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Salhi Ahmed University Center - Naama



Faculty of Technology
Department of Electrical Engineering

Exercises Brochure for the Subject

Telecommunications Systems and Networks

Created by:

- Dr. REKKALKAHINA

“TD” Designed for third-year students in Telecommunications
Bachelor's degree program.

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FOREWORD

This tutorial handout is intended for third-year students in the Telecommunications Bachelor's program, within the framework of the "Telecommunication Systems and Networks" module. The tutorials presented in this document are primarily based on courses delivered by the Department of Electrical Engineering at the Salhi Ahmed University Center in Naama.

The exercise statements, along with their solutions, will help students familiarize themselves with the application of the concepts covered in class. The aim of this handout is to provide valuable support in understanding and mastering the concepts related to the Telecommunication Systems and Networks module, thereby ensuring students' success in their third year of the Bachelor's degree.

I also hope that this document will serve as a practical and effective resource for telecommunications instructors. I would be very grateful to readers who point out any potential errors or provide constructive feedback.

The evaluation of student work (TD mark) will be conducted in two parts: continuous assessment, consisting of two tests, accounting for 40% of the grade, and a final exam at the end of the semester, accounting for 60%.

The tutorials presented require a solid understanding of the fundamental concepts of the "Telecommunication Systems and Networks" module.

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Exercises**Telecommunication Systems and Networks.**

Course: 45 hours (lectures: 1.5 hours, tutorials: 1.5 hours)

Credits: 4

Coefficient: 2

Course Content:

Chapter 1: Digital Transmission Systems

Chapter 2: Data Transmission

Chapter 3: Modems and Interfaces

Chapter 4: Error Protection

Chapter 5: Telecommunication Networks

Assessment Method: Continuous assessment: 40%; Exam: 60%.

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Chapter 1: Digital Transmission Systems - Summary Reminder

1.1 Introduction

Digital transmission systems are designed to convey information between a source and a recipient using various physical media such as cables, fiber optics, or radio frequency channels. These systems handle digital signals (from data networks) or analog signals (converted to digital). Their main goal is to transmit the signal reliably, preserving its quality until it reaches its destination.

1.2 Standardization Organizations

Standardization involves establishing technical norms and standards to facilitate harmonization within a given sector. These standards are created by various specialized organizations, often from governmental or professional entities. Key standardization organizations include the ITU (International Telecommunication Union), ANSI, ETSI, and TTC. The purpose of standardization is to provide solutions to recurring technical issues in economic, scientific, and technical relationships.

1.3 Transmission Supports and Channels

To enable communication between two devices, a transmission medium is essential. This can be a copper network cable, fiber optics, or wireless technologies such as Wi-Fi and Bluetooth. There are two main types of supports: guided (wired) and unguided (wireless).

1.3.1 Guided Supports:

- **Twisted Pair:** Simple and economical, but sensitive to noise and signal attenuation over long distances.
- **Coaxial Cable:** Better protected against electromagnetic interference and offers more bandwidth than twisted pair, but is more expensive.
- **Fiber Optic:** Provides very high data rates with low attenuation, but remains costly.

1.3.2 Unguided Supports (Wireless):

- **Microwave Links:** Used for long-distance transmission via electromagnetic waves.
- **Satellite Transmission:** Offers extended coverage and long-distance communication but suffers from propagation delay.
- **Wireless Networks:** Use technologies like laser or infrared waves for entirely digital transmissions.

1.4 Data Link Principles

A data link can be either baseband or broadband.

1.4.1 Baseband: The digital signal is sent directly without modulation, but this method is limited to short distances.

1.4.2 Broadband: Uses analog modulations (such as ASK, PSK, FSK) to transmit digital signals over longer distances, thereby eliminating signal degradation.

1.5 General Structure of a Transmission Chain

1.5.1 Digital transmission follows a processing chain:

- **Transmitter:** Transforms the input data (such as voice or images) and prepares it for transmission. It includes several blocks like the source encoder, channel encoder, and modulator.
- **Transmission Channel:** This is the physical medium (cable, fiber optic, air, etc.) that carries the signal to the receiver.
- **Receiver:** Receives the transmitted signal, decodes it, and converts it into a form understandable by the transducer (e.g., speaker, screen).

1.6 Types of Modulation

- **ASK (Amplitude Shift Keying):** Modulation where the amplitude of the carrier varies to represent binary data. It is sensitive to noise.
- **PSK (Phase Shift Keying):** Modifies the carrier's phase to encode binary data, offering higher transmission speeds than ASK.
- **FSK (Frequency Shift Keying):** Alters the carrier's frequency to transmit data, with distinct frequencies for each binary bit.

1.7 Baseband Modulation

Digital transmission systems in baseband send signals as currents that directly reflect the bits to be transmitted. Various coding methods can be used to adapt signals to transmission lines, such as NRZ code, bipolar code, or Manchester code. Signal degradation over long distances limits this method to short-range transmissions.

TD1: Digital Transmission Systems**Exercise 1.1**

Q1- What acronym designates a group of computers connected within a geographically close network (e.g., a set of computers in a room)?

- a. MAN
- b. LAN
- c. WAN

Q2- Which type of network does the Internet corresponds to?

- a. LAN
- b. MAN
- c. WAN

Q3- Which operation associates a sequence of binary elements with each character?

- a. Numbering
- b. Coding
- d. Decoding

Q4- Who created the EBCDIC code?

- a. Microsoft
- b. IBM
- c. HP

Q5- What is baseband transmission?

Q6- Among the encodings used in baseband transmission, which one is used in Ethernet networks (IEEE 802.3)?

Q7- On which types of media is baseband transmission possible?

- a. Twisted pair
- b. Fiber optic
- c. Wireless networks

Q8- In PSK modulation with 3 bits per phase state, what is the elementary value of phase shifts?

- a. 90°
- b. 45°
- c. 22.5°

Q9- How can one easily distinguish between a man's voice and a woman's voice?

Q10- How can binary information be represented in analog signal? For example, how can the information 0110 be represented in an analog signal?

Q11- Assume a local Ethernet network composed of two stations, denoted as A and B. These two stations are connected using a hub. The network has a bitrate of 10 Mbps and a propagation speed of 100,000 km/s. The cables used to connect the devices all have a length of 10 meters.

a. Suppose station A sends a frame of 1500 bytes to station B. Calculate the reception time, denoted as T_r , which corresponds to the time between the emission of the first bit of the frame by A and the reception of the last bit by B.

b. Now, replace the hub with a Store and Forward switch. Does this change have any influence on the T_r parameter calculated in the previous question? If yes, recalculate T_r with this new configuration.

c. If a Cut Through switch had been used, what would have been the value of T_r ?

Q12- On a wired local network, which statements are correct?

a. Distances between devices are limited to 50 km.

b. Usual speeds are limited to 100 Mbps.

c. The network interface card performs routing operations.

Q13- On a wireless local network, which statements are correct?

a. The speed is generally inversely proportional to the distance.

b. All stations can communicate with each other simultaneously.

c. Emission powers are not regulated.

d. Digital signals are transmitted without modulation.

Q14- In twisted pair cables, why is transmission done over two twisted wires?

a. Transmission over two wires allows for longer distances.

b. Differential transmission between two wires cancels additive noise.

c. Twists cancel out disruptive electric currents.

d. Twists give more flexibility to the cable.

Q15- Regarding fiber optic cables, which statements are correct?

a. Internal radiations limit the bit rates to 1 Gbps per fiber.

b. The fiber is very sensitive to electromagnetic disturbances.

c. Connectors are not required.

d. Its usage is gradually being abandoned in favor of coaxial cables.

Q16- At a given frequency, which medium corresponds to the shortest maximum transmission distance?

a. Coaxial cable

b. Twisted pair

c. Fiber optic

Q17- A WLAN necessarily includes a base station.

- a. True
- b. False

Q18- When a mobile station is turned on and wants to join an IEEE 802.

Q19- The frequency band allocated to WiFi transmissions is:

- a. 78 - 110 MHz
- b. 5 - 5.24 GHz
- c. 2.4 - 2.4835 GHz

Q20. A local network is intended to transfer two types of information: text files with a maximum size of 10 MB requiring a minimum transmission time of 0.5 s; interactive messages with a maximum of 500 characters transmitted in less than 1 ms.

Calculate the capacity of the medium for baseband transmission.

Exercise 1.2

Below is an evolution of telephony:

- 1) An Indian wants to transmit a message to his tribe using smoke signals.
- 2) Two children communicate using "tin can telephones."
- 3) A person converses with another using a landline telephone (referred to as "classic").
- 4) A person converses with another using a mobile phone.
- 5) A person converses with another using a VoIP phone connected to a router.

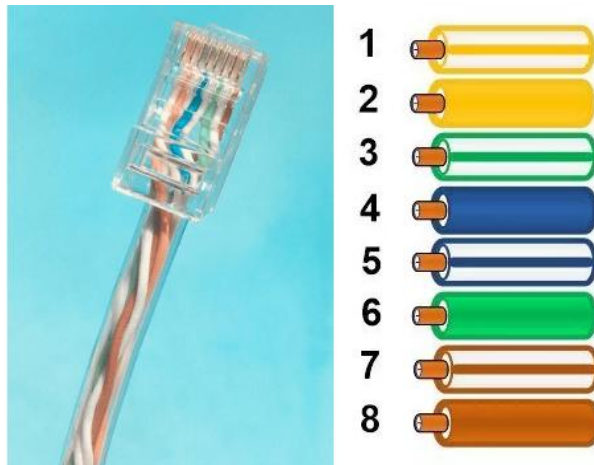
Fill in the following table.

Situation	Sender	Transmission Channel	Type of Transmission	Type of Signal Transported by the Channel	Receiver
(1)					
(2)					
(3)					
(4)					
(5)					



Exercise 1.3

1- What does the figure below represent? What is it composed of? As you can see, these electrical wires have different colors. What are they?



2- Complete the table and rename the numbering of the following figure:

Old Name	New Name	Shielding of 4 Pairs	Shielding Per Pair
UTP	U/UTP		
STP	U/FTP		
FTP	F/UTP		
FFTP	F/FTP		
SFTP	SF/UTP		
SSTP	S/FTP		



3- Provide the different categories of twisted-pair Ethernet cabling, their frequency, and the corresponding theoretical data rate.

Exercise 1.4

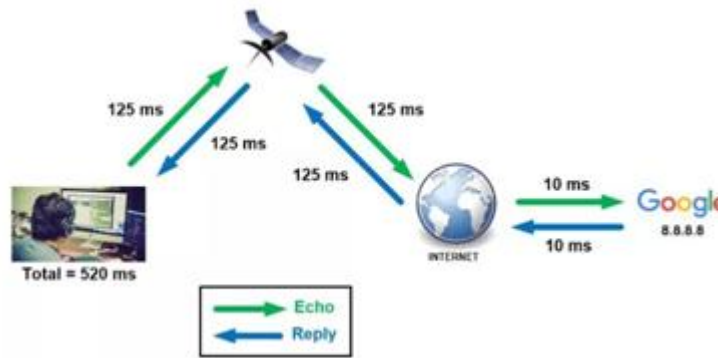
What are the advantages and disadvantages of fiber optics? And what are its different modes?



Exercise 1.5

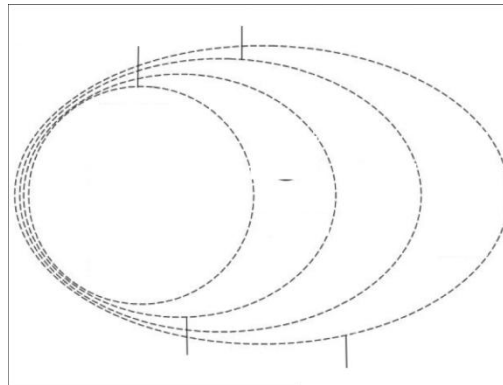
In which cases do we need to access the internet via satellite links? List the advantages and disadvantages of such a connection.

In the figure below, what is the total time required to receive information?



Exercise 1.6:

-Complete the following wireless technologies diagram:



-Complete the following table by specifying the corresponding class in each box.

Wireless Network	Class
WWAN	
WBAN	
WLAN	
WMAN	
WPAN	
ad hoc	
Cellulaire	

Chapter 2: Data Transmission - Summary

2.1. Introduction

Transmission media often affect signals due to various disturbances and degradations resulting from their characteristics such as bandwidth, attenuation, and noise sensitivity. This chapter covers the exploitation modes, types of links (point-to-point and multipoint), transmission modes (parallel, serial, synchronous, asynchronous, and isochronous), as well as the characteristics of transmission media: bandwidth, modulation speed, bit rate, attenuation, and noise sensitivity.

2.2. Modes of Exploitation (Information Direction)

Transmission channels can be used in different modes, including:

- **Simplex Link:** A unidirectional link where data flows in one direction only (e.g., from a computer to a printer).
- **Semi-Duplex Link:** A bidirectional link where communication alternates between the sender and receiver. Both can transmit but not simultaneously.
- **Full-Duplex Link:** A bidirectional link where data flows simultaneously in both directions, requiring the bandwidth to be divided between the two directions if the same transmission medium is used.

2.3. Link Types (Point-to-Point and Multipoint)

- **Point-to-Point:** A direct connection between two devices (one sender and one receiver).
- **Multipoint:** A connection between one sender and multiple receivers, allowing communication with several devices over the same link.

2.4. Transmission Modes

Transmission can occur in different ways based on the direction, mode of data transmission, and synchronization:

2.4.1 Serial vs. Parallel Transmission:

- **Parallel:** Multiple bits are sent simultaneously. Common in internal computer connections.
- **Serial:** Bits are transmitted one after another.

2.4.2 Synchronization:

- **Asynchronous:** Data is sent without a clock signal, with start and stop bits used to mark the beginning and end of data packets.
- **Synchronous:** Data is sent in a continuous stream, synchronized by a clock signal.
- **Isochronous:** Data must be transmitted at a constant rate, with no delays. Used in applications like telephony.

2.5. Multiplexing

Multiplexing allows multiple signals to share a single transmission medium. The main types are:

- **Time-Division Multiplexing (TDM):** Divides the transmission time into intervals assigned to different signals.
- **Static TDM:** Each channel is allocated a fixed time slot.

- **Statistical TDM:** Time slots are dynamically assigned based on demand, improving bandwidth utilization.
- **Frequency-Division Multiplexing (FDM):** Divides the available bandwidth into smaller subbands, each used by a different signal. This technique is more commonly used for analog transmission.

2. 6. Transmission Media Characteristics

Transmission media are characterized by several factors that determine their performance:

2.6.1 Bandwidth: The range of frequencies that a transmission medium can carry effectively. A higher bandwidth allows for more data to be transmitted.

2.6.2 Attenuation: The reduction of signal strength over distance, requiring amplification or regeneration for long-distance transmission.

2.6.3 Noise Sensitivity: The degree to which external interference can affect signal quality.

2.6.4 Attenuation Ratio

The attenuation ratio is the ratio of the emitted signal amplitude to the received signal amplitude, indicating how much the signal weakens over distance.

2.6.5 Maximum Distance

The maximum distance over which a signal can travel without requiring amplification or regeneration. This distance is longer for optical fiber.

2.6.6 Bit Error Rate (BER)

The probability of bit error is calculated by dividing the number of erroneous bits by the total number of bits transmitted.

2.6.7 Channel Capacity

The channel capacity is the maximum amount of data that can be transmitted in one second, given a specific bandwidth and signal-to-noise ratio. According to Shannon's theorem, this is expressed as:

$$C = W \log_2(1 + S/N)$$

6.7 Modulation Speed

The modulation speed (R) refers to how fast symbols (representing bits) are transmitted over a channel. It is measured in baud and relates to the modulation interval.

$$R = \frac{1}{\Delta}$$

6.7.1 Maximum Modulation Speed

The maximum modulation speed is determined by the channel's bandwidth, with the Nyquist theorem stating that the maximum modulation rate is :

$$R_{\max} \leq 2W$$

6.8 Symbol Value (Valency)

The valency of a signal represents the number of distinct states a signal can take. This value is usually a power of 2 and corresponds to the number of bits required to represent these states.

6.9 Bit Rate (D)

The bit rate is the number of bits transmitted per second. It is related to modulation speed and valency as:

$$D = \frac{\log_2(V)}{\Delta} = R \log_2(V) = n R$$

TD2: Data Transmission**Exercise 2.1**

TV channels offer a bandwidth of 6 MHz; what is the achievable bit rate, expressed in bits/s, if a 4-level encoding is used?

Exercise 2.2

- a) What is the maximum achievable data rate when transmitting a series of binary information in a channel with a bandwidth of 3 kHz and a signal-to-noise ratio of 20 dB?
- b) Same question with a signal-to-noise ratio of 30 dB.

Exercise 2.3

What is the signal-to-noise ratio required to transmit 1.544 Mbit/s over a line with a bandwidth of 50 kHz?

Exercise 2.4

Consider a digital signal with a modulation rate four times slower than the bit rate. What is the signal's valence? If the modulation rate is 2,400 baud, what is the available bit rate?

Exercise 2.5

The Manchester code has the advantage of having at least one signal transition in the middle of the interval for proper receiver synchronization, but it can have too many transitions, especially if the binary data stream contains a long sequence of 0s, for example.

- 1) Represent the transmitted signal using the Manchester code for the data 10000000001.
The Miller code offers an interesting alternative. It involves removing one transition out of two from the Manchester code.
- 2) Draw the transmitted signal for the same data and show that the decoding is unambiguous.

Exercise 2.6

Four analog information streams are multiplexed on a telephone line with a bandwidth of 400-3100 Hz. Each stream has a bandwidth of 500 Hz.

- Explain the process of multiplexing.

Exercise 2.7

Three lines are multiplexed on a packet-switched link with a length of 1200 bits. Each line carries messages with respective lengths of 3600 bits, 12000 bits, and 4800 bits. The

switched link has a data rate of 4800 bits/s. Describe the process of multiplexing.

Exercise 2.8

For a digital transmission channel with a bit rate $D = 10600$ bits/s, calculate the modulation rate R if the signal valence $V = 4$.

Exercise 2.9

- What are the corresponding values in dB for the following ratios: 10 dB, 3 dB, 40 dB, 37 dB?
- Convert the following ratios to decibels: $P_a/P_b = 2000, 500, 10000, \text{ and } 500000$?
- A telephone handset emits with a power of 2 dBmW. What is the emitted power in watts?
- If the sound power S of a large motorcycle is measured at 87 dB, what is the sound power, in decibels, produced by a group of 8 identical motorcycles traveling at the same speed? Find the actually emitted sound power.
- In the preliminary study for installing a network, it is desired that the emitted signal power be 2000 times greater than the noise power. What is the power, in decibels, associated with the bandwidth of the medium to be installed?

Exercise 2.10

- Apply Shannon's formula and determine the maximum theoretical capacity of a channel with a bandwidth $\beta = 4.5$ MHz and a signal-to-noise ratio $S/N = 35$ dB.
- A channel has a capacity of 20 Mbits/s. The channel bandwidth is 3 MHz. What should be the signal-to-noise ratio?

Exercise 2.11

- If the attenuation is 30 dB, what is the ratio $|V_e/V_s|$ of a section of transmission line?
- A transmission line has a length $L = 350$ m. At the input, the power is measured as $P_e = 2.2$ kW, and at the output, the power is $P_s = 1.9$ kW. Calculate the linear attenuation coefficient.
- The gain between V_s and V_e is defined as $G(\text{dB}) = 20\log(V_s/V_e)$. A line has an attenuation of 25 dB, and V_e is set to 1 V.

-Calculate the voltage at the output of the line.

A second line is added at the end of the first line. This line has an attenuation of 10 dB.

-Calculate the total attenuation.

Exercise 2.12

The attenuation of a signal in an optical fiber depends on its frequency. This property is illustrated in the graph below.

- a) What is the name of the physical quantity represented on the x-axis?
- b) What is the name of the physical quantity represented on the y-axis?
- a) At what wavelength do we observe maximum attenuation?
- b) Which domain of the electromagnetic spectrum does this wavelength correspond to?

We use a light source with a wavelength of 900 nm.

- a) What is the attenuation coefficient for this wavelength?
- b) What length of fiber can be used before reaching an attenuation of 3 dB?
- c) What wavelength should be used for an attenuation of 1 dB?

Exercise 2.13

A transmission channel has an attenuation coefficient of $\alpha = 8.0 \text{ dB.km}^{-1}$; the measured input power is $P_e = 100 \text{ mW}$, and the receiver requires an output power of $P_s = 3.8 \text{ }\mu\text{W}$ to function.

- What is the maximum length L_{max} of the line that allows information transmission?

Exercise 2.14

Consider the logical frame of an asynchronous serial connection:

A transmission channel has an attenuation coefficient of $\alpha = 8.0 \text{ dB.km}^{-1}$; the measured input power is $P_e = 100 \text{ mW}$, and the receiver requires an output power of $P_s = 3.8 \text{ }\mu\text{W}$ to function.

- What is the maximum length L_{max} of the line that allows information transmission?
- Given that the transmitted data is encoded in one byte, includes parity, and has 1 stop bit, determine the transmitted data in hexadecimal format.

Exercise 2.15

Calculate the minimum duration of sending 900 characters encoded in 7 bits using asynchronous serial transmission at a rate of 9600 bits per second. We are using a recent computer that requires 0.5T for the stop bit.

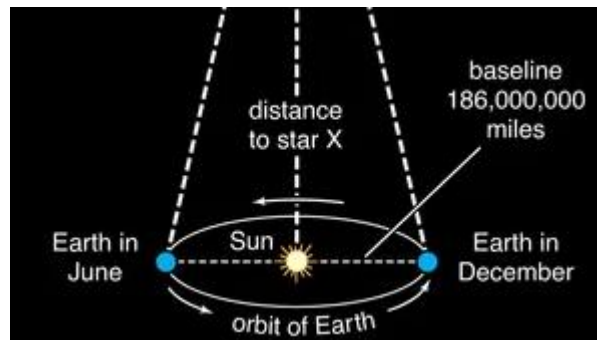
Exercise 2.16

Suppose you have a point-to-point link between Earth and a solar star. The distance between Earth and this star is 400,000 km, and data travels at the speed of light (3108 m/s).

- a. What is the minimum round trip time on this link?

We are transmitting an image of 25 megabytes on this link at a transmission rate of 56000 b/s.

b. How much time is needed to retrieve it?



Chapter 3: Reminder on Modems and Interfaces

3.1 Introduction

Modems and codecs are responsible for converting signals to allow data transmission over various media. The ISO and ITU have standardized the terminology related to these devices. The DTE (Data Terminal Equipment) and DCE (Data Circuit-Terminating Equipment) interact to manage communication through an interface that ensures data transmission management.

3.2 The Modem

The modem, short for "modulator-demodulator," converts digital data into analog signals for transmission over analog networks. Upon reception, it performs the reverse operation. There are several types of modems, including those for ADSL, ISDN, GSM, WiFi, etc. Modems are characterized by their speed, mode of operation (simplex, duplex), modulation type, and type of medium used (e.g., telephone network).

3.2.1 Modem Characteristics

Modems vary based on transmission speed (e.g., 56kbit/s for recent standards), mode of operation (synchronous, asynchronous), modulation type (FSK, QAM, PCM), and connection type (electrical, acoustic).

3.2.2 Modem Standardization

The ITU-T, formerly known as CCITT, has standardized modem characteristics, including speeds and modulation types. Standards such as V21, V32, V90, and V92 have been defined to ensure modem interoperability.

3. Interfaces

An interface is the junction between the DTE and DCE, enabling data transfer and transmission management. It includes mechanical (connector type), electrical (voltage levels), functional (pin roles), and procedural (commands and exchanges) aspects. Standards like V24 and RS232 are commonly used for these interfaces.

3.1 Main Interfaces

Interfaces define the mechanical, electrical, functional, and procedural characteristics of connections. For instance, the DB25 connector for serial interfaces and the V24 standard

for data transmission are widely used.

3.2 USB Interface

The USB interface is a very popular serial interface in modern modems. It allows speeds of up to 480 Mbit/s and supports hot-plugging of devices without needing a restart.

4. Circuit Nomenclature

Circuit nomenclature defines the functions of the interface pins. Each function is identified by a specific number and a standardized abbreviation (e.g., DTR for "Data Terminal Ready," RTS for "Request To Send").

5. Establishing a Link Between Two Systems

5.1 Establishing a link between two systems involves three phases:

- Initial connection,
- Link initialization,
- Data transmission.

Each phase involves exchanges of control signals (e.g., DTR, RTS, and DCD) to establish and maintain communication.

6. ADSL Modem

ADSL allows fast internet connections while sharing the traditional telephone network.

- Characteristics: Speeds up to several Mbit/s, with bandwidth shared between the telephone, upload, and download streams.
- Operation: The bandwidth is divided into several sub-channels for managing phone service, upload, and download.
- Developments: Versions like ADSL2+ and VDSL offer higher speeds by modifying the frequency band used. VDSL+2 promises even faster speeds.

TD 3**Exercise 3.1**

We want to digitize an analog signal using the MIC technique, whose frequency range is between 1000 Hz and 2000 Hz. The quantization is done on a scale of 58 values.

- What is the minimum bitrate in b/s required to correctly transmit the digitized signal? (Provide only the value)

Exercise 3.2

Consider an asynchronous transmission with one Start bit, two Stop bits, one Parity bit, and two Signal bits (one Space bit is inserted between two characters) at 14400 bps.

- What is the effective bitrate in bits/s (for the transmitted data bits) of this line? Provide only the value.

Exercise 3.3

Give the bitrate (without specifying the unit measured in kbps) of a digital signal on a telephone line, knowing that the signal frequency varies between 1 kHz and 4 kHz, and its valence is 256.

Exercise 3.4

Consider a signal with a cutoff frequency of 1200 Hz.

- Give the bitrate (without specifying the unit measured in bits/s) of this signal after modulation to four states on a telephone line.

Exercise 3.5

- What is the minimum bitrate required to transmit speech of better quality than telephone speech (sampling with 10-bit samples instead of 8-bit samples) on a network with a bandwidth of 10 kHz?
- Does frequency-division multiplexing transport more information for the same bandwidth compared to time-division multiplexing?

A transmission channel carries 16 distinct signals.

- What is the maximum amount of binary information that can be transported by each signal?

The signal-to-noise ratio of a transmission channel is 30 dB, and its bandwidth is 2 MHz.

- What is the approximate theoretical capacity of this channel?

Exercise 3.6

A digitized TV image needs to be transmitted from a source that uses a display matrix of 450x500 pixels, with each pixel capable of taking 32 different intensity values. It is assumed that 30 images are sent per second.

- a. What is the bitrate D of the source?
- b. The TV image is transmitted over a channel with a bandwidth of 4.5 MHz and a signal-to-noise ratio of 35 dB. Determine the capacity of the channel.

Exercise 3.7

A digital transmission system operates at a bitrate of 9600 bps.

If one elementary signal allows the encoding of a 4-bit word, what is the minimum bandwidth required for the channel?

- Same question for encoding an 8-bit word.

Exercise 3.8

Two stations exchange information via a communication satellite located 36,000 km above the Earth's surface. The signal propagation speed over the transmission medium (air) between the satellite and a ground station is equal to the speed of light, approximately 300,000 km/s assuming that one of the stations sends a message to the other station with a size of 800 bits and a bitrate of 64 Kbps:

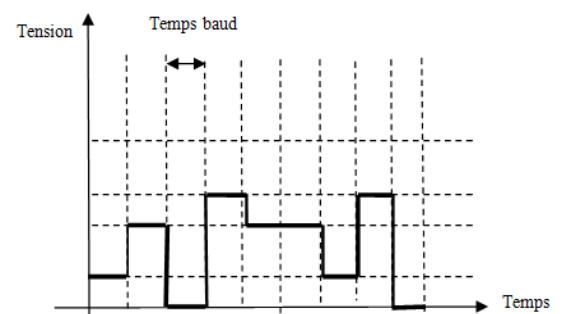
1. Calculate the transmission time of this message.
2. Calculate the transfer time.
3. One of the simplest methods for detecting transmission errors is for the receiver to send back a copy of the received message. The transmitter then compares the two messages.
4. Calculate the communication time assuming the transmission is utilized in Half and Full duplex.

Exercise 3.9

We have a signal in the form shown below:

What is the number of bits per baud that can be transmitted?

Assuming that the transmission protocol specifies that the levels from lowest to highest correspond to binary values from 0 to 3, what is the bit sequence represented by this signal?



Exercise 3.10

1. Which combination was used for the transmission of the following signal?
2. How many bits per baud are transmitted if all possibilities of the used combinations are presented in this signal?
3. Assuming that the four amplitude-frequency combinations: low-low, low-high, high-low, and high-high, respectively encode 00, 11, 01, and 10. What is the bit sequence representing the signal?

Exercise 3.11

A transmission channel carries 8 distinct signals; its modulation rate is $R = 1200$ bauds.

- What is the bit rate of this line?

A digital transmission system operates at a bit rate of 9600 bits/s. If an elementary signal allows the encoding of a 4-bit word, what is the minimum bandwidth required for the channel?

Suppose a digital signal has a modulation rate four times lower than the bit rate. What is the signal's valence? If the signal's modulation rate is 2400 bauds, what is the available bit rate?

- Calculate the modulation rate of a signal with a valence of 8, given that the transmission of 100 bytes takes 0.8 ms.

Exercise 3.12

Consider a transmission medium characterized by its extreme frequencies of 60 and 108 kHz and a signal-to-noise ratio (S/N) of 37 dB.

- What is the theoretical maximum bit rate of this line?
- What happens to this result if the S/N ratio is 40 dB?

Exercise 3.13

Let's assume we have a signal with a modulation rate of 105 bauds.

- What is the bit rate if the signal is binary? What about if it's quaternary?

With such a signal and a modulation rate of 105 bauds, what valence is required to achieve a bit rate of 800 Kbits/s?

- What is the minimum bandwidth of the link carrying such a signal? (Refer to R, D, and V from the previous question)
- What should be the minimum signal-to-noise ratio if the bandwidth of the link is 1000 Hz to achieve the same bit rate?

Exercise 3.14

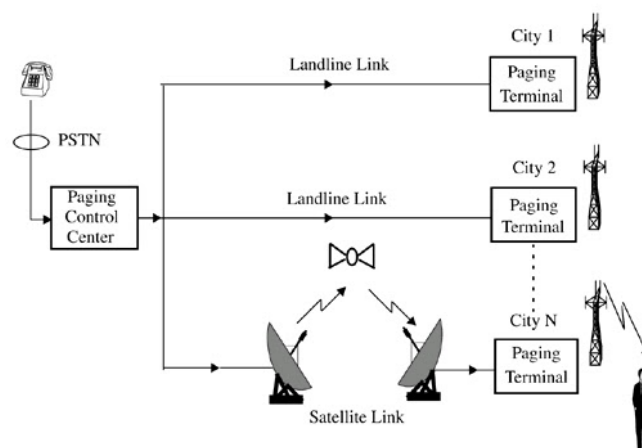
Consider the modulated signal to be transmitted below:

- How many different phases are there? List them.
- How many different types of amplitude are there? List them.
- Calculate the valence.
- How many bits per baud are transmitted by such a signal?
- Calculate the modulation rate.
- Propose a binary value for each possible combination.
- Deduce the binary information carried by the signal.

Exercise 3.15

A pocket paging system (a service for sending radio messages to users) has the following technical characteristics:

- Frequency band: 169.425 MHz - 169.800 MHz.
 - 4-state frequency modulation.
 - Modulation rate: 3,125 bauds.
 - Receiver signal-to-noise ratio (S/N): 76 dB.
1. What is the actual bit rate used in this paging system?
 2. Assuming one character is transmitted per byte, how long does it take to transmit a 200-character message on a paging receiver?
 3. Instead of the bit rate found in question 1, what theoretical bit rate could be achieved by fully exploiting the technical characteristics of the paging system?



Exercise 3.16

We consider the two sites A and B composed of the following equipment:

- Site A: - 04 servers - 60 PCs
- Site B: - 10 PCs

Answer questions 1.1 - 1.12 by selecting the appropriate equipment from the list of words that follow. Note the response with the corresponding character.

a. Router	b. Crossover RJ45 cable	c. Multiplexer	d. Analog modem
e. Front-end	f. Straight RJ45 cable	g. Printer	h. Baseband modem
i. Port	j. RJ11 cable	k. Serial cable	l. Network card
m. Proxy q. PC	n. Switch	o. Hub	p. Address bus

Question 1.1. What equipment should be used to connect the PCs at Site A in a local network?

Question 1.2. What equipment should be used to connect the servers at Site A in a local network?

Question 1.3. What equipment should be used to interconnect the two equipment from answers 1.1 and 1.2 if all their ports are of the same type?

Question 1.4. What equipment should be present on the workstations at Site A to enable them to communicate in a network?

Question 1.5. To which equipment at Site A will a network printer be connected?

Question 1.6. What equipment should be used to connect Site A to the high-speed data transmission public network?

Question 1.7. What type of modem should be used to connect this equipment to the high-speed data transmission public network?

Question 1.8. What equipment should be used to connect the PCs at Site B in a local network?

Question 1.9. What type of cable should be used to connect the PCs to this equipment?

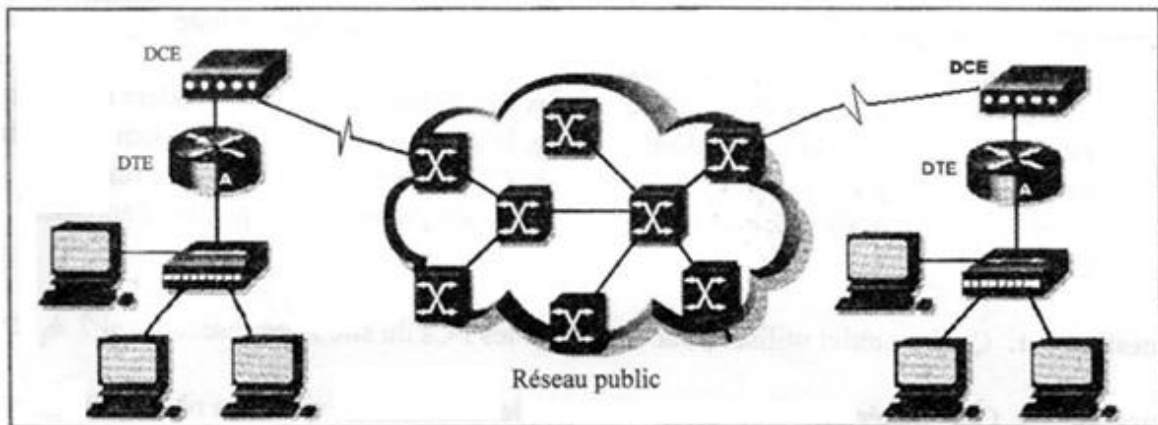
Question 1.10. What equipment should be used to connect Site B to the switched telephone network?

Question 1.11. On which equipment should this equipment be placed?

Question 1.12. To which equipment at Site B will a printer be connected?

Exercise 3.17

Consider the communication network depicted in the figure below.



Question 2. Answer questions 2.1 - 2.12 by selecting the appropriate response from the list of options provided. Note the answer by indicating the corresponding character.

a. Packet-switched network	b. RTC	c. RNIS	d. Wi-Fi network
e. Circuit-switched network	f. HDLC	g. SLIP	h. Daisy Chain
i. Both end nodes	j. PPP	k. TCP/IP	l. Hub
m. All network nodes	n. Modem	o. Router	p. Multiplexer
q. 2 adjacent nodes	r. FDDI	s. Ethernet	t. Token Ring
u. Communication interface	v. Network card	w. Computer	x. CSMA/CD
y. Slotted ALOHA	z. Switch		

- Question 2.1. What type of public network is it?
- Question 2.2. Which protocol does this public network implement at the link layer?
- Question 2.3. Which nodes are included in the scope of this protocol?
- Question 2.4. Which frame encapsulates the other, Ethernet or HDLC?
- Question 2.5. On which hardware is TCP/IP implemented?
- Question 2.6. On which equipment is CSMA/CD executed?
- Question 2.7. Which hardware represents the DCE?
- Question 2.8. What is the Layer 2 protocol of the router?
- Question 2.9. What is the access network layer protocol of the PCs?
- Question 2.10. Where is the mapping table between port number and MAC address located?
- Question 2.11. On which equipment does the ICMP protocol run?
- Question 2.12. Which equipment supports the configuration of VLANs?
- Question 2.13. The routing approach deployed on this network is distance vector because:
- The protocol used is OSPF.

- The protocol used is EIGRP.
- The routing tables are calculated hop by hop.
- The updates of the routing tables are synchronous.
- The network nodes have a global knowledge of the network.

Exercise 3.18

- A modem uses amplitude modulation, which allows for encoding 16 different values. For a distance of 5km, a modulation rate of 340 kilobauds is achieved. What data rate can this modem achieve?
- A modem uses phase modulation with the phases: 0 , $\pi/4$, $\pi/2$, $3\pi/4$, π , $5\pi/4$, $6\pi/4$, $7\pi/4$. What is the data rate of the modem if the modulation rate is 9600 bauds? Draw its constellation diagram.

Exercise 3.19

What are the data rates offered by modems using a modulation rate of 9600 bauds and complying with the following standards :

- V21, which uses 2-frequency modulation?
- V22, which uses 4-phase modulation?
- V29, which uses 16 combination amplitude/phase modulation?

Exercise 3.20

A V29 modem operates at 9600 bits/s over a bandwidth (BW) channel of 500 to 2900 Hz. It uses octavalent phase modulation with bivalent amplitude.

- Calculate the valence of the modulated signal.
- Represent the constellation diagram of this modem.
- Calculate the theoretical modulation rate and the maximum modulation rate.
- Calculate the signal-to-noise ratio to ensure proper functioning of this modem.

Exercise 3.21

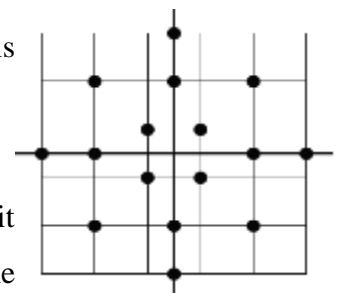
We want to transmit the bit sequence 00101101 through a modem. .

- Draw the sequence of signals transmitted by the modem in quadrivalent phase modulation and bivalent frequency modulation.

Exercise 3.22

The V27 standard defines a modem providing a data rate of 4800 bps. This modem uses eight “8” distinct phase modulations.

- What is the modulation rate of this modem?
- Provide a value for each modulation in the diagram so that only one bit differs between two neighboring modulations. For each modulation in the



diagram, provide a value so that only one bit differs between two neighboring modulations.

Exercise 3.23

The V29 recommendation defines the following constellation for a modem intended for 9600 bps transmission:

- What is the number of bits for each modulation and its modulation rate?
- Calculate the phases and amplitudes of this modem.
- For what reasons is the entire set of 32 states not used?
- Propose a code for each of these groups.

Exercise 3.24

Let's consider a modem operating at 2400 bauds and supporting Quadrature Amplitude Modulation (QAM), defined by the signal $s(t) = A(t)\cos(2\pi ft + \varphi(t))$

$A(t)$	3	3	$\sqrt{2}$	$\sqrt{2}$	$3\sqrt{2}$	$3\sqrt{2}$	-3	-3	$-\sqrt{2}$	$-\sqrt{2}$	$-3\sqrt{2}$	$-3\sqrt{2}$
$\varphi(t)$	0	$\frac{\pi}{2}$	$\frac{\pi}{4}$	$\frac{3\pi}{4}$	$\frac{\pi}{4}$	$\frac{3\pi}{4}$	π	$\frac{3\pi}{2}$	$\frac{5\pi}{4}$	$\frac{7\pi}{4}$	$\frac{5\pi}{4}$	$\frac{7\pi}{4}$
Code	0000	0001	0010	0011	0100	0110	0111	1000	1001	1010	1011	1100

We are interested in transmitting the sequence $S = 001011001111$.

- Specify the number of amplitude and phase levels.
- Calculate the maximum bit rate allowed by this modem.
- Represent the spatial diagram.
- Graphically represent the modulated signal corresponding to S.

Exercise 3.25

A company is connected to the telephone network through a digital link (as shown in the figure below). This type of connection, during data transmission, eliminates the need for signal digitization, which is the main source of noise. The established link is asymmetric, and quantization noise only affects the User/Company direction. This process is implemented in V.90 modems. The signal-to-noise ratio for each element of the link is indicated as follows:

- Analog local loop (2×10^5)
- Quantization noise of the codec (A/D conversion) (10^3)
- Transport network (2×10^8)
- Digital local loop (hybrid network-DCE or MIC/PCM) (2×10^5)

In this link, the user's mobile modem (analog modem) generates an analog signal and

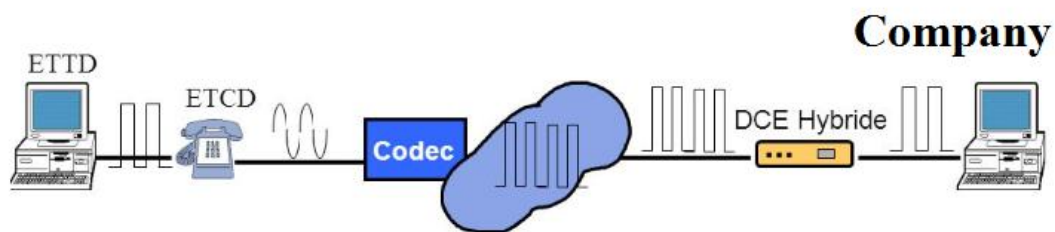
receives a modulated G.711 signal. The hybrid or digital modem generates a G.711 signal and receives an analog signal digitized by the codec, which is the source of quantization noise.

Given that the signal-to-noise ratio of a link composed of n elements is given by:

- Calculate the S/N ratio in the User/Company direction and the Company/User direction.

Given that a high-pass filter, upstream of the codec, limits the bandwidth to 3400Hz:

- Determine the achievable modulation rate for this link in both directions.
- Calculate the maximum permissible data rate in each direction.
- The modem is conventional and uses a QAM-type modulation. What is the number of states for the maximum achievable normalized data rate in both directions?



Exercise 3.26

- Match the V24 signals to their corresponding circuits using arrows.

Signal	Circuits
Data transmission and reception	TD (Transmit Data) CTS (Clear to Send)
Line connection	DTR (Data Terminal Ready) DCD (Carrier Detect)
Transmit validation	DSR (Data Set Ready) RTS (Request to Send)
Carrier detect	RD (Receive Data)

- In a V24 connection, what are the response signals to DTR, RTS, TD, and RD signals?
- Draw the phases of establishing a simplex connection between two systems.



Reminder: CHAPTER 4 - ERROR PROTECTION**4.1 Introduction**

During information transmission, errors can occur unintentionally. To address this, it is crucial to use error detection and correction techniques. This involves adding control bits (or redundancy) to the sequence of bits to be transmitted, enabling the receiver to verify the integrity of the data and correct it if necessary.

4.2 Error Detection

Error detection allows the receiver to verify whether the received data is valid. For instance, in digital telephone line transmissions, the bit error rate (BER) can range from 10^{-4} to 10^{-6} . For computing equipment, a BER below 10^{-9} is often required to ensure transmission quality.

Four main techniques are used for error detection and correction:

- Echo detection
- Repetition detection
- Checksum-based detection (VRC, LRC, CRC)
- Code-based detection and correction (Hamming)

4.2.1 Echo Detection

In asynchronous transmissions, the receiver sends back an echo of the message it received. The sender verifies if the echo matches the sent message. If there is a difference, the message is retransmitted.

4.2.2 Repetition Detection

Each message sent is accompanied by its duplicate. If the two received messages differ, the receiver requests retransmission. This method is used in highly disturbed environments.

4.2.3 Error Detection Using Calculated Checksums

A verification code is calculated from the transmitted message and appended to the data. Upon reception, the receiver recalculates this code and compares the results. If the values do not match, an error is detected, and retransmission is requested.

a- VRC Parity Check

This method, primarily used in asynchronous transmissions, adds a parity bit (even or odd) to the bit sequence. It detects an error if the number of 1s is odd or even, depending on the chosen method.

b- LRC Parity Check

In synchronous transmissions, the Longitudinal Redundancy Check (LRC) adds an additional parity bit for each column of bits in a data block.

c- Cyclic Redundancy Codes (CRC)

Cyclic Redundancy Check (CRC) uses a polynomial to generate a verification code added to the data. Transmission is validated if the remainder of the division of the data by the polynomial is zero. If not, a transmission error is detected, and retransmission is requested.

4.3 Error Detection and Correction Using Codes

Error-correcting codes not only detect errors but also correct them. This process, called Forward Error Correction (FEC), enables the receiver to correct errors without requiring retransmission, making it especially useful in unidirectional channels.

4.3.1 Hamming Distance

The Hamming distance measures the difference between two binary words, indicating the number of bits that need to be altered to transform one word into another. This distance determines a code's error detection and correction capabilities:

- If the Hamming distance is $d_H = 2e$, the code can detect e errors and correct $e-1$.
- $d_H = 2e+1$, the code can both detect and correct e errors.

4.3.2 Hamming Code ($n=7$, $k=4$, $d_H=3$)

The Hamming code (7, 4, 3) uses a system of 4 data bits and 3 parity bits. The parity bits are calculated from the information bits and allow detection and correction of a single error. The receiver uses the parity matrix to identify and correct any errors that occurred during transmission.

TD 4 : Error Protection**Exercise 4.1**

The word OSI is encoded using the following three 7-bit characters:

O=1001111, S=1010011, I=1000011.

1. Give the 8-bit code word associated with each character using even parity VRC, then the corresponding LRC.
2. Repeat for odd parity. What do you observe?
3. Calculate the LRC of the word OSI using polynomial division with generator polynomial $G(x) = X^8 + 1$, assuming the eighth bit is the even parity bit.
4. We want to transmit the hexadecimal digits A9C5, with the first digit transmitted being A. Error protection is done using LRC.
 - A. Give the polynomial form of the transmitted message.
 - B. Give the complete binary sequence transmitted to the receiver (code word transmitted).

Exercise 4.2

Let's consider a Hamming code of length 15:

Code word	1	0	1	1	0	1	1	1	1	0	1	1	0	1	1
Index	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

What are the parity check bits?

- o What is the received message?
- o Does the received message correspond to the transmitted message?
- o What was the transmitted message?
- o Represent the information to be transmitted using NRZ, Bipolar, and Manchester codes.

Exercise 4.3

We will use the generator polynomial: $x^4 + x^2 + x$.

1. We want to transmit the message 1111011101. What CRC should be added?
2. Repeat for the Word 1100010101.
3. I just received the following messages: 1111000101010 and 11000101010110. Are they correct?

Exercise 4.4

For an error detection transmission, a generator polynomial of $x^4 + x + 1$ is used. The transmitter wants to send the sequence 1101011011. Determine the redundancy.

Exercise 4.5

Consider the message composed of the string: NET. Apply longitudinal redundancy check with even parity. Provide the calculated key bit sequence. Assume characters are encoded using ASCII code.

ASCII Codes: N = 1001110, E = 1001001, T = 1010100

Exercise 4.6

Given the information to be transmitted $X^9 + x^8 + X^6 + x^4 + x^3 + x + 1$ and using the generator polynomial $x^4 + x + 1$, determine the transmitted frame.

Exercise 4.7

Consider a teleinformatics link that uses a modulation combining amplitude with 2 levels and phase with 8 levels. The link has a baud rate of 400 bauds. You want to transmit a message of 500 characters encoded in ASCII on this link. Each character has an additional parity bit. Calculate the time in seconds required to transmit this message.

Consider the following code composed of 4 code words:

{0 00000000 0, 111110000 0, 000001111 1, 111111111 1}.

Check the correct characteristics of this code:

- Hamming distance = 10; it can detect 5 errors; it can correct 3 errors.
- Hamming distance = 10; it can detect 5 errors; it can correct 2 errors.
- Hamming distance = 10; it can detect 10 errors; it can correct 5 errors.
- Hamming distance = 7; it can detect 5 errors; it can correct 3 errors.
- Hamming distance = 5; it can detect 4 errors; it can correct 2 errors.
- Hamming distance = 5; it can detect 5 errors; it can correct 3 errors.
- Hamming distance = 5; it can detect 4 errors; it can correct 2 errors.
- This code is invalid as it does not have a Hamming distance.
- This code has a Hamming distance; however, it is unable to detect errors.

Exercise 4.8

Given $g(x) = x^3 + x^2 + 1$ as a generator polynomial for a (6,3) polynomial code, provide the code word for $U = 011$.

Exercise 4.9

We want to use 16QAM modulation on a radio channel. The available frequency band is 150 kHz. What is the maximum theoretical modulation rate? On the channel, the measured noise power density is $N_0 = 2 \times 10^{-21}$ W/Hz. The transmission power is $P_s = 5 \times 10^{-15}$ W. Calculate the noise power and the E_b/N_0 ratio if a modulation rate of 1×10^5 symbols/s

(bauds) is used. Calculate the energy per bit.

Exercise 4.10

We receive a message encoded using repetition code:

0100011010001001011001101101111101010101000110000110001.

If each character is encoded using 4 bits, determine the received characters and their duplicates.

Find the retransmitted message and calculate the bit error rate (BER) if the initial message is given as: 0100100101101111101010000001.

Exercise 4.11

In the ITU-T1 alphabet, the word "OSI" is encoded using the following 7-bit characters:

O = 1001111, S = 1010011, and I = 1000011.

- Give the 8-bit code word using even parity to calculate the VRC for each character and the LRC of the word "OSI."
- Same question using odd parity.

Exercise 4.12

We want to transmit the message "Bonjour." The ASCII codes for the characters are:

B	j	n	o	r	u
42	6A	6E	6F	72	75

- What is the transmitted message using even parity VRC?
- What is the transmitted message using odd parity VRC+LRC?

Exercise 4.13

The following sequence is 11101100101101110110. Knowing that the encoding at the transmitting station was done using the double parity technique with the word divided into 4-bit blocks; determine the VRC and LRC of this sequence.

Exercise 4.14

A keyboard and a microcontroller are connected by an RS232 serial link. This link is configured as follows: 1 Start bit + 8 data bits + 1 even parity bit + 2 stop bits with a transmission rate of 19200 bits/s.

The letters "OK" are entered, and then "Enter" is pressed, which causes the transmission of control characters LF and CR.

The letters are encoded in 8 bits as follows: O = 4F, K = 4B, LF = 0A, and CR = 0D in hexadecimal.

Provide the transmitted sequence for each letter. Represent the sequence "OK" using RS232 signal levels.

What is the percentage ratio between the number of useful bits and the number of transmitted bits?

Calculate the time of one bit in this link and the elementary time required.

Exercise 4.15

We want to transmit the message "ERREUR" using an asynchronous transmission configured as follows: 1 Start bit = 0, 8 data bits, 1 even parity bit, 2 stop bits = 1, with a useful transmission rate of 28400 bits/s.

Calculate the time of one bit in this link and the total transmission rate.

Provide the VRC for each character.

Give the binary sequence of the message to be transmitted if the character codes are: E = 45, R = 52, U = 55.

b) Now we want to transmit the same message using synchronous transmission with 8 synchronization bits, 8 control bits, data block, and 7 control bits.

Calculate the ratio between the useful transmission rate and the total transmission rate.

Compare the time taken to send the message using the two transmissions.

Exercise 4.16

We will use the generator polynomial $x^4 + x^2 + x$.

If we want to transmit the message 1111011101, what CRC should be added?

We receive the following messages: 1111000101010, 11000101010110. Are they correct?

Exercise 4.17

Let the generator polynomial be $G(x) = x^6 + x^4 + x + 1$.

We receive the message (101011000110).

- Is the received message correct? If yes, what is the originally transmitted message?
- Same questions for the message (110111111000).

Exercise 4.18

We want to use a CRC to send the sequence 6B96 (in hexadecimal). The generator polynomial $G(x)$ used is $G(x) = x^4 + x^3 + x + 1$. Provide the binary form of $G(x)$.

By calculating the CRC, give the transmitted bit sequence.

Assuming an error occurs at the 6th bit.

Reminder on CHAPTER 5: Telecommunication Networks

5. Introduction: Wireless and mobile systems (e.g., GSM, Wi-Fi, Bluetooth) have seen significant growth, supporting both infrastructure-based networks (e.g., Wi-Fi) and ad hoc networks. They enable easy communication among devices, prioritizing mobility and extended coverage through cellular systems like GSM. Current developments also include WRAN (IEEE 802.22) for wide rural coverage using TV bands.

5.1 Fixed Networks

Fixed access networks are evolving to support high-speed data services via multiple technologies:

1. Switched Telephone Network (RTC)

- Historically used for analog voice services, now supports digital services via ISDN (64/128 kbit/s).
- RTC is leveraged for internet access and enables interconnection between fixed and mobile operators.

2. xDSL Technologies

- Use copper telephone lines for high-speed data, offering symmetric/asymmetric speeds.
- **ADSL:** Most common, supports 8 Mbps download at distances up to 2.7 km.
- Enables "always-on" internet for high-speed, on-demand services.

3. IP and Ethernet Networks

- Ethernet, the dominant LAN technology, now extends into Gigabit Ethernet (up to 10 Gbps) over fiber.
- Used for integrated voice, data, and video services.

4. Fiber Optic Networks

- Support very high-speed traffic over long distances.
- Now being deployed for local loops to provide end-users with high-speed internet (up to 200 Gbps over tens of km).

5. Cable Networks (HFC)

- Combines fiber-optic backbone with coaxial cable for end-users.
- Provides broadband (10 Mbps downstream, 760 kbit/s upstream) and supports digital TV, VoIP, and data transmission.

6. Power Line Communication (CPL)

- Uses existing electrical infrastructure for local data transmission (5–10 Mbps).
- Suitable for localized multimedia streaming and VoIP within buildings.

5.2 Functioning of a Wireless Network

A wireless network enables communication between devices without using cables. Key concepts include:

- **Network Access Point:** Interface between wireless devices and the wired network.
- **Range and Bandwidth:** The farther the distance from the access point, the lower the bandwidth (e.g., 1 Mbps over 460 m in an obstacle-free environment, 90 m in a typical office setting).

Two operational modes:

1. **Infrastructure Mode:**
 - Fixed base stations connected to a wired network.
 - Communication between mobile units is routed through a base station.
2. **Infrastructure-less Mode (Ad hoc):**
 - No fixed stations; devices communicate directly.
 - Devices act as routers to ensure network connectivity.

5.4 Categories of Wireless Networks

Wireless networks are categorized based on their coverage area:

1. **WPAN (Wireless Personal Area Network):**
 - **Range:** A few meters.
 - **Examples:** Bluetooth, Home RF.
2. **WLAN (Wireless Local Area Network):**
 - **Range:** Local network (home, enterprise).
 - **Examples:** Wi-Fi (IEEE 802.11), HiperLan.
3. **WMAN (Wireless Metropolitan Area Network):**
 - **Range:** City or regional coverage.
 - **Example:** WiMAX (IEEE 802.16).
4. **WWAN (Wireless Wide Area Network):**
 - **Range:** Long distance (up to 3 km).
 - **Examples:** GSM, UMTS, satellite networks.
5. **WRAN (Wireless Regional Area Network):**
 - **Range:** Large rural areas, utilizing unused TV frequencies.
 - **Example:** IEEE 802.22 (under development).

5.5 Mobile Networks

A mobile network provides two key services:

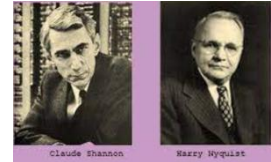
- Wireless access to information.
- Mobility with retained network address.

Mobile Addressing:

- **GSM Mobility:** Transition between visitor and subscriber networks.
- **IP Mobility:** A single IP address for global device localization.

5.6 Mobile Networks by Generation

1. **1G (1970s) – Analog Technology:**
 - Dedicated to voice calls.
 - **Standards:** AMPS, NMT, TACS, Radiocom 2000.
 - **Weaknesses:** Poor service quality, unsecured, expensive.
2. **2G (1990s) – Digital Telephony:**
 - **Bandwidth:** 9.6 kbps (GSM).
 - **Services:** Voice calls, SMS, MMS.
 - **Evolutions:**
 - **GPRS (2.5G):** Average bandwidth of 48 kbps, limited internet access.
 - **EDGE (2.75G):** Average bandwidth of 100 kbps, supports multimedia.
3. **3G – High-Speed Internet:**
 - **Bandwidth:** 144 kbps to 2 Mbps.
 - **Services:** Faster downloads, streaming, GPS, video conferencing.
 - **Evolutions:**
 - **3G+ (HSPA):** Up to 14.4 Mbps.
 - **H+ (HSPA+):** Up to 21 Mbps.
 - **H+ Dual Carrier:** Up to 42 Mbps.
4. **4G – Very High-Speed Internet:**
 - **Standard:** LTE.
 - **Bandwidth:** Theoretical 150 Mbps, practical ~100 Mbps.
 - **Evolution:** 4G+ (LTE-Advanced), up to 1 Gbps.
5. **5G – Ultra High-Speed Mobile Internet:**
 - **Bandwidth:** Up to 10 Gbps.
 - **Goals:** Economic revolution, massive connectivity.

TD 5**Exercise 5.1 : Shannon and Nyquist**

A physical communication medium has a bandwidth of 1 MHz.

Question 1: What is the maximum theoretical information rate that can be transmitted over this medium using a 2-valued (binary) modulation?

Question 2: The signal generated on this channel has a signal-to-noise ratio of 20 dB.

-What is the maximum theoretical information rate that can be transmitted over this channel?

-What valence would be required to approach this maximum theoretical information rate?

Exercise 5.2 : Modulation

It is recalled that the V29 modem operates at 9600 bit/s on a 4-wire full-duplex connection. The modulation process is a combined octavalent phase modulation and binary amplitude modulation (two levels are amplitude-coded for each phase used).

Suppose that a physical channel with a bandwidth of 3200 Hz is used.

Question 1: What is the valence of the modulated signal? What is its modulation rate?

Question 2: What is the minimum signal-to-noise ratio required for transmission, assuming that the channel is subject to Gaussian white noise (Shannon's formula)? If the signal-to-noise ratio is 10 dB, is transmission possible?

Exercise 5.3: The usefulness of error detection

On an urban radio link at 1200 bit/s, messages of 64 bits are transmitted. The transmission frequency is 12 messages/second.

Calculate the utilization rate of the link. As the link is of poor quality, the bit error rate (denoted as p) is between 0.01 and 0.001. p represents the probability that a bit is received incorrectly.

Calculate, as a function of p , the probability that a message is received incorrectly. It is assumed that the bit errors are independent.

Suppose that the transmitter knows when a message is received incorrectly and retransmits it.

Calculate, as a function of p , the average number of transmissions required. Is it possible to maintain the transmission frequency of 12 messages/second (neglecting the time elapsed between two retransmissions)?

Exercise 5.4: Polynomial codes

Consider the 14-bit polynomial code generated by the polynomial $G(x) = x^4 + x + 1$.

Recall the principle of polynomial codes. How many redundancy bits will be added by G ?

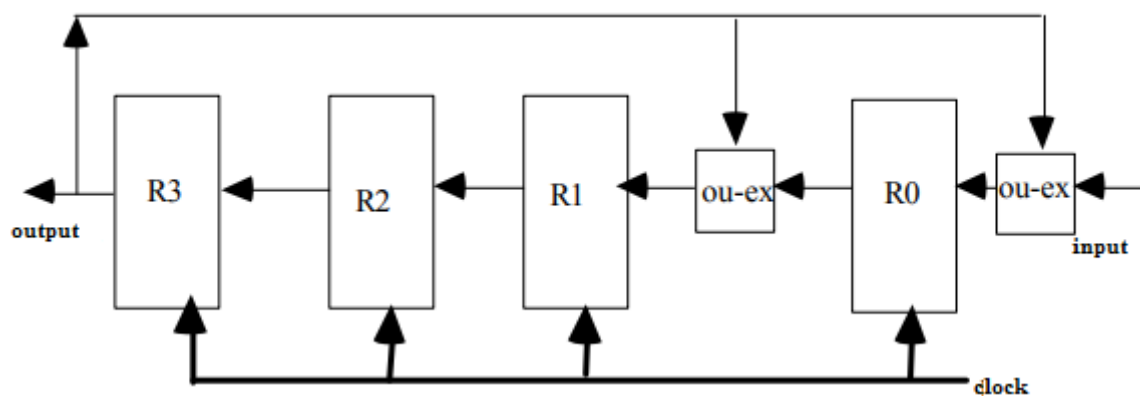
What is the size of the initial words? What types of errors can this code detect?

We want to calculate the redundancy bits of the word $M=1101011011$.

-Give $D(x)$, the polynomial corresponding to M .

-Calculate $R(x)$, the remainder of the polynomial division of $D(x).x^4$ by $G(x)$. Deduce the values of the redundancy bits.

Redundancy bits are generally produced by a simple hardware device, using logic gates and shift registers. For this example, the circuit has the following diagram:



The circuit receives as input the bits of the word M (starting with the most significant bit). Registers $R0 \dots R3$ are initialized to zero. By the 4th clock cycle, they have all received a value. By the 10th cycle, all bits of M have been loaded. It is during the next 4 cycles that the redundancy bits are generated.

Give the contents of the registers for each clock cycle.

Exercise 5.5: Error-correcting codes

Assume that a code for encoding three-bit messages is constructed using six-bit code words, meaning that three redundancy bits are added to the three data bits to form transmitted six-bit messages:

Message to be transmitted	Transmitted message
000	000000
100	100110
010	010011
110	110101
001	001101
101	101011
011	011110
111	111000

- 1) A recipient receives the message 101111. Is this a correct message?
- 2) A recipient receives the message 101111. Using this code as an error-correcting code, what message should it be corrected to (what is the transmitted message)?
- 3) In a code, what is called the code distance?
- 4) The code studied in this problem is a linear code. In a linear code, the code distance is equal to the smallest weight of a correct message (or alternatively, to the distance between the message 0000...000 and the nearest message). What is the code distance defined in this text?
- 5) How many errors can a code with a distance D detect? How many errors can this code correct?
- 6) How can the matrix G (the generator matrix of the code) be constructed from the code words? Show that the generator matrix of this linear code is the following matrix G.

$$G = \begin{bmatrix} 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 1 & 0 & 1 \end{bmatrix}$$

- 7) What is the check matrix of this linear code? Show using the check matrix that the message 100110 is correct and the message 101111 is incorrect.

Exercise 5.6: Switching

It is recalled that MIC modulation is intended to digitize the transmission of telephone voice. The time interval between two samples of the same voice is 125 μ s. The analog signal is sampled on 8 bits.

Question 1:

What is the rate used to transmit a telephone voice? These sampling parameters result from the bandwidth offered by a telephone line.

- What is the bandwidth considered in MIC? What relationships link bandwidth, rate, and sampling parameters?

Question 2:

The main switching technique used on digital telephone exchanges (associated with MIC modulation) is synchronous time-division switching.

- What is a telephone exchange used for? Explain in a few lines the principles of synchronous time-division switching.

Question 3:

A switch manages N input lines and N output lines. For simplicity, assume that all lines have the same rate and no time-division multiplexing is performed. The switch uses a memory whose read or write time is 50ns (this time corresponds to a read or write between

the line interfaces and the memory). The following pseudo-code describes the switching process, except for the assignment of input lines to output lines.

Switching process:

type num_line: integers in [1..N];

var sample: array (1..N) of bytes;

output_line: array (1..N) of num_line;

i: num_line;

begin

cycle

 for i:=1 to N do

 wait_for_top;

 read(i, sample(i));

 write(output_line(i), sample(i));

 endfor

 endcycle

end

- What is the purpose of the output_line array?
- What do the read and write operations do?
- What is the purpose of the wait_for_top instruction?

Assuming that the read and write instructions take a memory access and that the access time to the index and the loop management time are negligible (the actual implementation is wired).

- What is the maximum value of N (justify)? Let T be the time between two wait_for_top events.
- If N=600, what value should be given to T (justify)?

Question 4:

Suppose that the same switching problem (without multiplexing) must be solved using cell switching. Each cell corresponds to a sample.

- Briefly recall the principles of cell switching. How should the information structures defined in question 3 be modified to perform cell switching (the problem of routing table management will not be addressed)?
- Rewrite the pseudo-code for the packet switch.

We aim to use packet switching principles in datagram mode to transmit high-speed information such as voice, digitized television images, data, etc. What are the main

technical problems this poses?

Exercise 5.7: T1 Multiplexing

In the United States and Japan, telephone networks use a multiplexing technique called T1, which consists of 24 bytes forming a basic frame (T1 multiplex frame). There are different versions of T1 encoding. Here, we consider the case where the 24 bytes are associated with samples of telephone channels.

Question 1:

In a T1 frame, a bit is added to the telephone samples at the head of the frame, which is used for frame resynchronization in case of synchronization loss (long-term noise). What is the overall bit rate of a T1 multiplex?

Question 2:

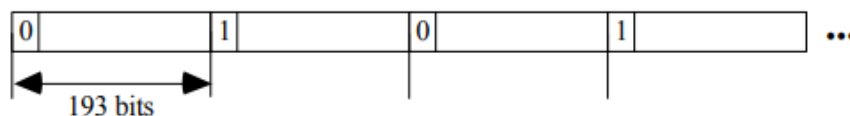
Consider a synchronous time-division T1 multiplex switch with shared memory whose access time is 20 ns - meaning that accessing a sample in memory, for both reading and writing, takes 20 ns. How many T1 multiplexes can such a synchronous time-division switch support at maximum?

Question 3:

A sample is switched from an input multiplex of the switch to an output multiplex of the switch after a certain delay. What can be said about the maximum, minimum, and average value of the delay required for a switching operation (delay introduced in the propagation of the sample on a telephone circuit by a switch)?

Question 4:

Recall that the first bit is added for frame synchronization. Synchronization is found when the first bit of successive frames follows the sequence 0, 1, 0, 1, 0... More precisely, the sequence of frames is:



To be synchronized, it is necessary to observe the alternating sequence 0, 1, 0, 1, 0, ... for all 193 bits if the first read bit was 0, or 1, 0, 1, 0, 1, ... if the first read bit was 1.

Suppose the multiplexer tries to resynchronize (for example, after experiencing noise on several successive frames). To do this, it positions itself on a bit that it estimates to be the beginning of the current frame and checks that 193 bits later, it finds the start bit of the next frame (with the opposite value to the previous value). We assume that bits 0 and 1 appear with the same probability of 1/2 in the samples at any position in a frame.

How many frames must be examined to have a resynchronization error probability less than 0.001?

Question 5:

We now want to calculate the number of frames that must be examined on average to be sure that synchronization is not correct. We position ourselves on a given bit, assuming that this bit is the beginning of a frame.

If this bit is not the start bit of a frame, give the probability of learning that resynchronization is not found by reading one frame, then reading two frames, and then reading n frames (using some of the calculations from the previous question).

Deduce how many consecutive frames on average must be examined to learn that synchronization is not correct for a given position.

We recall the formula for:

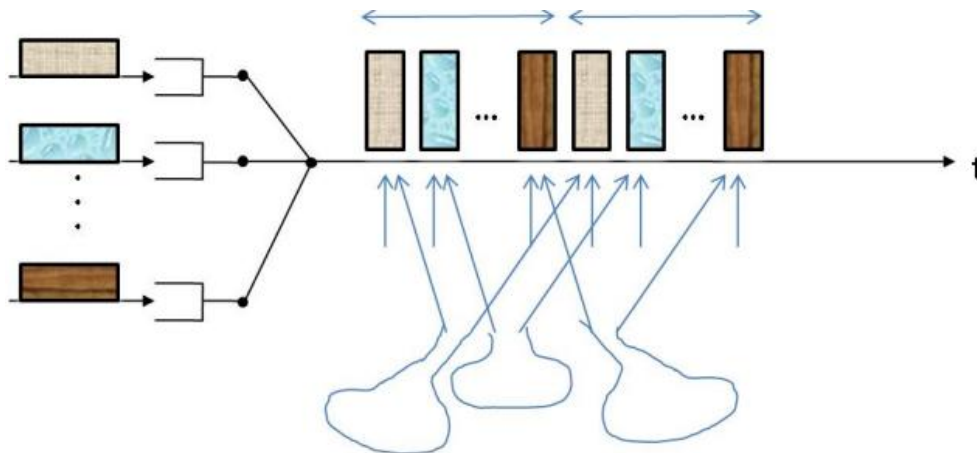
$$|x| < 1, \sum_{n=1}^{+\infty} nx^n = \frac{x}{(1-x)^2}$$

Exercise 5.8: Multiplexing.

Give the definition of multiplexing.

Name 3 types of multiplexing and explain them.

Identify on the figure the terms channel, circuit, frame, time-slot, low-speed line, high-speed line.



QCM 1

Q1. Do the following devices belong to the category of ETDD?

a) PC b) Modem c) Minitel d) Printer

Q2. Do the following devices belong to the category of ETCD?

a) Terminal b) Minitel c) ISDN Router d) Network card

Q3. What is the operating mode used in a communication by Minitel?

a) Simplex b) Half duplex c) Full duplex

Q4. Which V24 signal is used to transmit a carrier detection indication on the line?

a) CTS b) RI c) DCD

Q5. For data transmission to occur on an RS232 connection, what should be the voltage on pin 6 of a DB25 connector?

a) -12 V b) 6 V c) 0V d) 12 V

Q6. What standard is used on industrial local networks composed of several interconnected controllers on the same cable?

a) RS232 b) RS422 c) RS485 d) X21

Exercises 5.9:

- What is a data circuit composed of? Does a modem belong to it?
- Can a DTF be directly connected to the switched telephone network?
- What is the operating mode illustrated in figure 1?

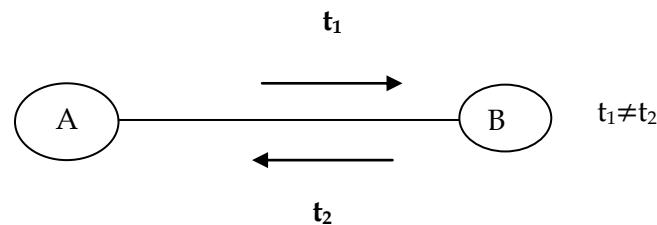


Figure 1.

How many wires are necessary at a minimum, at the junction, to achieve full-duplex transmission?

5. Same question for the transmission line.

6. Are the RS232C and V24 standards equivalent?

7. Does the ITU-T V24 recommendation concern the junction to the line, the junction to the terminal, or the characteristics of the modem?

8. What is the maximum data rate allowed on an RS232 connection?

9. What are the voltage values measured on the cable and connector for an RS232 connection?

10. What are the junction voltage values on a passive load for a V28 connection?

11. How many wires are necessary at a minimum on the cable for full-duplex RS422 connection?

12. What are the voltage values measured on the cable for a V11 connection?

13. In a V24 connection, what are the response signals to DTR and RTS signals?

14. At what logical level are the control signals of a V24 connection considered active?

What are the corresponding states of the circuits (open or closed) and the voltage values on the cable?

15. Establish the signal timing diagrams corresponding to the establishment of a half-duplex V24 connection between two remote systems; specify the different phases.

16. In an X21 connection, which signals are involved in establishing the link?

17. In an X21 connection, how does the DTE inform the DCE that it wants to transmit? How does the DCE signal that data transmission can begin?

18. Establish the complete connection diagram corresponding to a V24 connection between two DTEs described in figure 2.



Figure 2.

Correction:

QCM 1

Q1	Q2	Q3	Q4	Q5	Q6
a) ;c) ;d)	b) ;c) ;d)	c)	c)	b) ;d)	c)

Exercises 5.9:

1. A data circuit is composed of two ETCDs and an electrical connection linking them.
2. The output signals of a DTE are usually compliant with the V24 (or RS232C) standards. Telephone lines transmit analogue signals, so it is necessary to interpose a modem.
3. This is a unidirectional (simplex) connection. Information can be exchanged in both directions, but at different times (t1 and t2).
4. At least two wires (TD and RD) are required to ensure full-duplex communication, plus a common ground.
5. Two wires will be required if the bandwidth is limited, or one wire if the bandwidth allows for the use of two distinct carriers, plus a common ground.
6. The RS232C standard includes the V24 and V28 standards.
7. The V24 recommendation defines the functional characteristics of the junction between the DTE and the ETCD. It therefore defines the junction to the terminal.
8. The maximum data rate allowed is 20 Kbps. This rate can be exceeded, but at the

expense of other performance characteristics defined by the RS232 standard (maximum transmission distance, for example).

9. The voltages are between +3V and +25V for a logical level 0 and between -3V and -25V for a logical level 1.

10. On a passive load, the junction voltage is between +5V and +15V (or -5V and -15V).

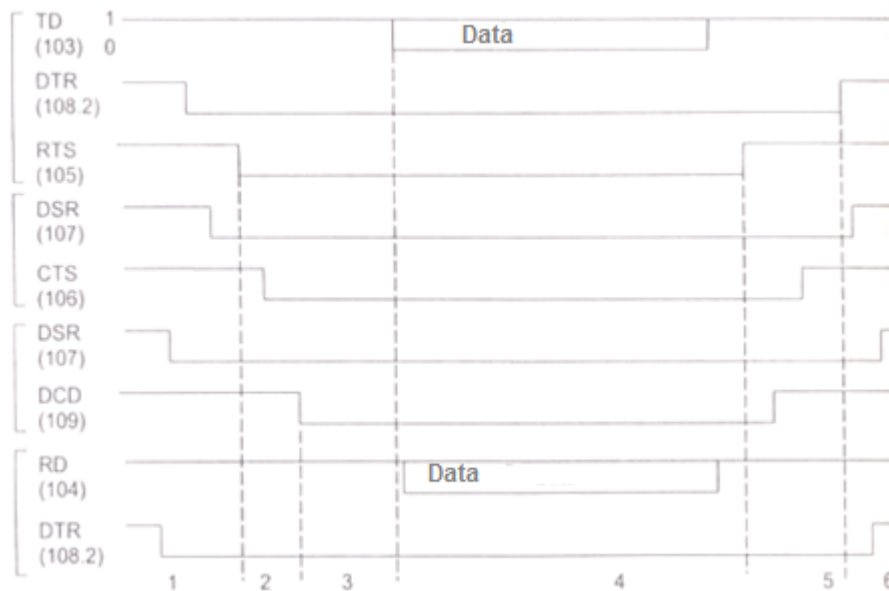
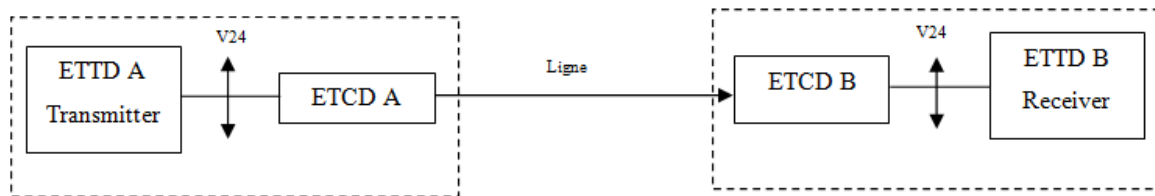
11. The RS422 connection, which uses differential voltages, requires two wires per channel, or four wires for a full-duplex connection.

12. For a V11 connection, the maximum voltage value is +6V (or -6V), and the minimum value is +0.3V (or -0.3V).

13. The response signals to the DTR and RTS signals are respectively DSR (Data Set Ready) and CTS (Clear To Send).

14. The control signals are active at a logical level 0, the circuits are then closed, and the voltage values on the cable are positive.

15. Establishment of a half-duplex connection between two remote systems A and B.



Phase 1: Line connection on systems A and B, the DTR and DSR signals can be validated following an automatic response procedure transmitted by circuit 125 (RI).

Phase 2: Validation of the transmission on A (RTS=0 and CTS=0), ETCD A transmits a carrier on the line (signal at a frequency of 1650 Hz for a V21 modem, for example).

Phase 3: Carrier detection by ETCD B (DCD=0).

Phase 4: Data transmission.

Phase 5: Stop transmission on A (RTS=1 and CTS=1).

Phase 6: Line disconnection on A and B (DTR=1 and DSR=1).

The initialization sequences of the transmitter and receiver are transposable for full-duplex transfer, only the carrier frequencies change depending on the transmission direction.

16. The signals involved in establishing an X21 connection are C (control), I (indication), T (transmission), and R (reception).

17. In an X21 connection, the ETTD signals that it wants to transmit by setting T and C to 0. The ETCD signals that it is ready to transmit by setting R to 1 and I to 0.

18. The connections on the calling EITD and called EITD side must be 6-8-20; the connections between the calling ETTD and called ETTD must be 2-3, 3-2, 4-5, 5-4, 7-7.

QCM 2

Q1. Which transmission mode requires the transmission of the clock signal?

- a) Synchronous b) Asynchronous

Q2. What is the role of the parity bit in an asynchronous frame?

- a) Synchronization b) End delimitation c) Error checking

Q3. Specify the format of the following asynchronous frame:



- a) 8-bit data, no parity
b) 7-bit data, even parity
c) 8-bit data, odd parity
d) 8-bit data, even parity

Q4. What role does the transmission level protocol serve?

- a) Connection establishment b) Flow control c) File segmentation

Q5. Which protocol(s) can be used on a half-duplex connection?

- a) DTR/DSR b) RTS/CTS c) Xon/Xoff

Q6. Which file transfer protocol(s) allow for the transfer of multiple files in a single session?

- a) Xmodem b) Ymodem c) Zmodem

Q7. Which circuit(s) is an asynchronous interfacing circuit?

- a) ACIA b) USART c) UART d) SCC

Q8. What functions can be found in an asynchronous interfacing circuit?

- a) FIFO b) Flag calculation c) CRC calculation d) Parity calculation

Q9. What fields are found in a synchronous frame?

- a) Flag b) Parity c) Control d) Address e) Stop
- Q10. Which mode of the HDLC procedure allows for full-duplex transmission?
a) LAP b) LAPB
- Q11. Which HDLC frame(s) are used for connection establishment?
a) RR b) REJ c) SABM d) DISC e) UA
- Q12. What does the value N(R) correspond to in an HDLC information frame?
a) Number of the sent frame b) Number of the received frame c) Number of the expected frame
- Q13. Which circuit(s) is a synchronous interfacing circuit?
a) ACIA b) USART c) UART d) SCC
- Q14. What is the bit rate used for transmitting STM-4 frames?
a) 56 Kbit/s b) 10 Mbit/s c) 155 Mbit/s d) 622 Mbit/s e) 1 Gbit/s
- Q15. State the size in bytes of an STM-1 frame.
a) 518 bytes b) 1024 bytes c) 2430 bytes d) 9720 bytes

Exercises 5.10:

1. In an asynchronous transmission at 9600 bits/s, what is the duration between the transmissions of two characters?
2. What type of parity is used in the frame shown in Figure 3?



Figure 3.

3. In an asynchronous transmission, what is the maximum number of bits corresponding to a frame?
4. What is the minimum transmission time for an ASCII file of 1024 characters at 19,200 bits/s?
5. Describe, using a flowchart, a transmission using the ETX/ACK software protocol (ETX character transmitted by the sender after each block, ACK character sent back by the receiver) for a transfer of three blocks of 256 characters and a reception buffer of 512 characters.
6. Establish the timing diagrams of the CLK, RxCLK, and RxD signals during reception synchronization with a 1:1 frequency ratio between the CLK and RxCLK signals (see Figures 3.10 and 3.11). Consider the worst-case scenario. Conclusion?
7. During synchronous transmission by modem, how is the bit-level clock signal transmitted?

8. Why is the HDLC procedure considered a bit-oriented procedure?

9. Complete Figure 4 (HDLC frame format: 1, N(S), N(R), P/F).

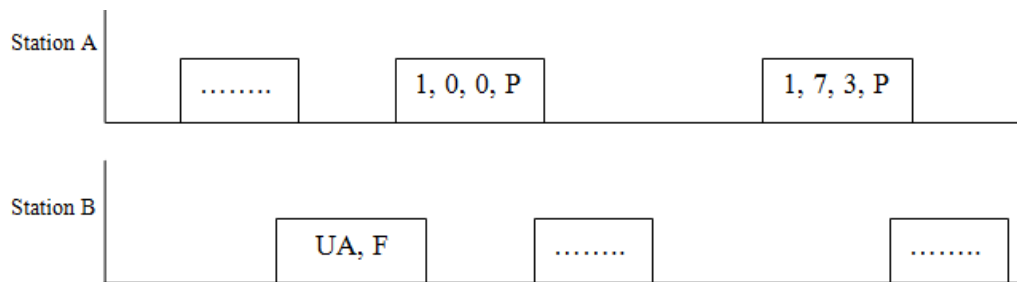


Figure 4.

10. Analyze the exchange of frames described in Table 1 (in hexadecimal values) and establish the exchange diagram.

Table 1:

Station							Réseau								
01	53	FCS	FCS	7E											
7E	01	53	FCS	FCS	7E										
							7E	01	73	FCS	FCS	7E			
							7E	03	3F	FCS	FCS	7E			
7E	03	73	FCS	FCS	7E										
7E	01	00	31	32	FCS	FCS	7E								
							7E	03	00	45	46	FCS	FCS	7E	

11. Same exercise:

Station							Réseau							
7E	01	53	FCS	FCS	7E									
7E	01	53	FCS	FCS	7E									
							7E	01	73	FCS	FCS	7E		
							7E	03	3F	FCS	FCS	7E		
7E	01	53	FCS	FCS	7E									
							7E	01	73	FCS	FCS	7E		
							7E	03	3F	FCS	FCS	7E		
							7E	03	3F	FCS	FCS	7E		
7E	03	73	FCS	FCS	7E									

12. Same exercise:

Station							Réseau								
7E	01	00	55	7A	FCS	FCS	7E								
								7E	03	00	45	23	FCS	FCS	7E
7E	01	02	26	62	FCS	FCS	7E								
7E	01	32	55	7A	FCS	FCS	7E								
								7E	01	34	FCS	FCS	7E		
7E	01	44	67	69	FCS	FCS	7E								

Correction

OCM 2

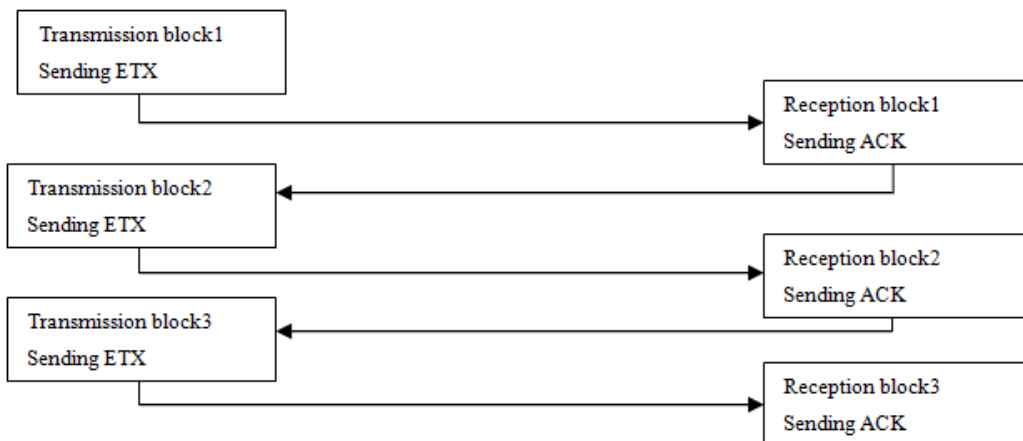
Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
a	c	c	b	ab	bc	ac	ad	acd	b
Q11	Q12	Q13	Q14	Q15					

<u>c</u>	<u>c</u>	<u>b d</u>	<u>d</u>	<u>c</u>
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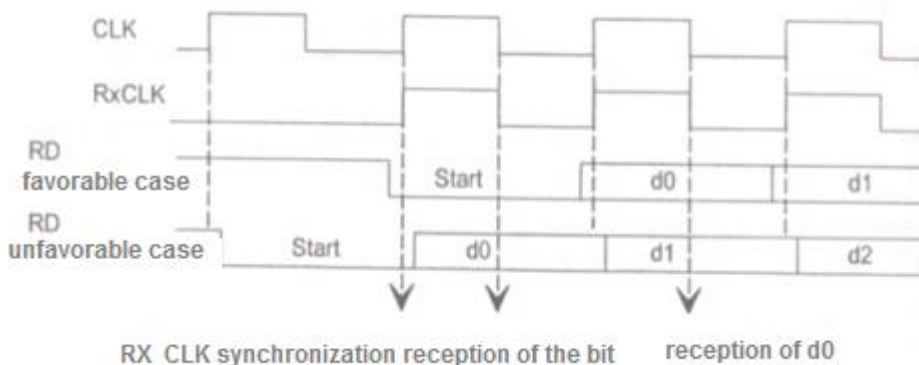
Exercise 5.10 :

1. In an asynchronous transmission, the duration between the transmissions of two characters can be arbitrary.
2. The number of bits set to 1 is 5. Therefore, it is an odd parity.
3. The number of bits in an asynchronous frame is generally limited to 11, which corresponds to the following two formats:
 1 start bit, 8 data bits, 1 parity bit, and 1 stop bit;
 1 start bit, 7 data bits, 1 parity bit, and 2 stop bits.
4. The smallest format will contain 9 bits per character, which is 9 x 216 bits to be transmitted. The minimum transmission duration will therefore be 9216/19200, which is 480 ms.
- 5.

Transmitter



6.



7. The RxCLK reception clock is synchronized after the detection of a start bit on the first rising edge of the reference CLK clock.
8. The length of the fields that make up the HDLC frame is variable. It is no longer a

juxtaposition of characters of identical length.

9. The first frame sent by station A is a setup frame: SABM, P. the frames sent by station B will be the acknowledgments respectively of frames 0 and 7 (in case of no rejection), i.e. RR, 1, F and RR, 0, F.

10.11.12. These are frames in the HDLC protocol. The first byte corresponds to the flag (7E or 01111110 in binary), the second byte gives the network address (01) or the station address (03) depending on whether it is a command or response frame, and the third byte identifies the frame.

QCM 3

Q1. In the V23 standard, what are the transmissions speeds corresponding to a dissymmetrical full duplex link?

a) 600 - 75 bit/s b) 1200 - 1200 bit/s c) 1200 - 75 bit/s

Q2. Knowing that the RTC has a maximum modulation rate of 6,200 bauds, what is the maximum transmission rate when using eight-state modulation?

a) 18,600 bit/s b) 28,800 bit/s c) 49,600 bit/s

Q3. For a signal modulated according to ITU-T recommendation V34, what are the possible transmission and modulation speeds in full duplex?

a) 28,800 bit/s b) 33,600 bit/s c) 33,600 bit/s d) 28,800 bit/s and 2400 bauds and 2400 bauds and 3200 bauds and 3200 bauds

Q4. How many V22 links can be realized on a line with a bandwidth of 60-108 kHz if frequency multiplexing is used?

a) 48 b) 12 c) 24 d) 20

Q5. How many low-speed channels at 300 bit/s can be multiplexed (time-division multiplexing) on a high-speed channel at 4,800 bit/s?

a) 12 b) 16 c) 8

Q6. For a MIC transmission on a 2,048 kbit/s line, what is the bit rate for each channel?

a) 64 kbit/s b) 8 kbit/s c) 32 kbit/s d) 2048 bit/s

1. In the absence of transmission, the binary level is constantly at "1". Code this signal in Manchester code, in bipolar code, and in Miller code. Explain the interest of these codes for the receiver.

2. Among the different coding methods, which one has the widest frequency spectrum, and which one has the narrowest? What is the benefit of reducing the frequency spectrum?

3. In a V22 link, depending on the channel used (carrier at 1,200 Hz or 2,400 Hz), how many periods can be counted on the modulated signal per modulation interval? Draw a

timing diagram of the binary signal and the modulated signal.

4. Calculate the capacity of a line whose bandwidth is 100-275 kHz and for a signal-to-noise ratio of 17 dB.

5. Calculate the transmission time and propagation time of a 20 KB file on an Ethernet network at 10 Mbit/s for distances of 10 m, 100 m, and 1 km.

6. For a 2,048 kbit/s MIC transmission, calculate the sampling period, the duration of a frame, the number of bits per frame, and the duration of an elementary time interval.

7. Four asynchronous terminals are connected to a statistical multiplexer allowing maximum composite rate of 19,200 bit/s and incorporating 8-bit buffers. The terminal rates are respectively 9,600 bit/s, 4,800 bit/s, 4,800 bit/s, and 4,800 bit/s. Calculate the effective rate on the composite channel and the duration of a frame in the different cases if only three terminals are active simultaneously. Conclusion?

8. We want to transmit a stereo HI-FI sound with a bandwidth of 20 Hz-20 kHz.

a) Can this signal be transmitted as is over the switched telephone network (STN)?

Justify your answer.

b) We digitize this signal with a sampling rate of 44 kHz. This results in 8 bits per channel to be transmitted every 22.7 ms. what is the required bit rate?

c) Is this bit rate compatible with current modem rates? Briefly explain the difficulty in increasing modem rates.

9. We want to transmit a binary file of 1 MB at a rate of 9,600 bit/s over the switched telephone network.

a) What are the problems posed by the transmission of such binary signals on a telephone pair of the STN?

b) Propose a modulation to correctly transmit the binary signal.

c) What is the modulation rate of the transmitted signal? Deduce the time available to the receiving modem to determine the characteristics (frequency, amplitude, and phase) of the received signal.

d) We use a Y-modem protocol. Calculate the number of bytes exchanged between the two computers during transmission.

e) Calculate the time required to transmit this file.

10. We want to use the 64 kHz - 200 kHz band to achieve a rate of 544 kbit/s on the upstream flow of an ADSL modem. How many bits per modulation interval must be transmitted?

11. Indicate the Hayes codes to be transmitted to the modem to program it in V34 mode and then to ask it to call the number 0955552222 using frequency coding.

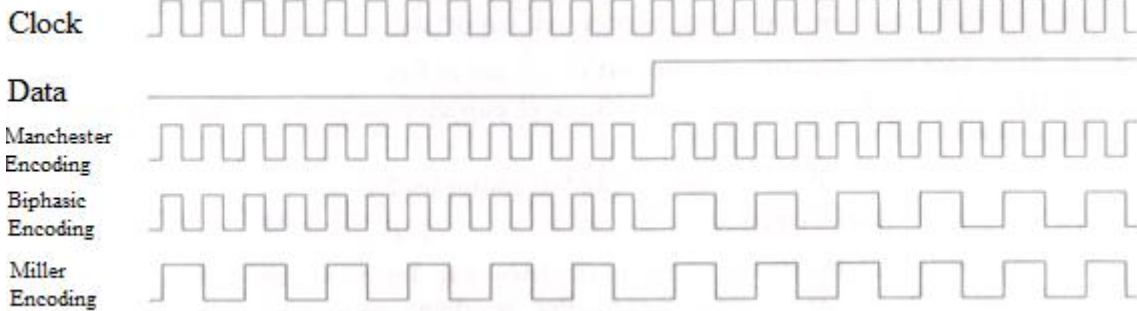
Correction

QCM 3

Q1	Q2	Q3	Q4	Q5	Q6
c)	a)	d)	d)	b)	a)

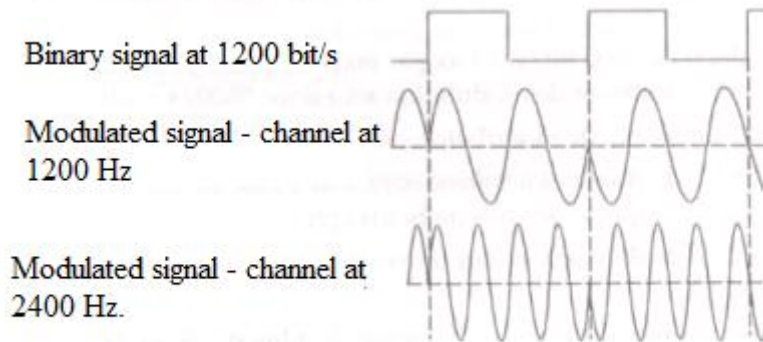
Exercise 5.10 :

1.



2. Miller encoding has a narrow spectrum, and therefore is less susceptible to interference. Manchester encoding has a wider spectrum, but operates at higher frequencies, which are less attenuated on the line.

3. In a V22 link operating at 1,200 bit/s (using dibit modulation), an interval of modulation lasts for 2 bits. Therefore, there will be two periods in an interval of modulation for the channel at 1,200 Hz and four periods for the channel at 2,400 Hz.



4. $C = 175 \cdot 10^3 \log_2 (1 + 10^{1.7}) = 993 \text{ kbit/s.}$

5. $T_i = 20 \times 1024 \times 8 / 10^7 = 16.4 \text{ ms.}$

$T_p = 4 \text{ } \mu\text{s}$ for 1 km;

$T_p = 0.4 \text{ } \mu\text{s}$ for 100 m;

$T_p = 0.04 \text{ } \mu\text{s}$ for 10 m.

6. The sampling period is $1/8 \cdot 10^3 = 125 \text{ } \mu\text{s}$. The transmission time of a frame corresponds to the time needed to multiplex the samples of all channels, which is 125 μs . The number of bits per frame is $32 \times 8 = 256 \text{ bits}$ ($2048 \cdot 103 \times 125 \cdot 10^{-6}$). The duration of the time interval IT corresponds to the time needed to transmit the 8 bits of a sample, which is

$$125 \mu\text{s}/32 = 3.9 \mu\text{s}.$$

Depending on the bit rates of the active terminals, two calculations can be performed:

$$d = 3 \times 4800 = 14400 \text{ bit/s et } Tc = \frac{3 \times 8}{3 \times 4800} = 1,67 \text{ ms}$$

$$d = 2 \times 4800 + 9600 = 19200 \text{ bit/s et } Tc = \frac{3 \times 8}{2 \times 4800 \times 9600} = 1,25 \text{ ms}$$

In the second case, the calculated bit rate is just equal to the maximum composite bit rate of the multiplexer. If the composite channel is synchronous, the number of bits that can be transmitted in a frame will be greater than the total bits of each asynchronous channel, since the control bits (Start, Stop, and Parity) are removed.

8. a) No. The bandwidth of the support used on the RTC (telephone pair) is 300-3400 Hz. All frequencies below and above this range will be heavily attenuated and therefore not received by the receiver.

b) In stereo, there are 2 channels or 16 bits every 22.7 μs . Bit rate: $16/22.7 \cdot 10^{-6} = 705 \text{ kbit/s}$

c) No. The bit rates currently standardized on modems are a maximum of 33.6 kbit/s in transmission. To increase the bit rate without increasing the modulation speed, it is necessary to increase the sensitivity of the receiving function of the modems and therefore the relative influence of noise.

9. a) Transmitting a binary signal at 9600 bit/s amounts to transmitting sinusoidal signals at frequencies whose lowest (fundamental frequency of 4800 Hz) is beyond the bandwidth of the support (300-3400 Hz). Therefore, all components will be heavily attenuated, which makes it impossible to transmit the binary signal without frequency shifting on a long-distance network such as the RTC.

b) V32, V34 and V90 modulations provide asynchronous transmission on the RTC at 9600 bit/s.

c) For a bit rate of 9600 bit/s, 4 bits per phase state are used on V32, V34, and V90 modulations. The modulation speed will therefore be $9600/4 = 2400$ bauds. The duration of a modulation interval is $1/2400 = 416 \mu\text{s}$.

d) There are 1024 KB of data to be transmitted, which is 1 block of 128 bytes and 1024 blocks of 1024 bytes (the last one contains padding bits). For each data block, 6 additional bytes must be transmitted (SOH, N, FF-N, CRC, CRC, ACK). For the file, 136 extra bytes must be transmitted (C, SOH, 00, FF, file name of 128 bytes, CRC, CRC, ACK, EOT). This gives a total of: $128 + 1024 \times 1024 + 1025 \times 6 + 136 = 1055 \text{ KB}$.

e) $t = 1055.103 \times 8/9600 = 879 \text{ s}$, or approximately 14 min 39 s.

10. The allocated bandwidth (64 kHz - 200 kHz) can be divided into 34 channels of 4 kHz

each. For a total bit rate of 544 kbit/s, the number of bits per modulation interval is $544000/(4000 \times 34)$, which is 4 bits.

AT&N 14 or ATB20 then ATDT0955552222.

OCM 4

Q1. A multipoint connection links:

a) 2 systems b) more than 2 systems

Q2. Can a single V24 link be multipoint?

a) yes b) no

Q3. What type of element does a network interface card belong to?

a) Terminals b) interconnection equipment c) communication controllers

Q4. What type of switching is used by the RTC?

a) circuit switching b) packet switching c) cell switching

Q5. What type of switching is used by the Transpac network?

a) circuit switching b) packet switching c) cell switching

Q6. What type of switching does not require data storage in the network?

a) Circuit switching b) Packet switching c) Cell switching

Q7. Which layers manage communications?

a) Lower layers b) Middle layers c) Upper layers

Q8. The network layer belongs to:

a) Lower layers b) Middle layers c) Upper layers

Q9. The dialogue between adjacent layers is defined by:

a) Protocols b) Services c) Service primitives

Q10. The unit of data passed by layer N to layer N-1 is:

a) SDU b) PCI c) PDU

Exercise 5.11:

1. For a Minitel-based seat reservation application, calculate the connection rate and activity rate if the traffic parameters are as follows:

- Maximum number of sessions per hour: 15
- Average session duration: 3 minutes
- Message size: 640 characters
- Line speed: 1,200 bits/s

2. Calculate the transmission delay for a message of 1,000 bytes for the two types of networks:

a) Packet-switched network with packet size of 1,000 bytes

b) Packet-switched network with packet size of 100 bytes

In both cases, the number of switches crossed is 3, the network speed is 9,600 bits/s, and propagation and waiting times in the switches will be neglected.

3. For a file transfer application over a switched network, files of 1 MB are transmitted every hour over a 9,600 bits/s line. Calculate the activity rate and connection rate if the line is switched for sessions of 20 minutes.

4. What is the required speed to transmit images with a resolution of 800 x 600 x 16 bits and a frame rate of 70 Hz with a compression rate of 20? What are the compatible physical media for such speeds?

5. Calculate the required speed to transmit a 16-bit digitized sound at 40 kHz. What are the compatible physical media for this speed?

6. What are the different transmission media options for installing a local network with the following constraints:

- Speeds up to 10 Mbps
- Maximum distance between stations: 4 km.

Correction

QCM 4

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
b	b	c	a	b	a	b	b	c	c

Exercise 5.11

1. For each character, 10 bits are transmitted (start + 7 bits + parity + stop).

$$E = \frac{15 \times 3 \times 60}{3600} = 0.75 ; T_t = \frac{640 \times 7}{1200} = 5.33 \text{ s} ; \sigma = \frac{3.73}{3 \times 60} = 3\%$$

The value of E, close to 1, justifies the use of a dedicated link.

2. Packets of 1000 bytes:

$$D_a = \frac{(4 \times 1000) \times 8}{9600} = 3.33 \text{ s}$$

Packets of 100 bytes:

$$D_a = \frac{(13 \times 100) \times 8}{9600} = 1.08 \text{ s}$$

$$3. E = \frac{20 \times 60}{3600} = 0.33 ; T_t = \frac{1024^2 \times 8}{9600} = 873.81 \text{ s} ; \sigma = \frac{873.81}{20 \times 60} = 73\%$$

The values obtained justify the use of a switched connection.

4. Screen size: 800 x 600 = 480,000 pixels, or 480,000 x 16 = 7,680,000 bits.

After compression: 7,680,000 / 20 = 384,000 bits per screen.

To have 70 images per second, we need: 384,000 x 70 = 26.88 Mbps.

Compatible media are: coaxial cable or fiber optic. Category 5 twisted pair can be used over a distance of less than 500m.

5. Required speed: $16 \times 40 = 640$ Kbps.

All media are compatible.

6. To support 10 Mbps over 4 km, coaxial cable or fiber optic is required.

QCM 5

Q1. What are the common speeds on a local area network?

a) 100 kbit/s b) 10 Mbit/s c) 100 Mbit/s d) 9600 bit/s

Q2. What is the required speed to transmit sound with CD-like quality?

a) 234 Mbit/s b) 64 kbit/s c) 1.4 Mbit/s d) 10 Mbit/s

Q3. Which topology is the most cost-effective in terms of cabling?

a) Star b) Bus c) Ring

Q4. At which level of the OSI model are the LLC and MAC sublayers located?

a) Level 1 b) Level 2 c) Level 3 d) Level 7

Q5. What is the IEEE standard associated with the MAC sublayer?

a) 802.2 b) 802.3 c) 802.4 d) 802.5

Q6. Which access method allows stations to transmit at any time?

a) CSMA b) CSMA/CD c) Token on bus d) Token on ring

Q7. In a network of 10 stations using the CSMA/CD access method, at what speed will collisions be less frequent?

a) 10 Mbit/s b) 100 Mbit/s c) 1 Gbit/s

Q8. Which interconnection element works on MAC addresses?

a) Repeater b) Bridge c) Router d) Gateway

Exercise 5.12

1. A local area network is intended to transfer two types of information:

- Text files of maximum 100 KB requiring a minimal transmission time of 5s;
- Interactive messages of up to 100 characters transmitted in less than 5 ms. Calculate the capacity of the medium for baseband transmission.

2. In a local network consisting of five stations, what are the consequences, depending on the topology used, of a break in the medium between stations 3 and 4 if the server is located in station 2?

3. Name the three types of services offered by the LLC sublayer. Indicate their main characteristics.

4. Is the collision probability higher on a network using the CSMA access method at 10 Mbps or 100 Mbps?
5. On a network of eight stations using the CSMA access method, calculate the vulnerability period, the time during which a station is at risk of not detecting the transmission of a frame. Given:
 - average distance between stations: 15 m;
 - Propagation speed: 200,000 km/s.
6. A 10 Mbps network using the CSMA/CD access method consists of three stations A, B, and C.
 - a) Calculate the maximum propagation time t_p between the two furthest stations for a 64-byte frame.
 - b) At time t_0 , station A wants to transmit to B; what is the minimum listening time required to detect a collision?
 - c) At time $t_0+t_p/3$, station C wants to transmit to B; at what time does the collision occur?
 - d) At what time is the collision detected by C and by A?
7. Compare the three frame release procedures on a ring network using the token method.
8. What is the maximum frame length on a 1 Mbps ring network if the propagation time over the entire length is 10 ms? Same question for a rate of 4 Mbps.
9. For a ring network of ten stations, calculate the minimum access time of a station for rates of 1 Mbps when all stations want to transmit (propagation times are neglected). How is the maximum waiting time defined?
10. What is the order of magnitude of the speed on a network using the IEEE 802.6 standard?
11. On a DQBD network consisting of five stations (figure 6.16), describe the different steps of a transmission sequence from X to Y if the request counter of X is equal to 2.

Correction**OCM 5**

<u>Q1</u>	<u>Q2</u>	<u>Q3</u>	<u>Q4</u>	<u>Q5</u>	<u>Q6</u>	<u>Q7</u>	<u>Q8</u>
a ;b ;c	c	b	b	b ;c ;d	a ;b	c	b

Exercise 5.12

1. Required speed for file transmission: $100 \times 1024 \times 8/5 = 164$ kbps.
Required speed for message transmission: $100 \times 8/5 \cdot 10^{-3} = 160$ kbps. Capacity of the medium: 164 kbps.
2. For a bus topology, only the stations separated from the server by the break in the medium are inaccessible (stations 4 and 5). The others (1, 2, and 3) remain active, but a

termination resistor must be added at station 3.

For a simple ring topology, the entire network is blocked. For a dual ring, the network remains usable for all its stations after reconfiguration.

3. LLC service 1 is connectionless and without acknowledgment. LLC service 2 is connection-oriented and with acknowledgment, it manages flow control and transmission error handling. LLC service 3 is connectionless but with acknowledgment.

4. The collision probability corresponds to the probability that a station will transmit during the propagation of the transmitted frame. This time only depends on the propagation time on the medium and its length. Therefore, the collision probability is the same for speeds of 10 Mbps and 100 Mbps.

5. In the worst-case scenario, the vulnerability period is equal to twice the propagation time between the two furthest stations, which is:

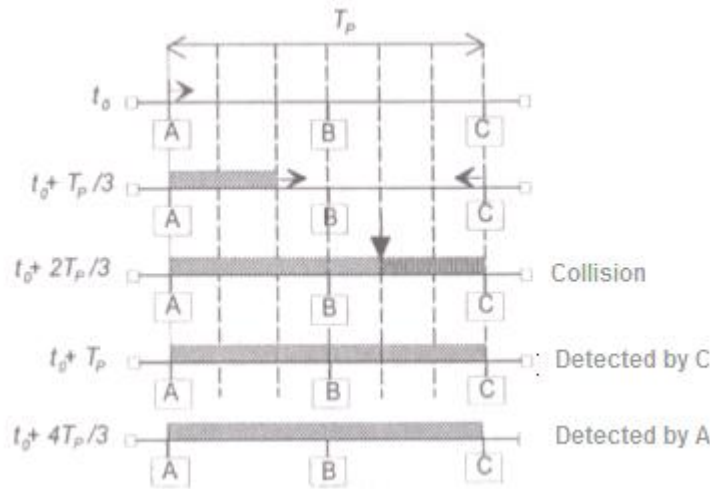
$$2 \times 7 \times 15/2 \cdot 10^8 = 1,05 \mu s.$$

6.

a) $tp_{max} = \frac{1}{2} \frac{64 \times 8}{10 \times 10^6} = 25.6 \mu s$

b) Minimum listening time: $2 tp = 51.2 \mu s$

c) and d)



7. We call T_e the duration of the frame transmission, T_s the propagation time between two stations, and T_p the propagation time on the ring and the processing time by the stations. If station n has the token and transmits, station $n+1$ will have to wait depending on the case: $T_e + T_p + T_s$ if the frame is released after complete reception; $T_p + T_s$ if the frame is released after header reception; $T_e + T_s$ if the frame is released at the end of transmission.

8. At 1 Mbps, the frame can contain $106 \times 10^{-2} = 10,000$ bits = 1,250 bytes. At 4 Mbps, the frame can contain $4 \times 106 \times 10^{-2} = 40,000$ bits = 5,000 bytes.

9. The maximum waiting time is calculated when all ten stations need to transmit

simultaneously. In the case where the priorities associated with the stations are not identical, the maximum waiting time will depend on the file size to be transmitted by the higher priority stations. However, if all stations have the same priority level, the maximum waiting time will be equal to the time required for nine stations to transmit a frame or nine times the token holding time (THT), which is: Transmission time: $9 \times 1261 \times 8/10^6 = 91$ ms. Token holding time: $9 \times 10 \times 10^{-3} = 90$ ms (default value of THT).

10. The speed on the DQDB protocol media is 160 Mbps.

11. Station X sends a request on bus B. Having received two requests, station X lets two free slots pass and writes its data in the third one.

OCM 6

Q1. What equipment allows for the separation of segments with different speeds on an Ethernet network?

a) Hub b) Transceiver c) MAU d) Switch

Q2. Which type of cabling allows for the highest speeds on an Ethernet network?

a) Thin Ethernet b) UTP c) STP d) Fiber optic

Q3. At which layer of the OSI model does the Ethernet architecture reside?

a) Layer 1 b) Layer 2 c) Layer 3 d) Layer 7

Q4. Which sub-layers are involved in the Token Ring architecture?

a) PHY b) MAC c) LLC

Q5. What is the maximum length in bytes of an IP datagram circulating on an Ethernet network?

a) 64 b) 256 c) 1500 d) 5000

Q6. How many subnets can be distinguished with a mask equal to 255.255.255.224 on a Class C network?

a) 2 b) 4 c) 8 d) 16

Q7. What is the minimum size in bytes of a TCP header?

a) 16 b) 20 c) 24 d) 64

Q8. On an Ethernet network using TCP/IP protocols, at which layer is flow control implemented?

a) MAC b) LLC c) IP d) TCP

Exercise 5.13

1. On an Ethernet network, how are collisions detected? What happens after a collision is detected?
2. Determine the minimum duration of bus occupancy by a frame on a 10 Mbps Ethernet network.
3. Calculate the maximum propagation time between the two furthest points on a standard Ethernet network. Deduce the theoretical maximum range of an Ethernet cable if the propagation speed is evaluated at 200,000 km/s.
4. The services provided by the MAC sublayer 802.3 to the LLC sublayer are accessible via primitives represented in Figure 5. Describe, using a diagram, the contents of the various data and control units (SDU, PDU, and PCI) of the MAC sublayer.

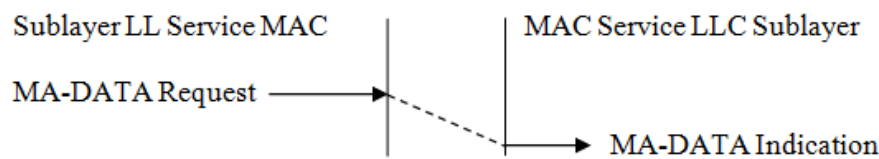


Figure 5.

5. Describe, using a diagram, the sequence of service primitives of the MAC and PHY sublayers of the 802.3 standard for the following sequences:
 - Data transmission
 - Data reception
 - MA-DATA Request
 - Collision detection
6. A standard Ethernet network consists of three stations A, B, and C. From an initial time t_n , the stations want to transmit in the following order:
 - At $t=t_0$, station A wants to transmit a 4 KB file
 - At $t=t_0+2$ ms, station B wants to transmit a 2 KB file
 - At $t=t_0+2$ ms, station C wants to transmit a 2 KB file.
 The successive values of the random number R are given for each station:
 - RA: 1,2,4,3,4,8;
 - RB: 0,1,3,2,9,12;
 - RC: 1,1,3,2,3,7.
 - a) Calculate the transmission times of the different frames transmitted by the three stations.
 - b) Establish a timing diagram showing the order of frame transmission, collisions, and waiting times.
 - c) Calculate the overall average throughput (ratio of the total number of bits transmitted to the total transmission time).

7. Why is a physical star topology referred to on a Token Ring network?

8. In a Token Ring network consisting of 5 stations, how long after initialization will station 5 have to wait to transmit if the supervisor is located in station 1 and if stations 2 and 4 also want to transmit a full frame each?

- Throughput: 4 Mbps;
- Average distances between stations: 20 m;
- Propagation speed: 200,000 km/s;
- Initialization by a 13-byte frame;
- Token released at the end of the frame;
- Transfer time in couplers negligible.

8. What procedures are implemented in a Token Ring network in the event of a station failure that has just received the token?

9. A 4 Mbps Token Ring network consists of three stations A, B, and C. From an initial time, the stations want to transmit in the following order:

- At $t=t_0$, station A wants to transmit a 14 KB file
 - At $t=t_0+15$ ms, station C wants to transmit a 9 KB file
 - At $t=t_0+40$ ms, station B wants to transmit a 14 KB file
- a) Calculate the transmission times of the different frames transmitted by the three stations in the case where the token is released at the end of the frame.
- b) Establish a timing diagram showing the order of frame and token transmission.
- c) Calculate the overall average throughput (ratio of the total number of bits transmitted to the total transmission time).

11. How are TCP and IP protocols identified in an Ethernet frame?

12. Why is it called an IP datagram?

13. A machine belonging to a local network is connected to the internet, and its configuration is as follows:

IP address: 192.168.54.53

Netmask: 255.255.255.224

What is the subnet address and the machine number in this subnet?

14. A local site consists of two physical subnets, connected by a router to the internet. This site has a class B IP address. Propose a addressing scheme for the various stations so that the router does not have to broadcast all received messages on each subnet.

15. An IP datagram can be fragmented.

a) What information is available to know that a packet is a fragment?

- b) How is a datagram reassembled at the destination?
- c) Can a router confuse two fragments that have the same following elements: source, destination, and fragment number?
16. How is packet headers processed in the following two cases:
- a) The transmitter and receiver are connected to the same TCP/IP network.
- b) The transmitter and receiver are connected to two TCP/IP networks connected by a router.
17. What do the port numbers of the UDP and TCP protocols correspond to?

Correction**OCM 6**

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
d	c, d	a,b	a,b,c	c	c	b	b,d

Exercise 5.13

1. Collision detection is done by detecting an overvoltage on the medium. If so, the station waits before attempting a new transmission for a time equal to $R_a = R \times T_b$, where:

N: number of retransmission attempts already made;

R: random number such that $0 \leq R \leq 2^k$

$k = \min(N, 10)$;

T_b : basic time.

If $N = 16$, the transmission attempt is abandoned.

2. The minimum size of a frame is 64 bytes. The transmission time of this frame is: $64 \times 8/10^7 = 51.2 \mu\text{s}$. To this time, the propagation time on the medium must be added.

3. The transmission time of the smallest frame must be greater than twice the propagation time between the two endpoints, hence:

$$2T_p \text{ max} = 64 \times 8/10^7 = 51.2 \mu\text{s} \text{ and } T_p \text{ max} = 25.6 \mu\text{s}.$$

For a propagation speed of 200,000 km/s, the maximum range is:

$$L \text{ max} = 2.108 \times 25.6 \cdot 10^{-6} = 5120 \text{ m}.$$

$$\text{X3 waiting time for A: } 51.2 \cdot 10^{-6} \times 4 = 204.8 \mu\text{s};$$

$$- \text{ For C: } 51.2 \cdot 10^{-6} \times 3 = 153.6 \mu\text{s}.$$

$$\text{X4 waiting time for A: } 51.2 \cdot 10^{-6} \times 3 = 153.6 \mu\text{s};$$

$$- \text{ For C: } 51.2 \cdot 10^{-6} \times 2 = 102.4 \mu\text{s}.$$

Average throughput per station:

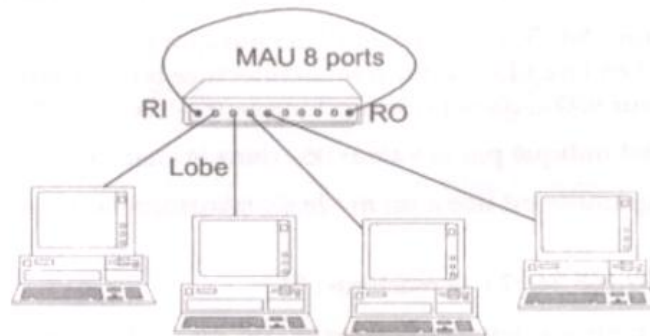
$$- \text{ Station A: } (2 \times 1518 + 1114) \times 8/7, 13 \cdot 10^{-3} = 4.65 \text{ Mbit/s};$$

$$- \text{ Station B: } (1518 + 566) \times 8/ (4, 23 - 2) \cdot 10^3 = 7.48 \text{ Mbit/s};$$

$$- \text{ Station C: } (1518 + 566) \times 8/ (6, 24 - 2) \cdot 10^3 = 3.93 \text{ Mbit/s}.$$

Overall average throughput: $(4 \times 1518 + 1114 + 2 \times 566) \times 8/7, 13 \cdot 10^{-3} = 9.34 \text{ Mbit/s}$.

7. The stations are connected to a MAU device using a star wiring. The MAU provides an internal connection corresponding to a ring topology.



8. Assuming that at initialization, station 1 sends an empty frame, and stations 2 and 4 send full frames (i.e. 5000 bytes):

Propagation time between 2 stations: $20/2 \cdot 10^8 = 100 \text{ ns}$.

Duration of transmission of an empty frame: $13 \times 8/4 \cdot 10^6 = 26 \text{ } \mu\text{s}$. Duration of transmission of a full frame: $5000 \times 8/4 \cdot 10^6 = 10 \text{ ms}$.

The initialization frame will circulate around the ring to initialize the stations, then stations 2 and 4 can transmit their frames before station 5 can transmit its own (the token is released at the end of frame transmission), which is:

$$26 \cdot 10^{-6} + 5 \times 10^{-7} + 10^{-2} + 2 \times 10^{-7} + 10^{-2} + 10^{-7} = 20 \text{ ms.}$$

9. Two mechanisms come into play. Stations located after the failed station will transmit a control frame to the supervisor indicating that they have not received a token within the maximum allotted time TRT. On its side, the supervisor will, either upon receiving a control frame from a station or upon the expiration of TRT, transmit a token purge and medium test frame.

10. Number of frames transmitted by each station (ignoring header sizes):

- A and C: $14 \times 1024/5000 = 2.87$, which is two full frames and one frame of 4336 bytes;
- Station B: $9 \times 1024/5000 = 1.84$, which is one full frame and one frame of 4216 bytes.

Durations of frame transmissions:

- 5000-byte frame: $5000 \times 8/4 \cdot 10^6 = 10 \text{ ms}$;
- 4216-byte frame: $4216 \times 8/4 \cdot 10^6 = 8.43 \text{ ms}$;
- 4336-byte frame: $4336 \times 8/4 \cdot 10^6 = 8.67 \text{ ms}$;
- Token (3 bytes): $3 \times 8/4 \cdot 10^6 = \mu\text{s}$.

Frame	A1	J	A2	J	C1	J	A3	J	C2	J	B1	J	B2	J	B3
Time (ms)	10		20.01		30.01		38.69		48.12		57.13		67.14		75.81

11. For an 802.3 architecture, the IP protocol is indicated by the value 06H in the DS AP and SS AP fields of the LLC header; for an Ethernet II type architecture, the IP protocol is indicated by the value 0800H in the length field of the MAC header.

The TCP protocol is indicated by the value 06H in the protocol field of the IP header.

12. The notion of datagram is related to a connectionless transmission mode, which is the case for IP packets.

13. Subnet address = 192.168.54.32; machine address: 21.

14. To address this for both subnets, we can use different subnet addressing or a network mask. The class B address contains the network number in the first two octets. The third octet can be used to identify the subnet, and the last octet can be used to code the addresses of the stations in each subnet, allowing for addressing of up to 256 stations in each subnet.

15.

a) The MF fragmentation bit, when set to 1, indicates that the datagram is a fragment.

b) The datagram is reassembled upon arrival by concatenating all the fragments in order, using the MF bit, the datagram offset field, and the message identifier.

c) No, there is no risk of confusion because the three data parameters mentioned above uniquely identify which message the fragment belongs to (even if the source and destination and the fragment number are the same, the message identifier will distinguish two fragments belonging to two different messages).

16.

a) Since both stations belong to the same network, there is no decrement of the TTL field, and the header is not modified.

b) Since the stations are on different networks, the TTL field is decremented by the access router to the second network, and the checksum is updated.

17. The port number is a value given in the TCP header that identifies the application (21 for FTP, 23 for Telnet...) or the machine. System ports are predefined and are less than 1000 (RFC1700). The list of used port numbers and corresponding applications is generally defined in the system in a file (/etc/services for UNIX).

Client ports are assigned on demand and are greater than 1000.

QCM 7

Q1. What are the different possible speeds on the Transpac network?

a) 9.6 kbit/s b) 48 kbit/s c) 64 kbit/s d) 2 Mbit/s

Q2. What is the maximum speed when transmitting on Transpac with RTC access?

- a) 9.6 kbit/s b) 48 kbit/s c) 64 kbit/s d) 2 Mbit/s

Q3. What is the packet size transported through the Transpac network?

- a) 32 bytes b) 64 bytes c) 128 bytes d) 256 bytes

Q4. What is the maximum size of the transmission window?

- a) 5 b) 8 c) 12 d) 16

Q5. What are the Télétel codes corresponding to the kiosk service?

- a) 3613 b) 3614 c) 3615 d) 3616

Q6. In frame relay networks, which devices are responsible for acknowledgments?

- a) End equipment b) Network equipment

Q7. What types of information can be exchanged on ISDN?

- a) Analog information b) Digital information

Q8. On ISDN, which public domain entity is connected to a private domain entity?

- a) TNA b) TNR c) TL d) TC

Q9. What is the speed of a basic access?

- a) 16 kbit/s b) 64 kbit/s c) 144 kbit/s d) 2 Mbit/s

Q10. On ATM, which layer interfaces with higher layer protocols?

- a) PMD b) ATM c) AAL

Q11. What ATM layers are found in network equipment?

- a) PMD b) ATM c) AAL

Q12. What is the size of ATM cells?

- a) 24 bytes b) 48 bytes c) 53 bytes d) 64 bytes

Q13. Which protocol allows the transport of voice over ATM?

- a) AAL1 b) AAL2 c) AAL3/4 d) AAL5

Exercise 5.14

1. List, according to the desired speed and volume of information to be transmitted, the different connection possibilities to the Transpac network offered to a user.
2. Are flow controls used at levels 2 and 3 of the X25 protocol redundant?
3. What is the benefit of remote packet acknowledgement (end-to-end flow control) compared to local acknowledgement (hop-by-hop flow control)? How does the transmitting ETTD indicate that it desires remote acknowledgement?
4. Establish the packet exchange diagram corresponding to a release by the network during circuit establishment and to a release by the network when the virtual circuit is established.
5. A synchronous terminal is connected to a server via a Transpac connection. Establish the

packet exchange diagram during the establishment, data transfer, and release phases with the following specifications:

- The terminal establishes two virtual circuits with the server.
- The available NVLs are between 2 and 12.
- The transmission window size is limited to 2 for both CVCs.
- Each ETTD wishes to transmit three packets to the other end, using the first available CVC.
- Data packet acknowledgements are local.
- The server releases the CVC.

6. Two microcomputers A and B are connected by a Transpac/X25 network. Each ETTD must transmit a 200-byte message to the other. Establish the packet and frame exchange diagram with the following specifications:

- ETTD A opens a CVC with ETTD B.
- The available NVLs are between 1 and 7.
- The packet length is fixed at 128 for both ETTDs.
- The anticipation factor at the link level is 7 for both ETTDs.
- The network level window equals 1 for the established CVC.
- Data packet acknowledgements are remote.
- The calling ETTD releases the CVC.

7. What are the functions performed by signaling? How is it carried out on ISDN?

8. Establish the diagram of an ISDN subscriber's installation equipped with a standard telephone set, a G4 fax machine, a Minitel, an X21 terminal, and an Ethernet local network. The diagram should show the necessary reference points and functional groupings.

9. What are the topological, physical, and functional characteristics of the S₀ interface?

10. On the S₀ interface frame, what is the duration of an information element? At what speed do the synchronization elements correspond?

11. A S₀ frame transmitted by a terminal on a symmetric pair is captured on an oscilloscope. The representation is given in Figure 6.

- Delimit the fields corresponding to the different channels.
- Provide the different values transmitted on this frame for channels B1, B2, and D.



Figure 6: S₀ frame transmitted from TE to TNR.

12. On an ISDN network, a terminal sends an information frame compliant with the LAP D protocol after establishing a level 2 connection. The frame is composed of the following bytes:

00 81 00 00 08 01 01 05 04 03 80 90 A3 18 01 83 24 01 80 6D 03 A0 32 32 ...

This frame encapsulates a level 3 message compliant with the D protocol.

- Identify the fields that make up the frame header and the message.
- Analyze the content of these different fields at the level 2 and level 3.

Correction

OCM 7

<u>Q1</u>	<u>Q2</u>	<u>Q3</u>	<u>Q4</u>	<u>Q5</u>	<u>Q6</u>	<u>Q7</u>	<u>Q8</u>	<u>Q9</u>	<u>Q10</u>
<u>a,b</u>	<u>a</u>	<u>c</u>	<u>b</u>	<u>c, d</u>	<u>c, d</u>	<u>b</u>	<u>b</u>	<u>c</u>	<u>c</u>
<u>Q11</u>	<u>Q12</u>	<u>Q13</u>							
<u>a,b</u>	<u>c</u>	<u>a</u>							

Exercise 5.14

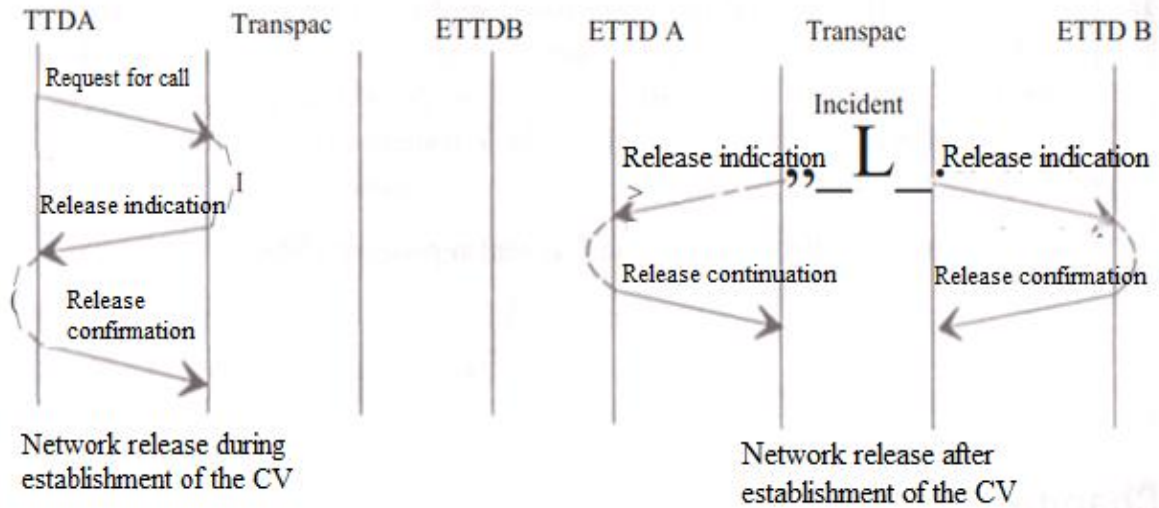
1. For low volumes and limited speeds of 2,400 bits/s, connection can be made asynchronously via RTC (using X32 protocol and PAD). For speeds up to 9,600 bits/s, synchronous access via RTC can be used (using X32 protocol). For larger volumes and speeds up to 48,000 bits/s, access must be made through a synchronous X25 connection.

2. At level 2, flow control concerns the frames exchanged on the access link between the station and the network. At level 3, flow control is carried out on each virtual circuit for packet management. These two flow controls are therefore not redundant.

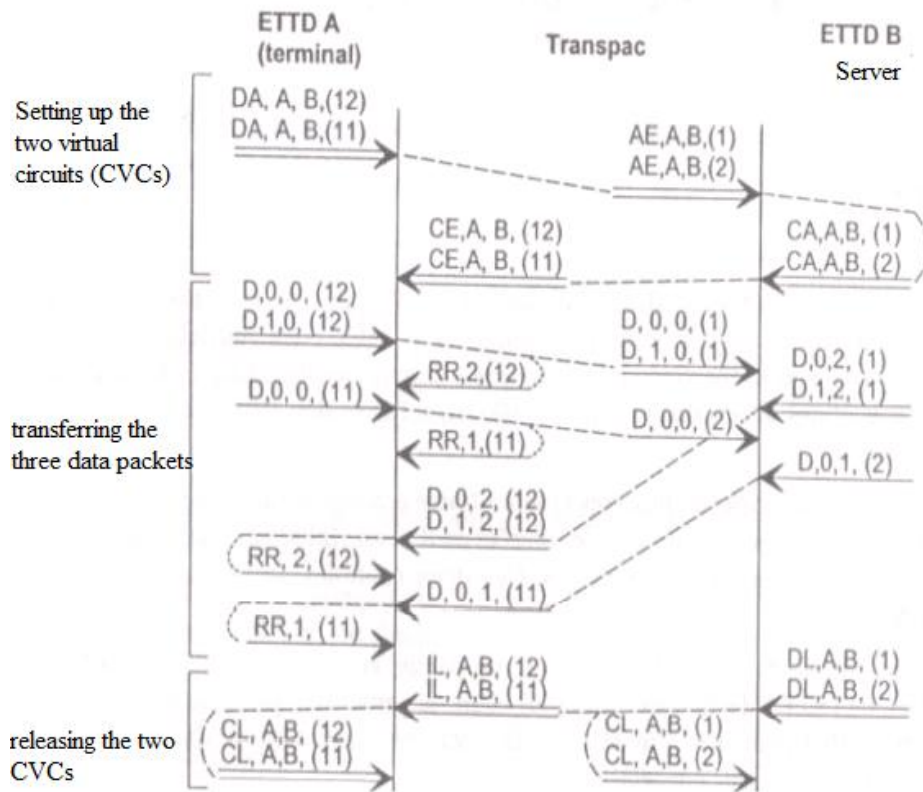
3. For end-to-end flow control, a packet will only be acknowledged by the network when the receiving ETTD has acknowledged it. This allows for detection of packet loss between the two endpoints. However, remote acknowledgement results in longer transfer times.

For hop-by-hop flow control, a minimal transfer time can be guaranteed, but in case of packet loss at any node in the network, data integrity must be ensured at the higher transport layer. The transmitting ETTD indicates that it desires remote acknowledgement by setting the D bit of the first byte of the transmitted data packet to 1.

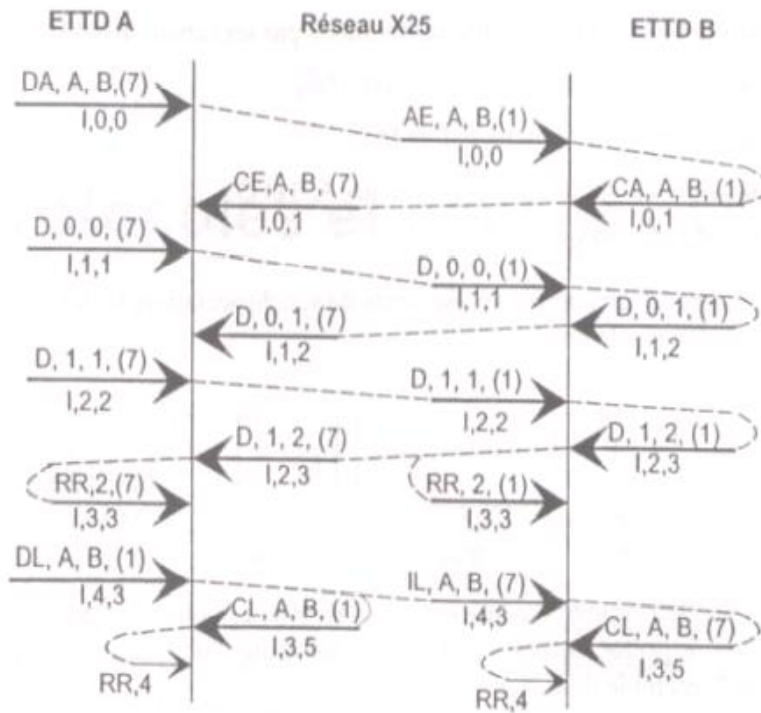
4. (No text provided)



5. For each transfer, the type of packets (D for Data...), the logical channel number (11, 12.), and the values of the counters (RR, 2...) are indicated.



6. Two data packets are required to transmit the 200-byte message. The counter values for the I-frames are indicated below the arrows.



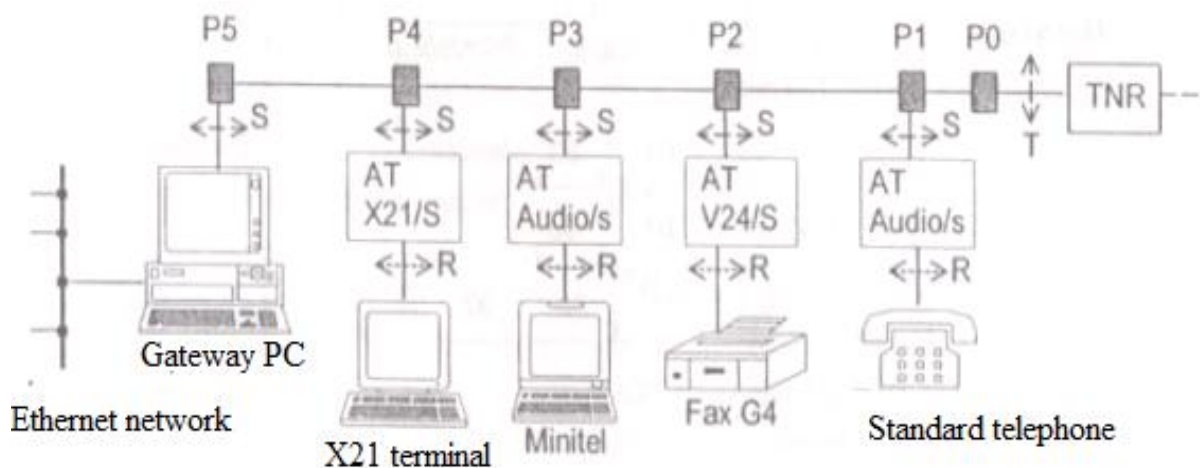
7. Signaling, which can be defined as the set of signal exchanges between functional entities of a network, has the function of managing signals for establishment, release, and resource management?

On ISDN, two signaling systems are distinguished:

- Internal signaling by semaphore network;
- Peripheral signaling by the D channel.

Depending on the system(s) used, signaling can be performed between the user and the network, between users, or be internal to the network.

8. (No text provided)



9. The S₀ interface can be associated with a point-to-point topology or with a passive or extended bus topology. The medium used consists of two symmetrical pairs connected to a

standardized eight-contact connector.

The main functional characteristics of the S0 interface are as follows:

- Located at the S and T reference points, between the TE and TNR (or TNA) groupings;
- Bidirectional transmission of information via channels B1 and B2;
- Signaling via the D channel;
- Synchronization via channels F, L, and M;
- Maintenance and power supply via channels A, S, and Q.

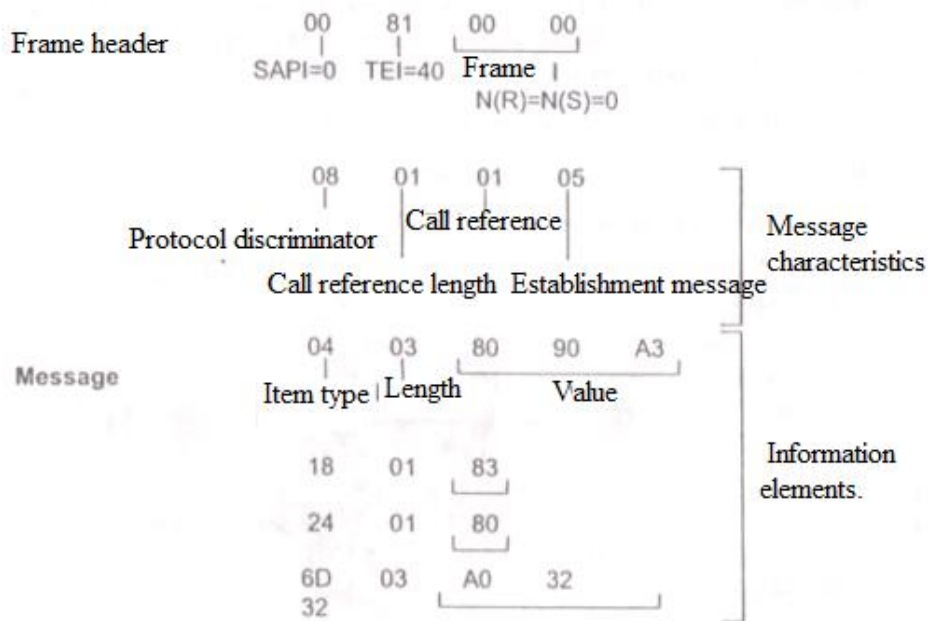
10. $IT = 250 \mu s / 48 = 5.2 \mu s$. For an S₀ frame, there are six synchronization elements, so the corresponding bit rate is $6 / 250 \mu s = 24 \text{ kbit/s}$.

11.



One can note on this framework that the alternation rule for coding level 0 is not always respected, which is justified by the need to obtain a null continuous component for the entire framework.

12.



OCM 8

Q1. The owners of Internet networks are:

- a) Service providers

b) Cable operators

c) Transport operators

Q2. The protocol used on Internet networks is:

a) NetBEUI

b) IPX/SPX

c) TCP/IP

Q3. The protocol for dynamic allocation of IP addresses is called:

a) DHCP

b) DNS

c) Proxy

Q4. The connection of a client to a provider through a telecommunications network is called:

a) Full Internet

b) Dial-Up

Q5. The POP3 protocol regulates the exchange of messages between:

a) Mail servers

b) Station and mail server

Q6. The IRC protocol allows:

a) Sending messages

b) Live discussions

Q7. The HTML protocol is:

a) A programming language for animating documents

b) A set of rules for structuring a hypertext document

c) A set of rules for creating forms.

Correction

QCM 8

Q1	Q2	Q3	Q4	Q5	Q6	Q7
b	c	a	b	b	b	b

Exercise 5.15

Bit rate:

Assuming the modulation speed of a transmission line is 8000 bauds according to its manufacturer, what is the maximum bit rate allowed by this line for the main types of encoding?

Client-server application

- A client-server application requires a binary bit rate of 20 kbit/s for optimal performance. What is the minimum modulation speed that the physical line used for this connection should offer? It is assumed here that network interfaces use Manchester code.
- A twisted pair cable is available that offers a bandwidth of [10 KHz, 22 KHz], but its modulation speed is unknown. Can Manchester code baseband transmission be used for the studied client-server application?
- If modulation is decided to transmit information between the two modules, what should be the quality of the electromagnetic environment in which the line is placed, knowing that the latter offers a bandwidth of 2200 Hz?

Modem rates

What are the bit rates proposed by modems complying with the V21, V22, and V29 standards and having a modulation speed of 9600 bauds?

Modulations

We want to set up a modem with a modulation speed of 28000 bauds and a bit rate of 56 kbit/s.

- Propose the specifications of a modem using amplitude shift modulation and meeting the above characteristics.
- Propose the specifications of a modem using frequency shift modulation and meeting the same characteristics.
- Provide a representation of the signal transmitted on this line when the message sent is: 101111100001, using the modulations defined above.

Correction :

1. Bit rate

$$D = \frac{R_m}{k} \log_2(V)$$

NRZ code: The encoding of a bit is done by transmitting an electrical voltage on the transmission medium, which can take two distinct values: $n V$ to encode bit 1 or $-n V$ to encode bit 0: the valence V is therefore 2 and the number k of physical values required to encode a logical value is 1.

$$D = \frac{8000}{1} \log_2(2) = 8000 \frac{\text{bit}}{\text{s}}$$

Manchester code: differential Manchester code and Miller code: to encode a bit, a voltage variation is performed, i.e., a transition from a voltage of $-n$ to $n V$ or vice versa. Therefore, the interpretation of binary information requires reading two successive values of the voltage: $k=2$.

$$D = \frac{R_m}{k} \log_2(V) = \frac{8000}{2} \log_2(V) = 4000 \frac{\text{bit}}{\text{s}}$$

2. Client-server application

a.

$$D = \frac{R_m}{k} \log_2(V) \text{ d'où } = \frac{D \times k}{\log_2(V)} = \frac{20000}{\log_2(2)} = 40 \text{ kbauds.}$$

b. The Nyquist's law states that the maximum modulation speed $R_{m\max}$ of a line is:

$$R_{m\max} = 2W, \text{ where } W \text{ is the bandwidth, hence } R_{m\max} = 2 \times 12000 = 24 \text{ kbauds.}$$

However, as per question (a), the required modulation speed for the application to function is $R_m = 40$ kbauds. Therefore, the twisted-pair cable does not have sufficient characteristics to allow this operation.

c. The maximum bit rate supported by a transmission line on which a signal is modulated is provided by Shannon's theorem:

$$D_{\max} = W \log_2\left(1 + \frac{S}{N}\right)$$

The signal-to-noise ratio (S/N) being the minimum quality required.

$$\text{therefore: } \frac{D_{\max}}{W} = \log_2\left(1 + \frac{S}{N}\right),$$

$$\text{therefore: } \frac{S}{N} = 2^{\frac{D}{W}} - 1 = 2^{\frac{2000}{2200}} - 1 = 2.17.$$

The quality of the environment must be at a minimum of 2.17, meaning that the signal power must be more than 2.17 times that of the external electromagnetic noise on the cable for the application to function at the desired bit rate.

3. Modem standards

- V21 Standard: A V21 standardized modem uses a frequency shift modulation technique based on two carrier frequencies, hence:

$$D = \frac{R_m}{k} \log_2(V) = 9600 \log_2(2) = 9600 \frac{\text{bit}}{\text{s}}$$

- V22 Standard: The V22 standard defines a phase shift modulation using four distinct phases: $V=4$.

$$D = \frac{R_m}{k} \log_2(V) = 9600 \log_2(4) = 19200 \frac{\text{bit}}{\text{s}}$$

- V29 Standard: The modulation used by a V29 modem is based on both phase and amplitude shift: eight phase states are defined, each of which can be associated with two different amplitudes, resulting in a total of 16 possibilities.

$$D = \frac{R_m}{k} \log_2(V) = 9600 \log_2(16) = 38400 \frac{\text{bit}}{\text{s}}$$

4. Modulations

- a. Among the characteristics of the modem to be defined, we know the bit rate, modulation

speed, and the value of k (in modulation, only one physical value is required to represent a logical value): therefore, the only unknown is the valence V .

$$D = \frac{R_m}{k} \log_2(V) \text{ donc } V = 2^{\frac{D}{R_m}} = 2^{\frac{56000}{28000}} = 4.$$

Let's propose a quadrivalent amplitude shift modulation (a):

Bit rate	00	01	10	11
amplitude	1V	2V	5V	10V

b. A quadrivalent frequency shift modulation could be as follows:

Bit rate	00	01	10	11
frequency	500 Hz	1000 Hz	1500 Hz	2000 Hz

c. The binary sequence to be transmitted is: 101111100001.

Binary sequence	10	11	11	10	00	01
(a) in AM modulation (in V)	5	10	10	5	1	2
(b) in FM modulation (in Hz)	1500	2000	2000	1500	500	1000

Exercise 5.16

1. Activity rate:

A teleworker transmits data to a server of their company every day, using a modem connected to the PSTN network, operating at a bit rate of 33 kbit/s. The daily connection, lasting for duration of 2 minutes, takes place in three stages:

- an identification phase during which the person sends their ID (20 bytes) and password (10 bytes),
- transmission of the file (20 K bytes);
- Sending a disconnect command (2 bytes).

Calculate the activity rate. What observation can be made?

2. Message switching and packet switching

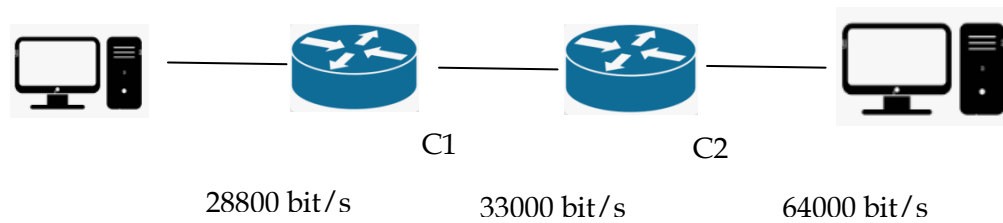
Two ETTD A and B are interconnected by a transmission network. The data transmitted by ETTD A passes through the network mesh: they pass through two switches before reaching ETTD B.

a. Draw the timing diagrams for the transmission of a binary sequence from A to B in the case of a message switching network and in the case of a packet switching network.

b. The communication lines offer a bit rate of 28800 bit/s.

Compare the total transmission time required for a binary sequence of 18000 bits to pass from A to B in the case of a message switching network and in the case of a packet switching network of 1000 bits. The switching time is 100 ms for each switch.

c. Now consider that not all lines have the same characteristics. The lines used for communication are as follows:



Calculate the total transmission time of the message described in b. in the case of a message switching network and in the case of a packet switching network.

d. ETTD B sends a response to A. Draw the timing diagram for this transmission. What observation can be made?

3. Wait/response protocol

Two computers A and B are interconnected by a communication line. A transmits a binary sequence of 22000 bits to B.

Each frame transmitted can only contain 16 kbits. The network interfaces manage communication using the wait/response protocol.

- a. Draw a timing diagram for the transmissions that will allow the transfer of the binary sequence between the two computers.
- b. Draw a timing diagram for the transmissions that will allow the transfer of the binary sequence between the two computers in the case where an error is detected during the reception of the first frame.
- c. Draw a timing diagram for the transmissions that will allow the transfer of the binary sequence between the two computers in the case where a line break occurs during the transfer of the acknowledgment of the first frame.

4. HDLC

The most common standardized protocol encountered in the data link layer is HDLC (High-level Data Link Control). HDLC, even though it is being replaced by more comprehensive protocols, is considered a "textbook case" and applies all the theoretical aspects studied: connection management, frame construction, and error handling.

The binary frames used by HDLC are structured as follows:

8 bits	8 bits	8 bits	n bits	16 bits	8 bits
Fanion de début	Adresse destination	Commande	Données	Contrôle d'erreur	Fanion de fin

The start flag and end flag indicate the two ends of the frame: they are made up of the

binary sequence 01111110.

- The destination address identifies the recipient ETTD.
- The command field contains all the information necessary for the interpretation of the frame.
- Depending on the role of the frame, the Data field contains a binary sequence or not.
- Error control is performed by a CRC code based on the generator polynomial $G(x) = x^{16} + x^{12} + x^5 + 1$.

Binary transparency processing is carried out as we have already described: a systematic reading phase of the frame is carried out before transmission to insert a 0 after five consecutive 1s. During reception, these artificially inserted 0s are removed.

a. An ETTD is detected on one of these ETCD by another ETTD for a data exchange.

During this exchange, it receives the following binary sequence:

```
0111111001011111000101000101111101010101000011101011011111
1001111110010111110101001011110010100110000011111100111111
11001011111010001101110011001110010101111110
```

Extract the frames contained in this binary sequence.

b. Perform binary transparency processing on the frames extracted in a.

c. Analyze these frames based on the information provided on HDLC: provide for each its type and detailed meaning.

d. Deduce from the results obtained in c. an overview of the ongoing exchange.

Correction 5.16

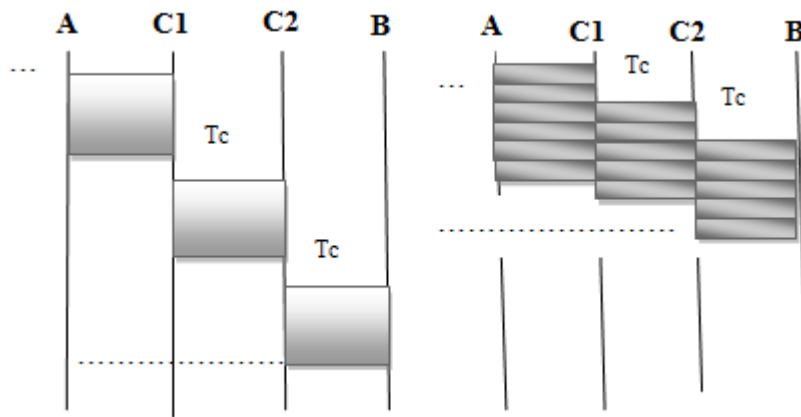
Activity rate

$$\sigma = \frac{T_t}{T} = \frac{(20 + 10 + 20000 + 2) \times 8}{33000} = 4\%$$

The very low activity rate (4%) indicates that the communication line is underutilized. Note that, given the plausibility of the proposed values, the context studied resembles many real situations: the PSTN network used for data transmission by modulation is mostly not used optimally.

2. Message switching and packet switching

a. The following timing diagrams describe the communication studied:



b. After studying the representations below, the total transmission time is calculated as follows:

- In message switching:

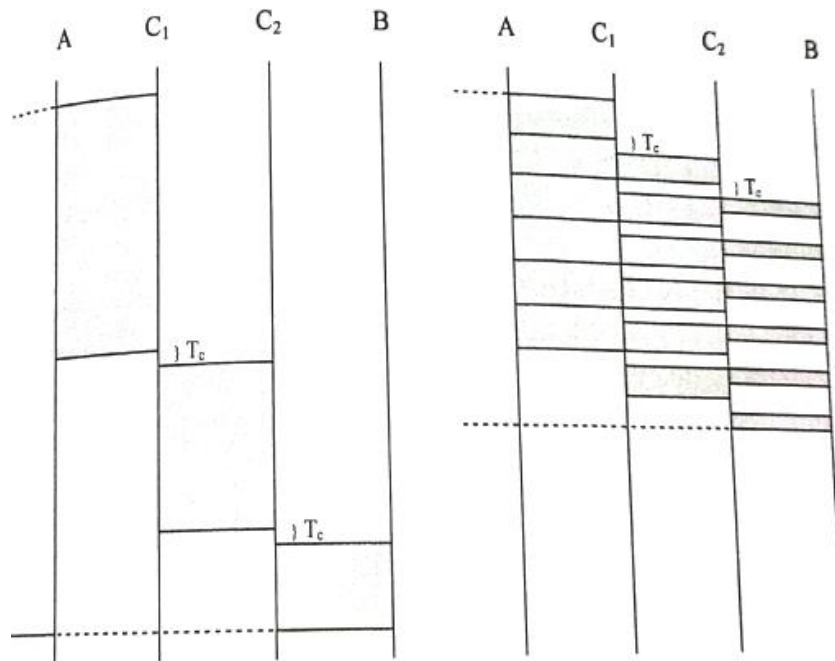
$$T_t = 3 \times \frac{L_{message}}{D} + 2T_c = 3 \times \frac{18000}{28800} + 2 \times 0.1 = 2.08 \text{ s.}$$

- In packet switching:

The number of packets to be transmitted is 18, hence:

$$T_t = (18 + 2) \times \frac{L_{paquet}}{D} + 2T_c = (18 + 2) \times \frac{1000}{28800} + 2 \times 0.1 = 0.89 \text{ s.}$$

c. Let's study the timing diagrams of the communication defined:



The total transmission time is calculated as follows:

- In message switching:

$$T_{t1} = \frac{L_{message}}{D_{ligne1}} = \frac{18000}{28800} = 625 \text{ ms}$$

$$T_{t2} = \frac{L_{message}}{D_{ligne2}} = \frac{18000}{33000} = 545 \text{ ms}$$

$$T_{t3} = \frac{L_{message}}{D_{ligne3}} = \frac{18000}{64000} = 281 \text{ ms}$$

$$T_t = T_{t1} + T_{t2} + T_{t3} + 2T_{tc} = 1.65 \text{ s.}$$

- In packet switching:

The number of packets to be transmitted is still 18, hence:

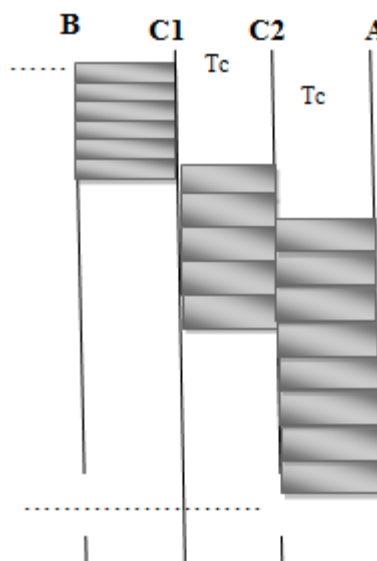
$$T_{t1} = \frac{L_{paquet}}{D_{ligne1}} = \frac{1000}{28800} = 35 \text{ ms}$$

$$T_{t2} = \frac{L_{paquet}}{D_{ligne2}} = \frac{1000}{33000} = 30 \text{ ms}$$

$$T_{t3} = \frac{L_{paquet}}{D_{ligne3}} = \frac{1000}{64000} = 16 \text{ ms}$$

$$T_t = 18 \times T_{t1} + T_{t2} + T_{t3} + 2T_{tc} = 876 \text{ ms.}$$

d. timing diagram:

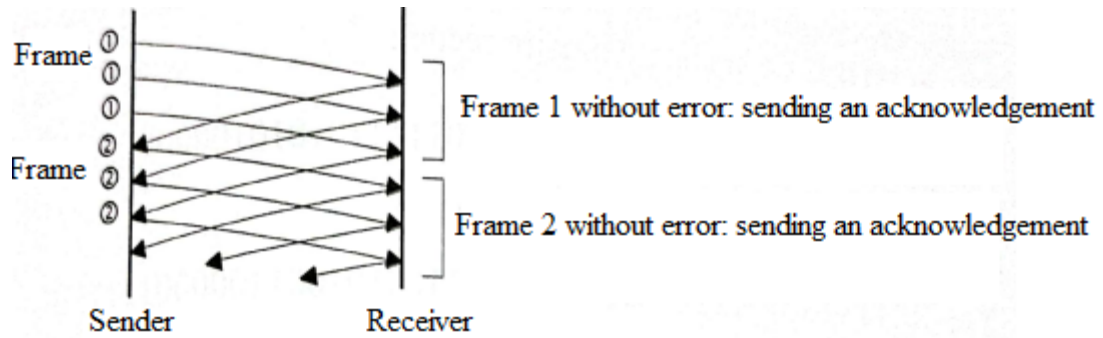


The representation below highlights a problem with the switches. Indeed, as the first line offers the highest throughput, switch C2 cannot retransmit the frames immediately after receiving them: if it does not have a sufficiently large buffer, it will quickly become saturated.

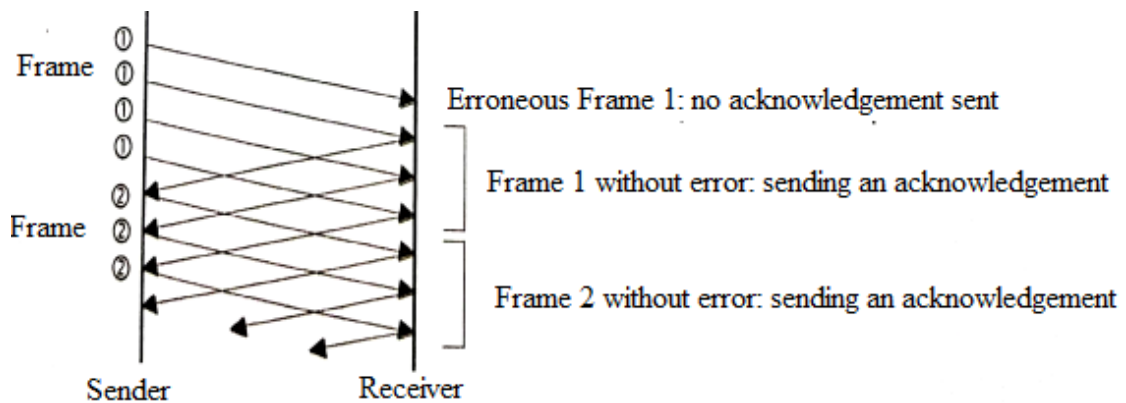
3. Wait/response protocol

Two frames are required to transmit the entire binary sequence.

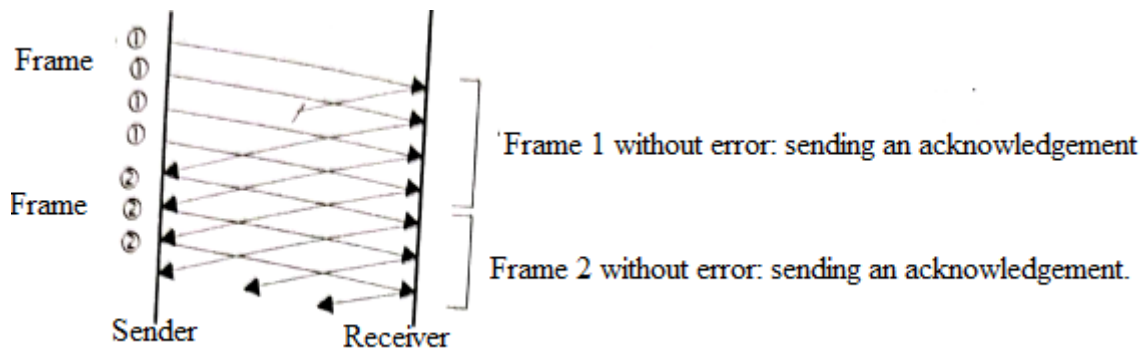
- As specified by the wait/response protocol, the second frame is only sent after the receiver has acknowledged the first one:



b. The first frame reaches the receiver, but it detects an error. The receiver thus does not send an acknowledgement to the sender, who continues to transmit frame 1:



c. The first frame reaches the receiver without any errors, but its acknowledgement is lost:



HDLC

a. Locating the start and end flags allow extracting 3 HDLC frames from the received binary sequence:

T1: 0111111001011111000101000101111101010100001110101101111110

T2: 011111100101111110101001011110010100110000011111110

T3: 011111100101111101000110111001100111001010111111110

b. Processing binary transparency at reception consists of removing the artificially inserted 0 bit after every sequence of five 1 bits during transmission. The flags are not affected: they were added after this processing phase.

The frames after processing are as follows:

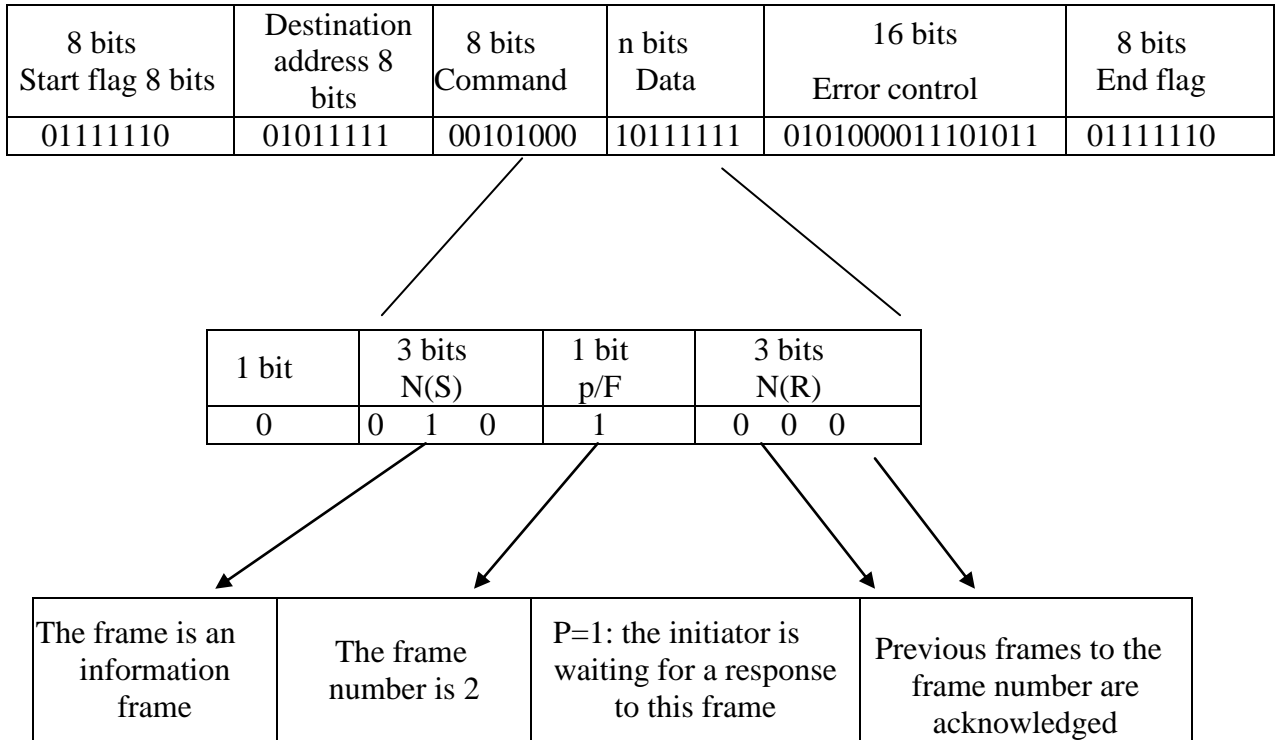
T1: 01111110010111110010100010111111010100001110101101111110

T2: 011111100101111110100101111001010011000001111110

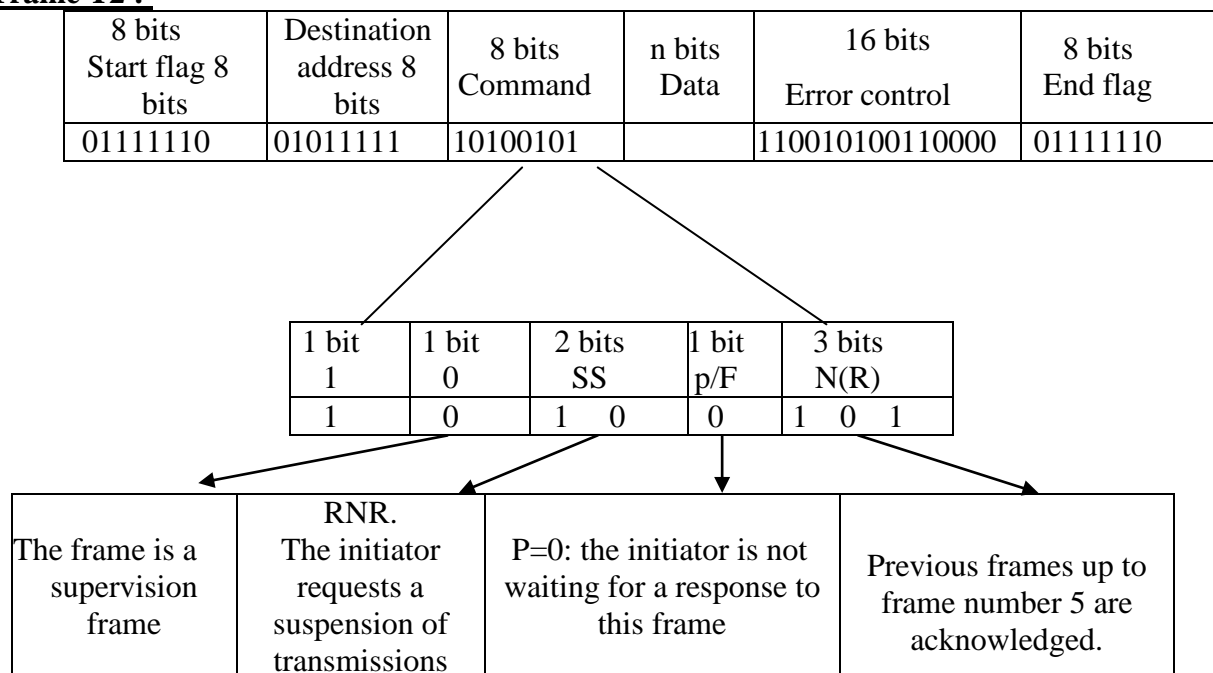
T3: 0111111001011111100011011100111001110010101111110

c. The analysis consists of breaking down the frame to interpret each field.

Frame T1:



Frame T2 :



Frame T3 :

8 bits Start flag 8 bits	Destination address 8 bits	8 bits Command	n bits Data	16 bits Error control	8 bits End flag
01111110	01011111	10100101		100110011100101	01111110

1 bit	bit	2 bits	1 bit	3 bits
1	0	SS	p/F	N(R)
1	0	0 0	1	1 0 1

The frame is a supervision frame	RR The initiator is ready to receive frames from its correspondent	r=0: the initiator is not waiting for a response to this frame	Previous frames up to frame number 5 are acknowledged
----------------------------------	---	--	---

d. From the above analyses, we can deduce that the information contained in frame T1 is a request that requires a certain number of response frames to be returned. Indeed, in T1, the initiator of the exchange is waiting for a response, and frame T2 acknowledges 5 frames that were returned to it.

We have no information indicating whether the response is complete, but the initiator sends a T2 frame solely to request an interruption of its correspondent's transmissions. If the response is not complete, the following frames will not be immediately transmitted. If it is complete, the correspondent will refrain from sending any request to the initiator. We have no information about the reason that prompted such a request to stop transmissions, which usually comes from higher-level layers (network or transport level quality, application-level system process management, etc.).

Frame T3 is the logical successor to T2: the initiator informs its correspondent that it is ready to receive frames again. The response to the T1 request can then be emitted, if necessary, or any other useful frame. Note that we cannot know the delay between the reception of T2 and that of T3, but a delay must have been observed, corresponding to the time during which the initiator was not in a position to receive.

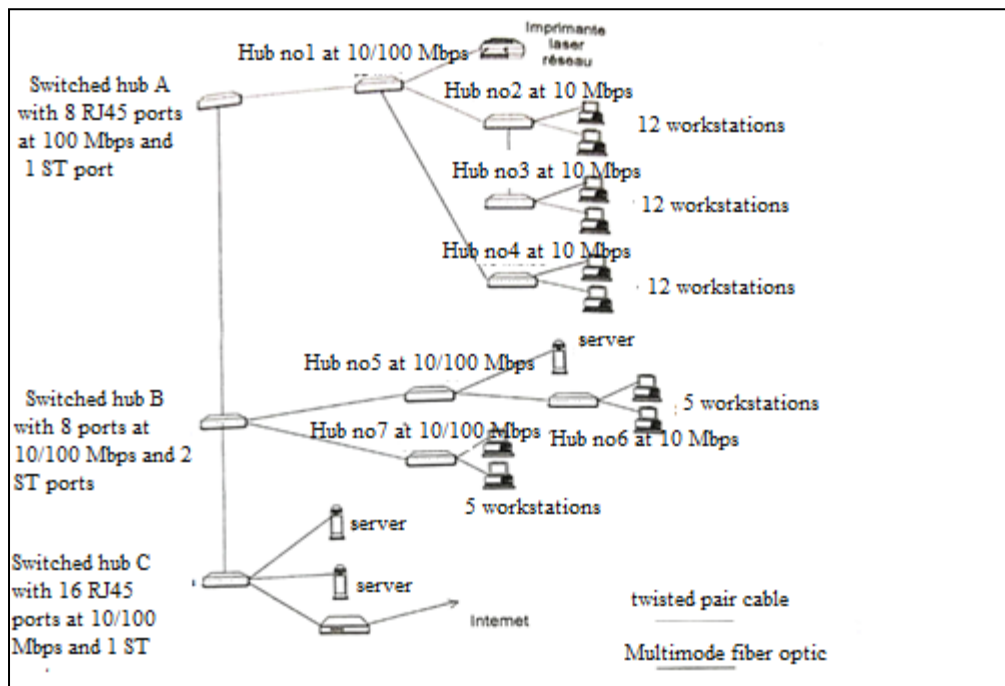
Exercise 5.16

1. Case study: A small business specializing in mail order sales has the following structure:

- An administrative department, located in a building (A), with 8 workstations spread across

- 5 offices and a server connected to the Internet dedicated to customer orders.
- A order management department, located in another building (B), 120 meters away from building (A), using 4 workstations.
- A storage room, located in building (B), where a stock management server is placed, connected to 4 workstations through an old Token Ring network.
 - a. We want to set up a local network between the 9 computers in the administrative department (workstations and server). Choose a suitable local network standard for this situation.
 - b. List the necessary network components for this setup.
 - c. Propose 3 solutions to connect the 4 workstations in the order management department to the local network set up in question b.
 - d. Propose a solution to interconnect the local network created in the previous question with the one already in place in the storage room.
 - e. How to use a firewall to secure access to the server connected to the Internet?

2. Standardization.



- a. The Ethernet local network whose organizational diagram is provided below (Fig) is not standardized. Explain why.
- b. Propose 3 possible solutions to standardize it.

Correction**Exercise 5.16**

Case study:

a. The office and management tools used in an SME tend to lead us to opt for an Ethernet-based architecture, which is the most common in such a context.

No network is currently installed in this department, and no information is provided regarding the amount of information to be transmitted on this network. Therefore, we have a choice between an Ethernet or a Fast Ethernet architecture. It seems judicious to implement Fast Ethernet architecture, following the IEEE 802.3u standard, which offers interesting technological advantages and a high capacity for evolution.

b. Each workstation must be equipped with an Ethernet network interface. The server should also have one.

A hub allows us to interconnect all the computers. For scalability reasons, we choose a hub with more input/output ports than computers to connect (for example, 16 ports). Given the limited number of computers to connect, the use of a switched hub is not necessary.

Since the distance separating the computers from the hub is obviously less than 100 meters, we use category 5 twisted pair cable with RJ45 connectors to connect them. Therefore, the input/output ports of the hub must also be in RJ45 format.

c. A first solution (Fig 7.) that is simple but very limited in terms of scalability is to add four additional connections between the workstations and the hub in place, which would maintain a perfectly homogeneous topology. The distance of 120 meters does not allow the use of twisted pair cable, so the only physical support available is optical fiber. The chosen hub in question b does not have ST or SC input/output ports, so a 100BaseTX/100BaseFX transceiver must be obtained at each end of each of the four connections, making it a very expensive solution.

Such a solution would not be implemented in a real case.

The second solution (Fig 7.) proposes to create a second Fast Ethernet network around a hub in the order management department, then to interconnect the two local networks created. As in the previous question, the only usable support is optical fiber, requiring a transceiver at each end. This structure is realistic and is frequently encountered in such situations.

The most comprehensive technical solution is a variant of architecture (2). The two local networks are no longer directly interconnected but interconnected through an active

electronic element (Fig 7.). The most suitable hardware for this role is a switched hub, which allows for collision domain segmentation and thus limits the transmission of Ethernet frames between the two hubs. The transmission medium used depends on the physical location of the switched hub: if the length of the connections between it and the hubs of the two departments does not exceed 100 meters, it is possible to choose either category 5 twisted pair cable or optical fiber. Moreover, this architecture is perfectly scalable: it is particularly easy to add a connection with a third network, for example, in a homogeneous manner.

The third solution (Fig 7.) is similar to the second: it consists of replacing the wireless connection (possible because the distance is less than 200 m). In Figure (7.2a), it is sufficient to replace the transceivers with Wi-Fi access points acting as a 802.3u/802.11 bridge. One can opt for the 802.11b or 802.11g standard to bring the inter-building link throughput as close as possible to that of the administrative department network.

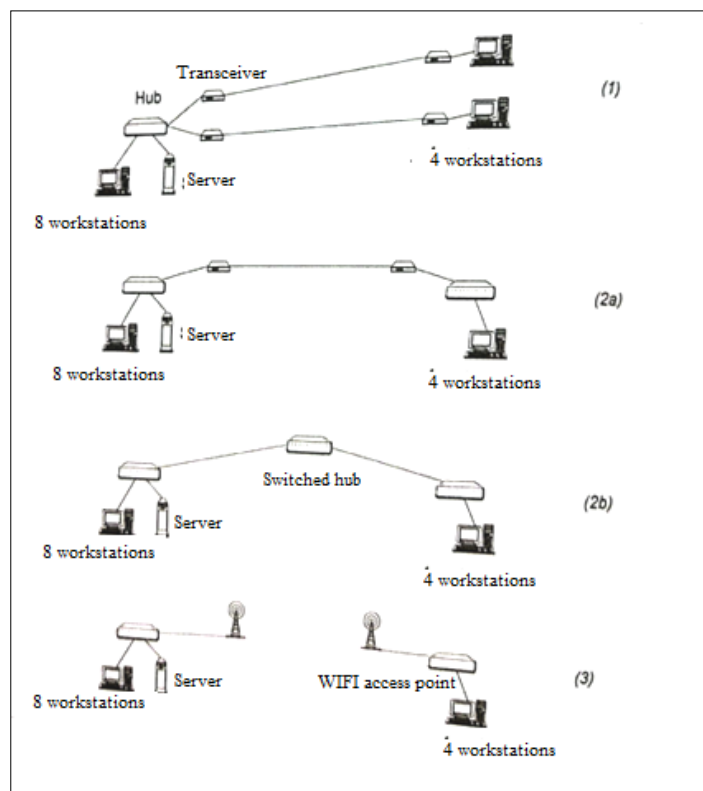


Figure 7: Possible solutions.

d. The network in place in the storage room is a Token Ring network, compliant with the IEEE 802.5 standard. The one built in questions as to c is a Fast Ethernet architecture, referring to the 802.3u standard. The element that allows us to interconnect two architectures with different standards is a bridge. Suppose that solution (3) below has been implemented: we will then use an 802.3u/802.5 bridge between the switched hub and a

MAU of the Token Ring network.

e. In our case, the order management server is connected on one hand to the Internet, and on the other hand to the local network created in question a. This structure can be a source of unwanted access or hacking on the internal local network by individuals outside the company.

The firewall is an element that allows us to physically separate two parts of a network by using two network interfaces and an application gateway managing communications between them. It is particularly interesting here to prohibit people connected to the server via the Internet from accessing other computers on the network. Therefore, the firewall will be placed between the server and the rest of the network (Fig 8). A cost-effective solution could be proposed by placing the firewall directly on the server, but it seems judicious to distribute the roles between two distinct entities to increase security.

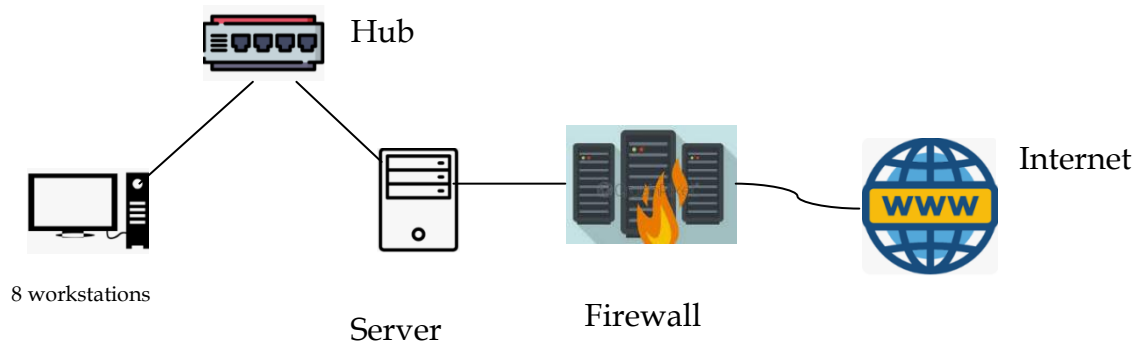


Figure 8: Using a firewall.

2. Standardization

- a. The 5-4-3 rule applies to each branch of the network originating from a switched hub. At the level of switched hub A, an Ethernet frame traveling from a station connected to hub no. 3 to a station connected to hub no. 4 does comply with the first two conditions. The third condition states that out of 4 hubs traversed, at most 3 can have stations connected to them, which is not the case here (the network printer is a network element just like a workstation).
- b. To standardize this local network, several solutions are possible. We propose three of them here, but many others are also correct.

One possible solution is to connect the network printer to switched hub A, so hub no. 1 is used only to interconnect hubs no. 2 and no. 4. This modification is simple at the organizational level, but may be complex to implement in reality.

A second possible solution is to connect hub no. 3 directly to hub no. 1, in order to traverse a maximum of 3 hubs, each of which can have stations connected to it. This transformation allows for a more homogeneous overall diagram: hub no. 1 is placed at the center of a star topology, each branch of which is a hub carrying stations.

The last proposal concerns the hardware, rather than the wiring: it is possible to keep the initial organizational diagram by replacing a hub, for example hub no. 1, with a switched hub. The normalization rule then applies to each branch originating from this new element.

Conclusion

Wireless networks, mobile systems, and fixed infrastructures are advancing rapidly. While wireless networks provide mobility and easy access, fixed networks like RTC, xDSL, and fiber-optic systems support high-speed and reliable services. Emerging technologies such as WRAN and CPL are expanding connectivity options for underserved areas.

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