Chapter II:
Data Transmission Fundamentals

II.1 – TRANSMISSION TECHNIQUES

Information transfer from one point to another necessitates the establishment of a series of conventions concerning the logical representation of data (as discussed in the preceding chapter), the physical parameters of transmission (electrical level, emission timing, etc.), and the mode of exchange control. This comprehensive set of conventions constitutes the transmission protocol, which defines the nature of a transmission and its operational capabilities.

The signal to be transmitted must be optimally adapted to the physical constraints of the transmission medium. Two primary types of adaptation or transmission techniques are considered:

- **Baseband Transmission:** This technique involves directly transmitting signals over the transmission medium (line coding).
- **Broadband Transmission:** This technique involves shifting the signal spectrum to a frequency band better suited to the system, typically achieved through modulation using a carrier frequency.

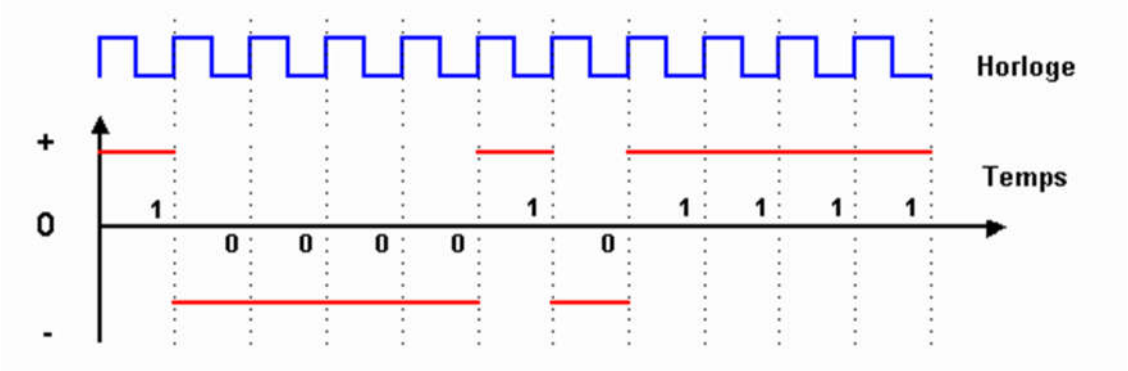
II.1.1 – Baseband Transmission (Line Coding)

Coding refers to the operation of associating a binary representation (source coding) with a symbol belonging to an alphabet. **Line coding**, or transcoding, specifically denotes the operation of substituting a digital signal (binary representation) with an electrical signal that is better adapted for transmission.

Transmission is classified as baseband if it undergoes no frequency transposition through modulation. The initial frequencies of the emitted signal are thus preserved. Consequently, baseband transmission is inherently limited to copper-based media.

A variety of line codes are employed, each with specific characteristics concerning signal representation, bandwidth efficiency, and error detection capabilities.

- **NRZ (Non-Return to Zero) Coding:** This code is very similar to basic binary coding. A '**1**' is encoded as a positive voltage (**+V**), and a '**0**' is encoded as a negative voltage (**-V**).



NRZ coding slightly improves upon basic binary coding by increasing the amplitude difference between '0's and '1's. Theoretically, the maximum data rate is twice the frequency used for the signal, allowing two bits to be transmitted per Hertz.

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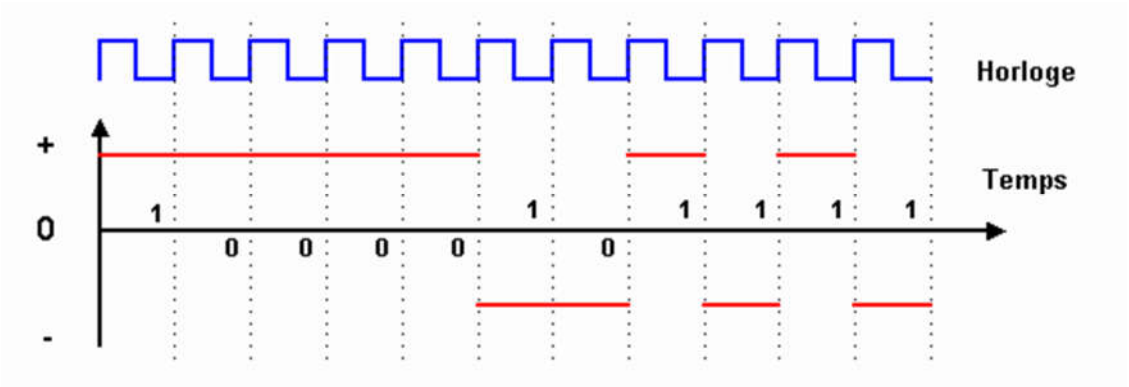
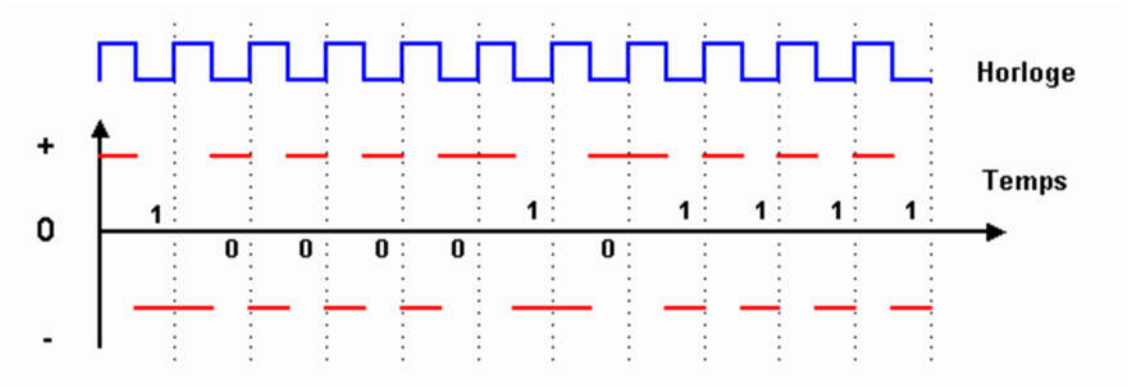
- **NRZI (Non-Return to Zero Inverted) Coding:** In NRZI, a transition in the signal is produced for each '**1**' bit, while no transition occurs for a '**0**' bit.



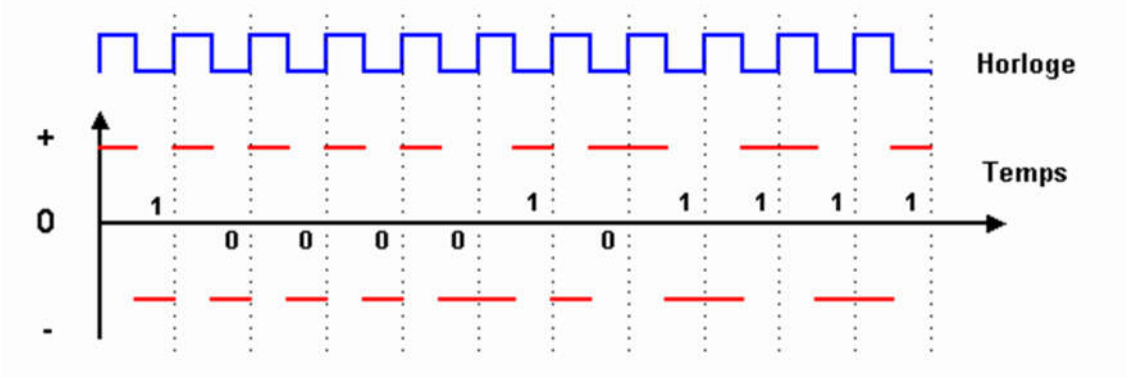
With NRZI coding, it is observed that transmitting long sequences of '**0**'s results in a signal without transitions over an extended period. The bit rate is twice the maximum signal frequency, enabling two bits per Hertz transmission.

- **Manchester Coding:** The fundamental principle of Manchester coding is to induce a signal transition for every bit transmitted. A '**1**' is represented by a transition from **+V** to **-V**, and a '**0**' is represented by a transition from **-V** to **+V** within the bit interval.



Synchronization between transmitter and receiver is consistently maintained, even when transmitting long sequences of '**0**'s or '**1**'s. Furthermore, since a '**0**' or '**1**' bit is characterized by a signal transition rather than a specific state (as in other codes), it is highly resilient to transmission errors. The presence of noise might damage the signal, making it incomprehensible to the receiver, but it cannot accidentally transform a '**0**' into a '**1**' or vice-versa.

- **Differential Manchester Coding:** In this coding scheme, the presence or absence of a transition at the beginning of the clock interval encodes the data. A '**1**' is encoded by the absence of a transition at the beginning of the clock cycle, while a '**0**' is encoded by a transition at the beginning of the clock cycle.



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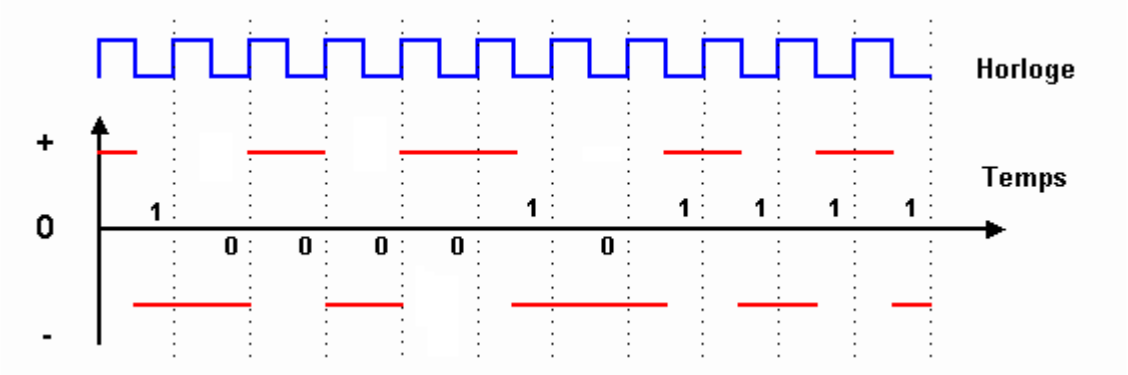
This coding shares the same drawback as Manchester coding, requiring a frequency equal to the useful bit rate. However, it offers an advantage: bit transitions, rather than signal states, represent the transmitted bits, making it impervious to wire inversions in cabling.

- **Miller Code (Delay Modulation):** If the data bit is '**1**', a transition is inserted in the middle of the significant interval. If the data bit is '**0**', there is no transition in the middle of the significant interval; however, if the subsequent bit is also '**0**', a transition is placed at the end of the significant interval.



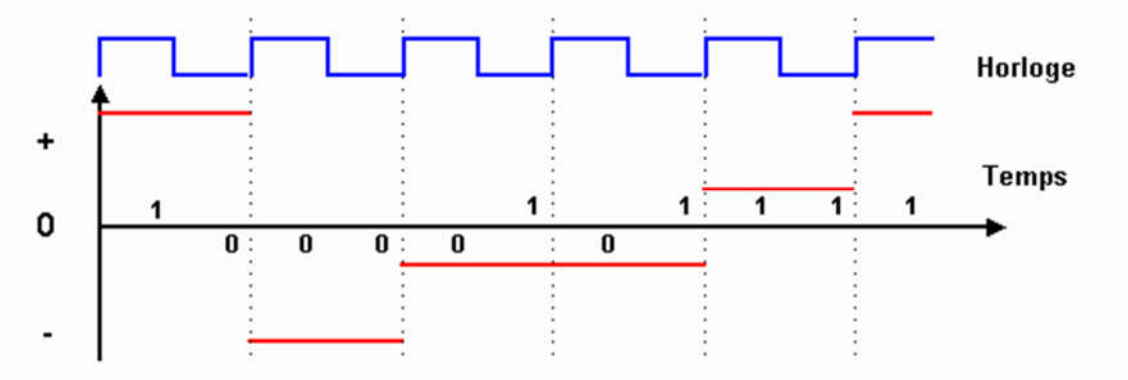
Miller code enables high data rates over limited bandwidth media. A non-zero power is transmitted for zero frequency, which can introduce distortions. The primary drawback of this code is its reduced immunity to noise compared to the preceding codes.

- **2B1Q (2 Binary, 1 Quaternary) Coding:**

  Principle: The 2B1Q code maps groups of two binary elements (dibits) to a quaternary voltage level, or symbol, which can take on four different values according to the table below:

Group of 2 bits	Tension
00	-3
01	-1
11	+1
10	+3

Table of 2B1Q Coding



Consequently, data is transmitted at half the signal frequency, effectively achieving higher spectral efficiency.

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Nyquist's Criterion

In a transmission medium, the signal undergoes deformations and distortions. The limits of transmission are reached when the received signal is no longer coherent with the emitted signal. In such cases, impulses overlap, making it impossible to coherently receive any information.

The limit is then established by the maximum number of transitions that a system can transmit, known as the modulation rate, expressed in bauds.

Nyquist's criterion specifies that the maximum modulation rate (Symbol rate) of a transmission medium is equal to twice its bandwidth (*Bw*).

$$S_R \leq 2.Bw$$

S_R : The Symbol rate (modulation rate), representing the maximum number of signal state changes per unit of time, in bauds.

$$S_R = \frac{1}{T_{symbole}}$$

T_{symbol} : The time taken to transmit one symbol.

The binary data rate (R_b) is also given by:

$$R_b \ = \ m.S_R = \ S_R \ . \ log_2(V)$$

V : The valence, which is the tobal number of possible states for the information (number of symbols).
m : The number of bits per symbol, such that

$$V = 2^m$$

II.1.2 – Broadband Transmission

Modulation aims to adapt the signal to be transmitted to the characteristics of the transmission channel. This operation involves modifying one or more parameters of a carrier wave:

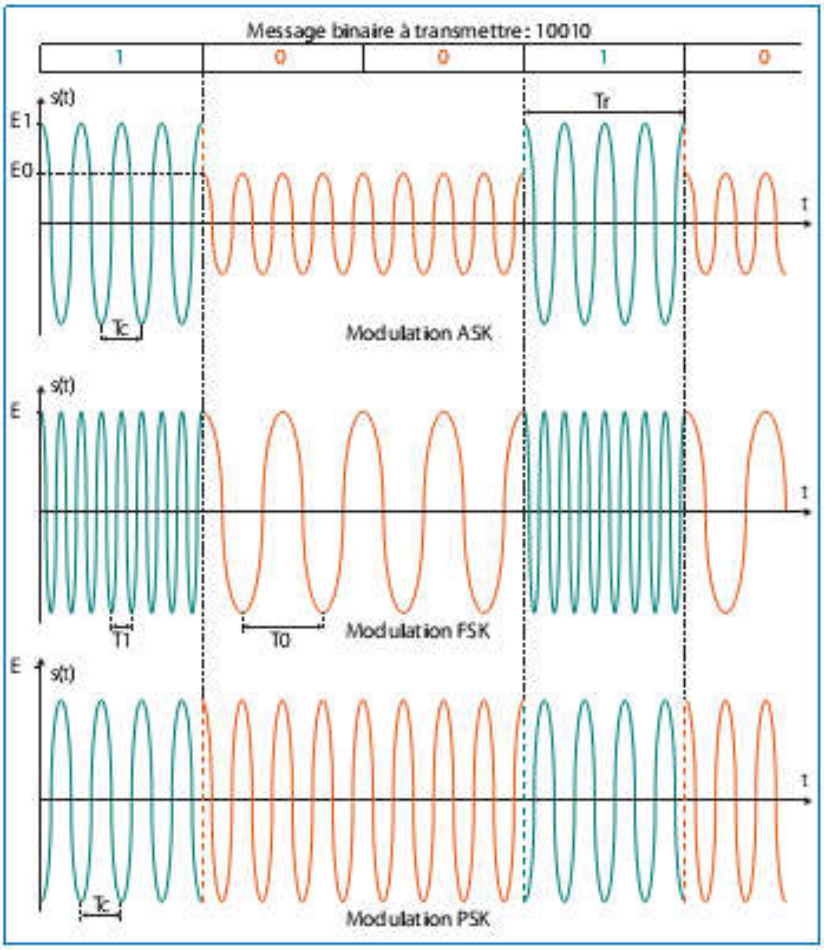
$$S(t) \ = \ A.cos(\omega_0.t + \varphi_0)$$

This carrier wave is centered on the frequency band of the channel. The modifiable parameters are:

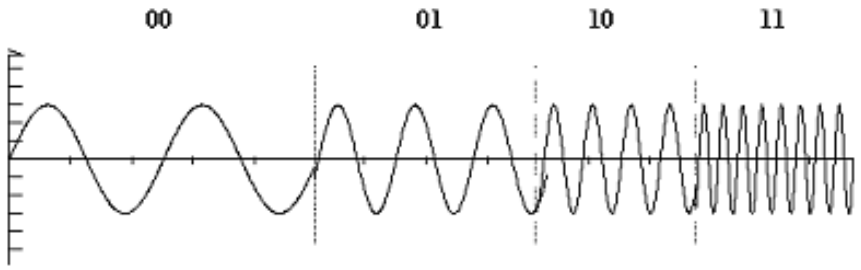
- **Amplitude:** A
- **Frequency:** : $f_0 = \frac{\omega_0}{2\pi}$
- **Phase:** φ_0

In binary modulation processes, information is transmitted using a parameter that takes on only two possible values. The most commonly encountered types of modulation are:

- **Amplitude Shift Keying (ASK):** Modulation by Amplitude Displacement.
- **Frequency Shift Keying (FSK):** Modulation by Frequency Displacement.
- **Phase Shift Keying (PSK):** Modulation by Phase Displacement.



In ***M***-ary modulation schemes, information is transmitted using a parameter that can take M distinct values. This allows a modulation state to be associated with ***n***-bit binary word, where the number of states is $M = 2^n$.



FSK-4 Modulation Example

II.2 – MODE OF EXCHANGE CONTROL

The primary purpose of a network is to exchange information between entities via a transmission channel. Communication between communicating entities is characterized by:

II.2.1 – Direction of Exchange

Based on the direction of exchange, three modes of transmission are distinguished:

- **Simplex Link:** Characterizes a link where data flows in only one direction, i.e., from the transmitter to the receiver.

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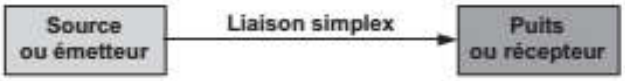
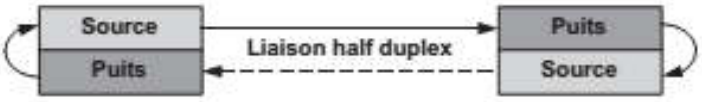
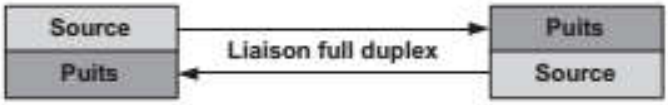


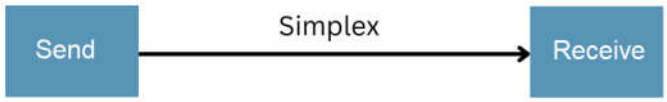
This type of link is useful when data does not need to flow in both directions (e.g., from your computer to a printer, or from a mouse to a computer).

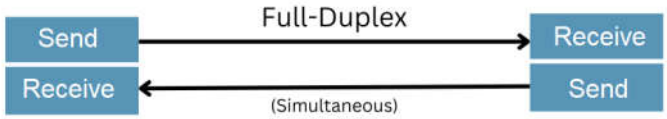
- **Half-Duplex Link (**or **alternat):** Characterizes a link where data can flow in either direction, but not simultaneously. Thus, with this type of link, each end of the link transmits in turn.



- **Full-Duplex Link (**or **integral duplex):** Characterizes a link where data flows bidirectionally and simultaneously. Thus, each end of the line can transmit and receive at the same time.







II.2.2 – Mode of Connection

a) Point-to-Point Link: In this connection mode, each correspondent is connected by a dedicated link to only one other correspondent. This is the case, for instance, for a link between nodes of the same network or between a computer and a terminal.

Point-to-Point Link

b) Multipoint Links: A link is called multipoint when the same medium is shared by several nodes. In this scenario, access conflicts are inevitable, making it necessary to establish an access policy for the medium. The set of specific mechanisms implemented to ensure shared access to the medium is called the channel access policy. Two modes of access control are distinguished

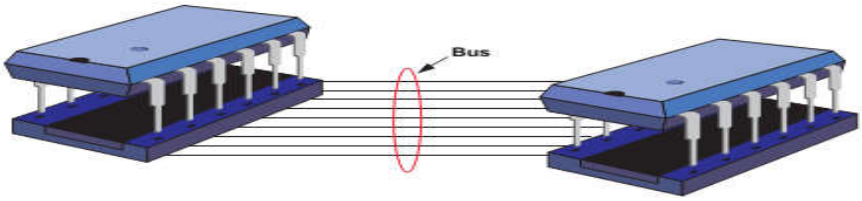
based on how the access policy is managed: centralized (master/slave) and decentralized (peer-to-peer).

- **Master/Slave Mode:** In this relationship mode, the primary entity, typically a multi-user computer, is responsible for initiating the dialogue, error recovery, and organizing exchanges.
- **Peer-to-Peer Mode:** In this type of configuration, all computers are authorized to transmit to any other computer at any time. This shared access can lead to message collisions or contentions (two stations transmitting simultaneously). However, unlike the master/slave relationship, here each computer executes an algorithm to ensure shared access to the medium. The access policy is decentralized.

II.3 – MODES OF TRANSMISSION

The transmission mode refers to the number of elementary information units (bits) that can be simultaneously transmitted over the communication channel. We distinguish:

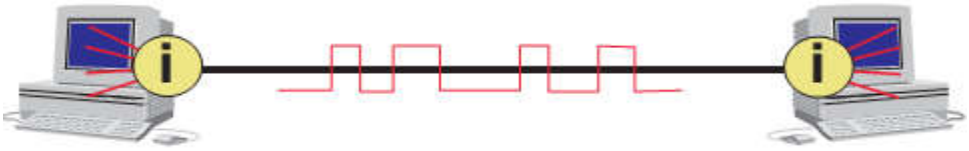
- **Parallel Mode:** Parallel link transmission refers to the simultaneous transmission of ***N*** bits. These bits are sent simultaneously over ***N*** different paths (a path being, for example, a wire, a cable, or any other physical medium). Parallel links in PC-type computers generally require 10 wires.



Parallel transmission

Parallel transmission presents several challenges, primarily crosstalk (radiation between conductors) and differences in propagation speed between conductors, which necessitate expensive electronic implementations.

- **Serial Mode:** In serial transmission, all bits of a word or message are transmitted successively over a single line.



Serial transmission

In computers, data (bits) are processed in parallel (bus). Serial transmission requires an interface to convert bits to serial for emission (parallel-to-serial conversion) and to parallel for reception (serial-to-parallel conversion). Serial transmission uses only two conductors for data transmission. Being less expensive, it is well-suited for transmissions over significant distances.

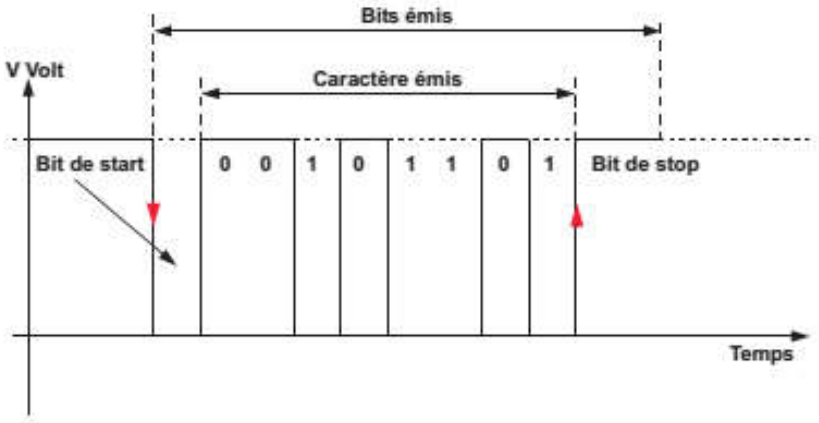
II.4 – SYNCHRONIZATION

Bits are emitted on the line at a specific rate, defined by a transmit clock. To correctly decode the received bit stream, the receiver must examine the incoming data at the same rate as the bits were emitted on the medium.

The operation of slaving the receiver's clock to the transmitter's clock is called synchronization. Depending on the synchronization mode of the receiver's clock with the transmitter's, two types of transmission are distinguished:

- **Asynchronous Transmission:** In asynchronous transmission, transmitted characters are preceded by a start bit and terminated by a stop bit. The two clocks at the two ends are not synchronized; the start bit triggers the clock, and the stop bit stops it.

  The transmission occurs character by character. The time interval separating each character can be arbitrary.



- **Synchronous Transmission:** In synchronous transmission, the synchronization of the transmit and receive clocks is maintained throughout the transmission by a specific signal: the synchronization signal. This allows for the transmission of large blocks of data. Each transmitted block is consequently preceded by a synchronization sequence that also serves to delimit the beginning and end of the block.

Synchronisation 8 bits	Commande 8 bits	Blocs de n caractères de données	Contrôle 8 bits

II.5 – MULTIPLEXING

Multiplexing is a widely used technique in telecommunications that involves transmitting multiple communications simultaneously over a single physical transmission medium. The inverse operation of multiplexing is called demultiplexing.

There are two modes of multiplexing:

II.5.1 – Time Division Multiplexing (TDM)

This technique applies to digital signals. It consists of cyclically assigning a time slot (called ***Time Slot***, or *TS*) to each of the communications to be transmitted. If ***N*** signals are to be transmitted, each with a data rate of ***X*** kbps, the medium must have a capacity greater than ***N*** times X kbps. This is the technique used in telecommunications for PCM (*Pulse Code Modulation*) links. The sequence corresponding to a scan of all multiplexed channels is called a frame. The frame structure is fixed.

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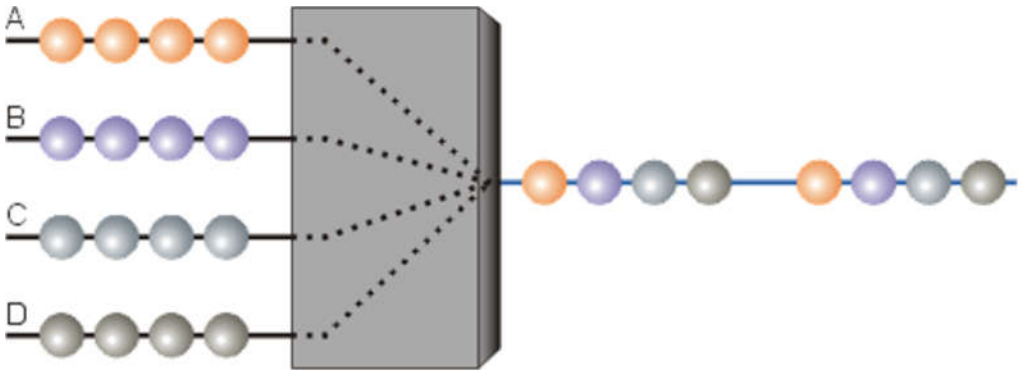
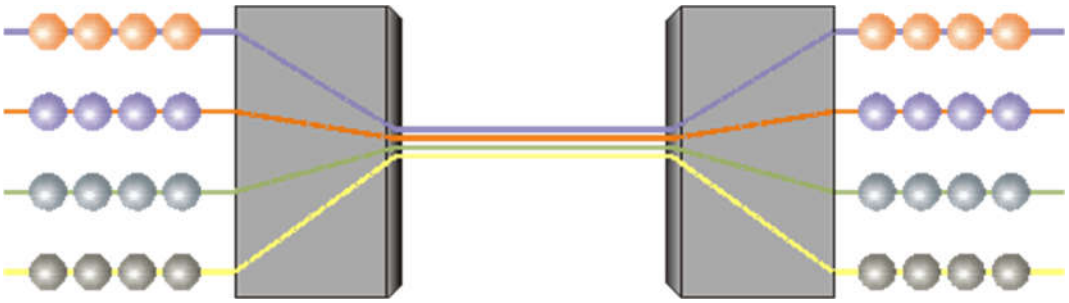


Time Division Multiplexing

- Telephone channels are no longer inserted into the frequency spectrum, but interleaved in the time domain.
- Time interval of 4 microseconds.
- Number of channels limited to 32.
- PCM (Pulse Code Modulation): voice is no longer transmitted analogically, but digitally in the form of bits.
- 1 Time Slot corresponds to 64 Kbps; the entire set (channel) represents 2048 Kbps.

II.5.2 – Frequency Division Multiplexing (FDM)

This technique is associated with analog signals and broadband transmission. It consists of carrying multiple signals simultaneously on the same medium. Each signal, which must have a bandwidth much lower than that of the medium, is assigned a portion of the medium's frequency range (or channel) by shifting or modulation.



Frequency Division Multiplexing

- A telephone channel is characterized by a frequency band of 4 kHz.
- Telephone channels travel on the same cable (or the same radio relay channel) and are transposed in the frequency domain so that they are arranged side-by-side without ever overlapping.