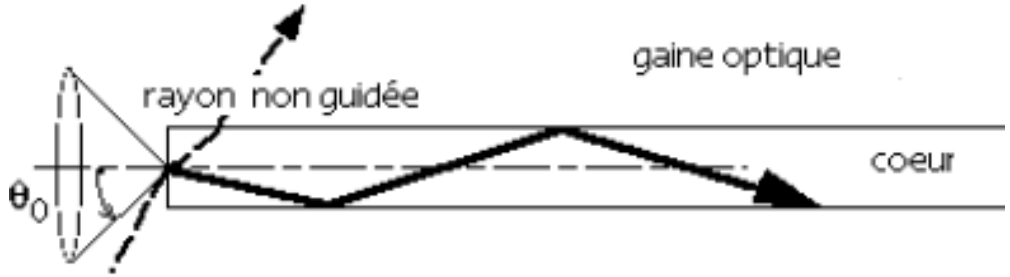
Optical fiber (1)

- The medium of the future!
- Cylinder of glass or plastic, extremely thin (diameter ~ µm), covered with an insulator
- A cable = several fibers gathered within the same protective sheath to form a cable
- Conducts a modulated optical ray: plays the role of a light waveguide
  - for wavelengths 850 nm, 1300 nm, 1500 nm
  - in the infrared range: 1014 to 1015 Hz
- Analog transmission only
- in pt-to-pt only
- Bandwidth from a few 10 MHz to 100 GHz
  - 600 Mbit/s, 2 Gbit/s or 10, 50 Gbit/s



How does light propagate in optical fiber?

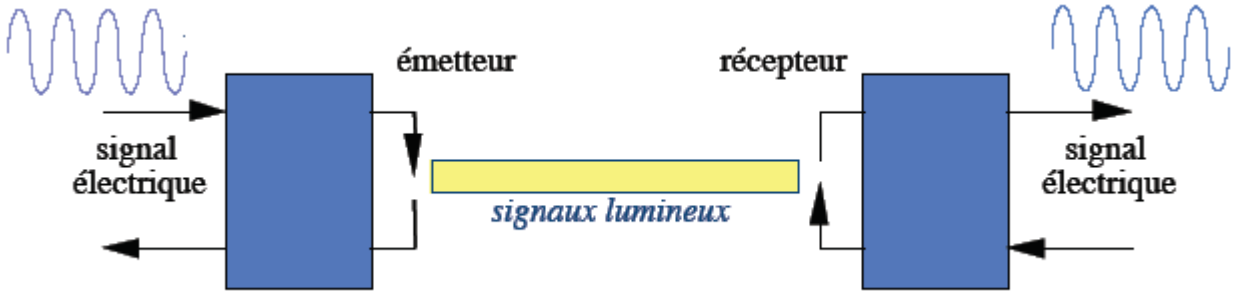
- When the light is emitted towards the fiber, it must penetrate with an angle greater than the critical angle θ_o
- The propagation of light (laser) in the optical fiber is done according to the total reflection of the light on the walls of the sheath.
- In fact, the optical fiber plays the role of a waveguide that holds the light prisoner in the core.



Optical fiber (2)

a connection requires

- An optical transmitter: Light-Emitting Diode (LED), laser diode or modulated laser.
- An optical receiver: photo diode which converts light into electric current



Optical fiber (3)

Advantages

- huge bandwidth (infinite)
- very high throughput
- lower attenuation
- insensitivity to electromagnetic interference
- low weight

Disadvantages

- Fragility
- point-to-point transmission
- unidirectional transmission
- delicate cabling
- high cost of interfaces

Waves (wireless transmission)

- A standard wireless network works much like a wired network
- A wireless network card with a transceiver (a device that transmits and receives analog and digital signals) is installed in each computer.
- The user communicates with the network as if it were a wired computer.
- There are two common wireless transmission techniques for a LAN:
  - Infrared transmission and
  - Narrowband (bande étroite) radio transmission.

Infrared transmission

- This technique uses infrared light to carry data between devices.
- There must be no obstacles between the transmitter and receiver.
- Any object that blocks the infrared signal will prevent communication from being established.
- These systems must generate strong signals, because weak transmission signals are susceptible to interference from light sources, such as windows.

Narrowband radio transmission

- The transmitter and receiver must be adjusted to a certain frequency.
- Narrowband radio transmission does not require visibility between the transmitter and receiver,
  - since it uses radio waves.
- However, this technique is subject to interference from metal objects.