Capítol 2. Elements tecnològics d'Internet

2.1 Model arquitectònic d'Internet

2.2 Protocols control d'enllaç

2.3 Mitjans de transmissió

2.4 Tècniques comunicacions de dades

2.5 Codificació de senyals

2.6 Modulació

2.7 Multiplexació

2.8 Commutació

2.1 Model arquitectònic d'Internet.

a la assignatura s'enfoca a internet,
però és un model de xarxes en general

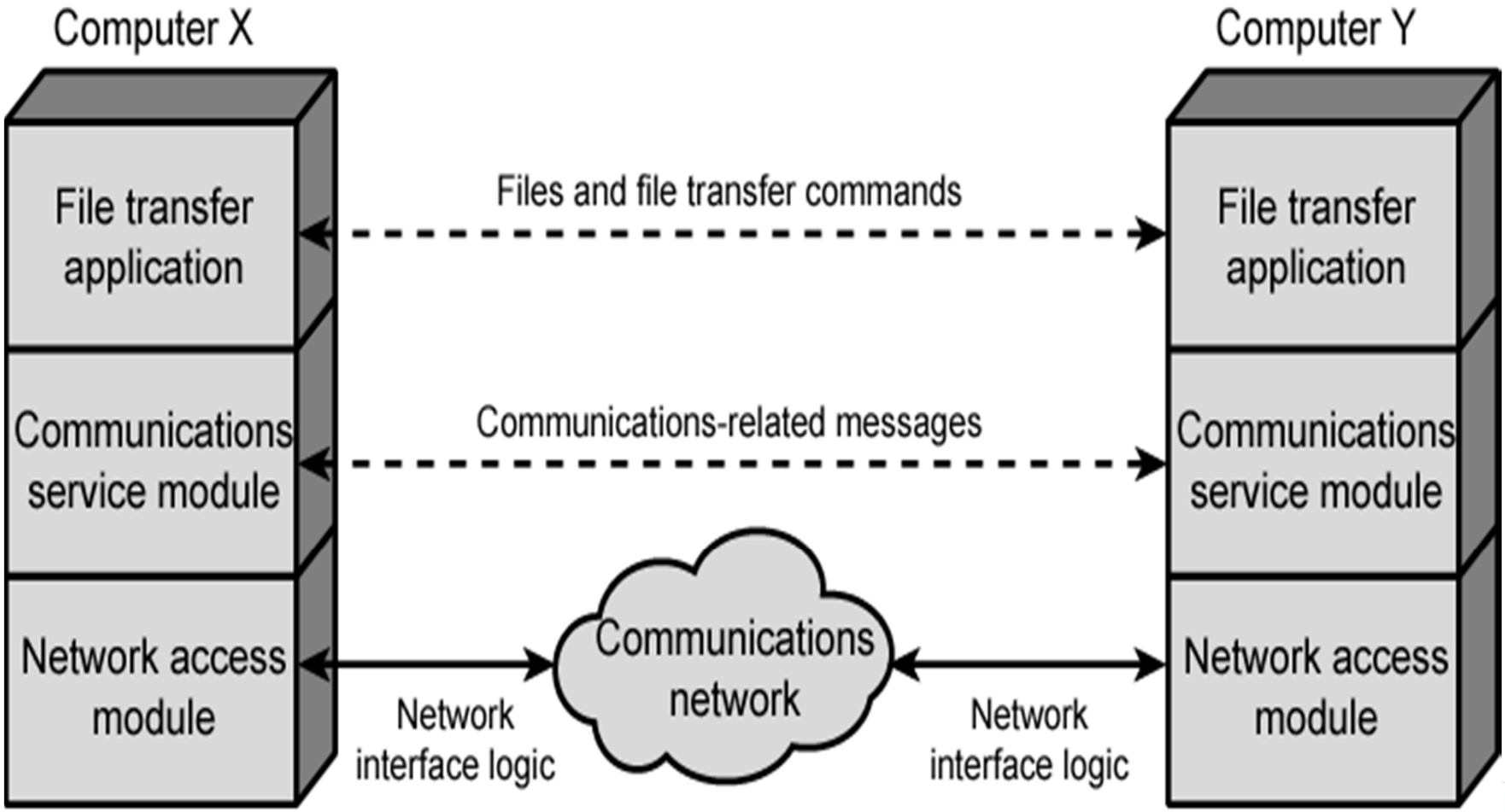
Història:

· als anys 40 es creen les xarxes de comunciacions sota monopolis

· als 80s es comença a desregularitzar i comencen a haver-hi diferents empreses en competència

· al final acaba sorgint una regularització que permet el lliure mercat en comptes dels monopolis

Simplified Network Architecture



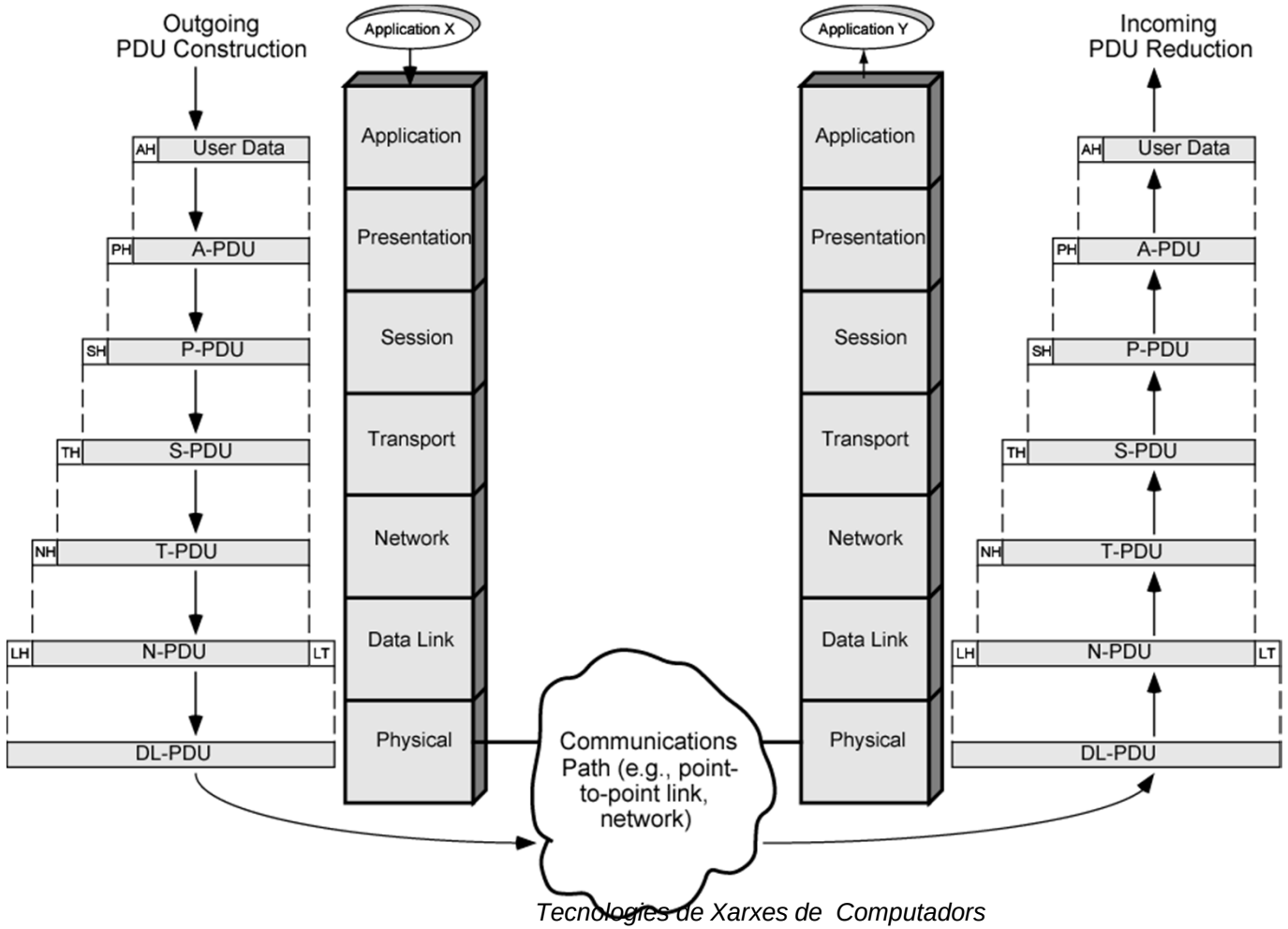
es va crear als 80's

OSI model

· és un model simètric, basat ne la encapsulació
·cada nivell del model executa funcions específiques que proporcionen serveis al nivell superior.
· es va fer una llista de funcions per nivell, buscant la simplificació de les interfícies(separacions entre nivells) i en van resultar 7

- Arquitectura ISO/OSI

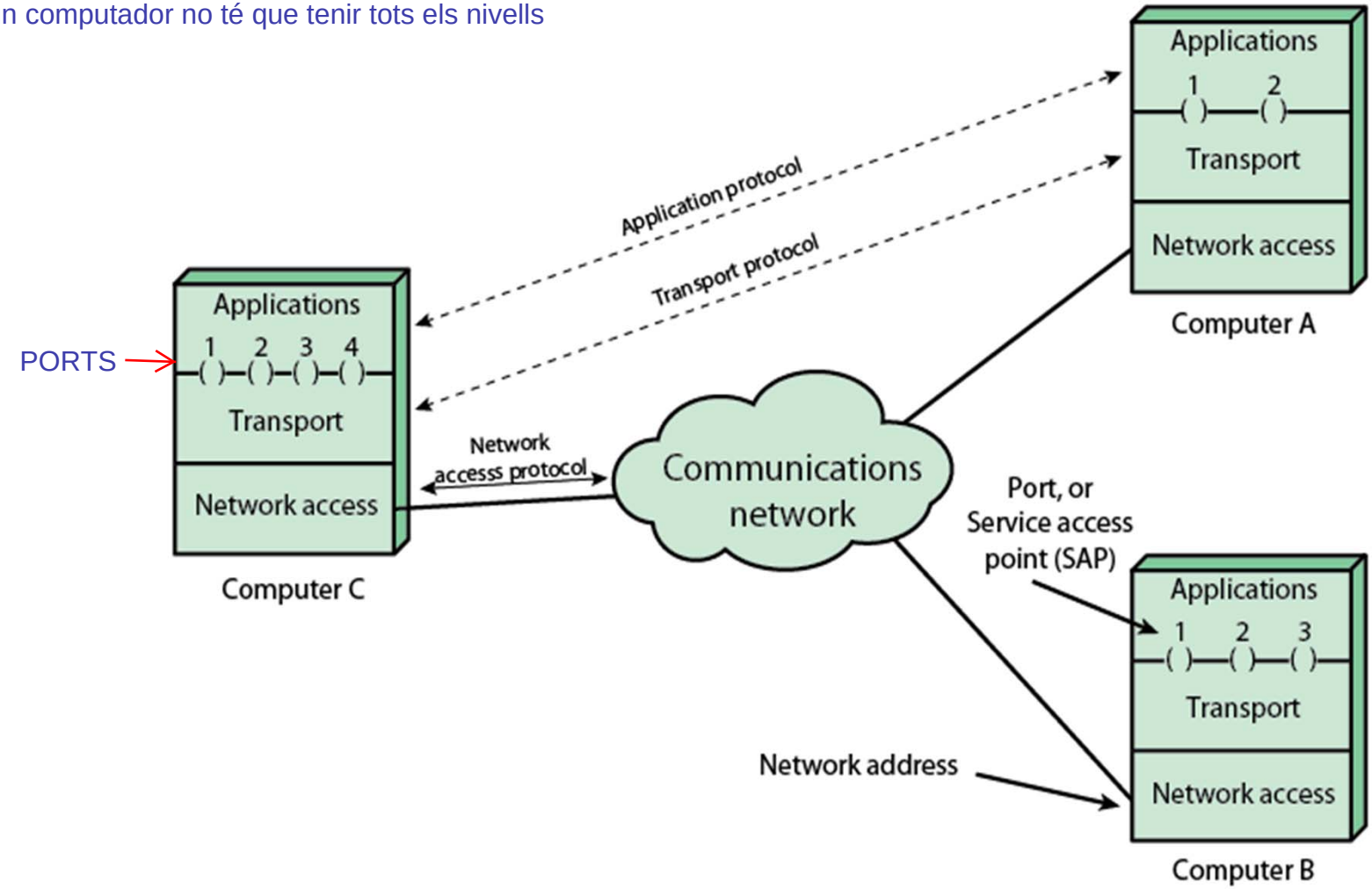
· la comunicació física entre nivells és vertical (a través d'interfícies), i la comunicació virtual entre nivells és horitzontal (protocol: a través dels headers)



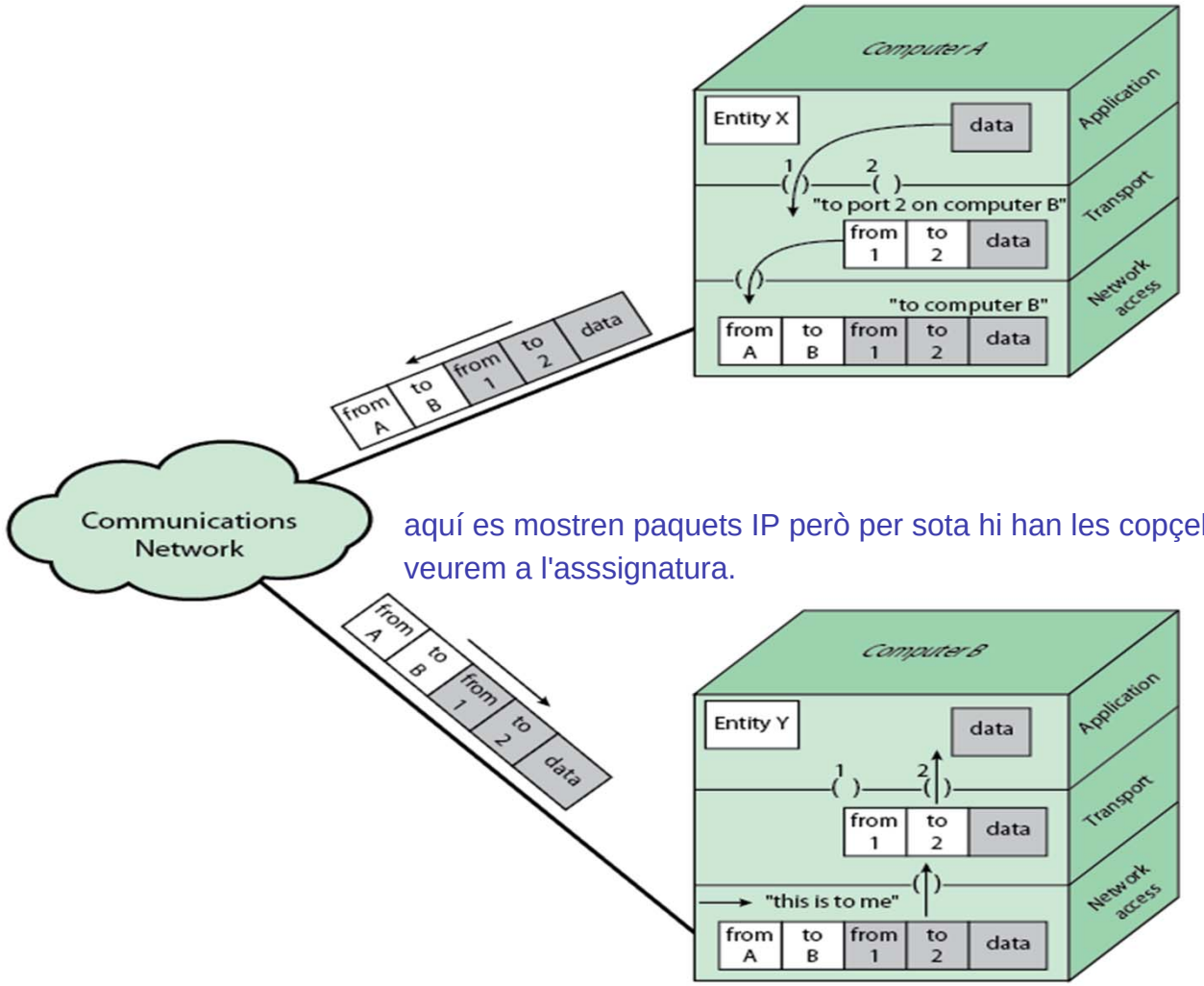
Criteri de disseny pel que es van fer 7 capes:
Simplificar les intefícies, que el tràfic entre interfícies fós mínim

Protocol Architecture and Networks

· un computador no té que tenir tots els nivells

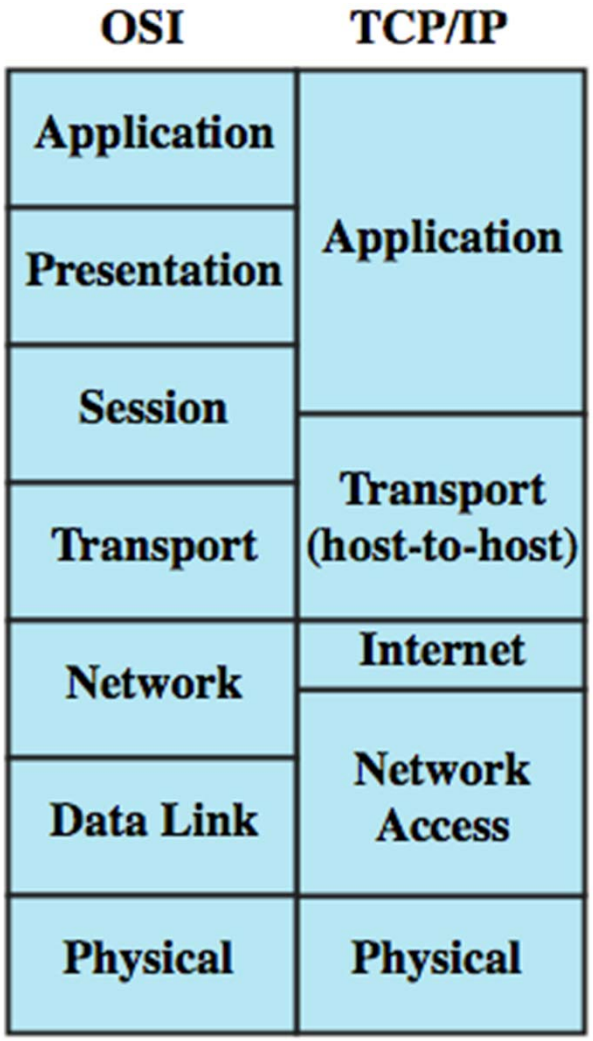


Protocols in a Simplified Architecture



aquí es mostren paquets IP però per sota hi han les copçeleres d'enllaç, que són les uqe veurem a l'asssignatura.

OSI v TCP/IP


OSI
TCP/IP
Application
Presentation
Session
Transport
Network
Data Link
Physical
Application
Transport (host-to-host)
Internet
Network Access
Physical

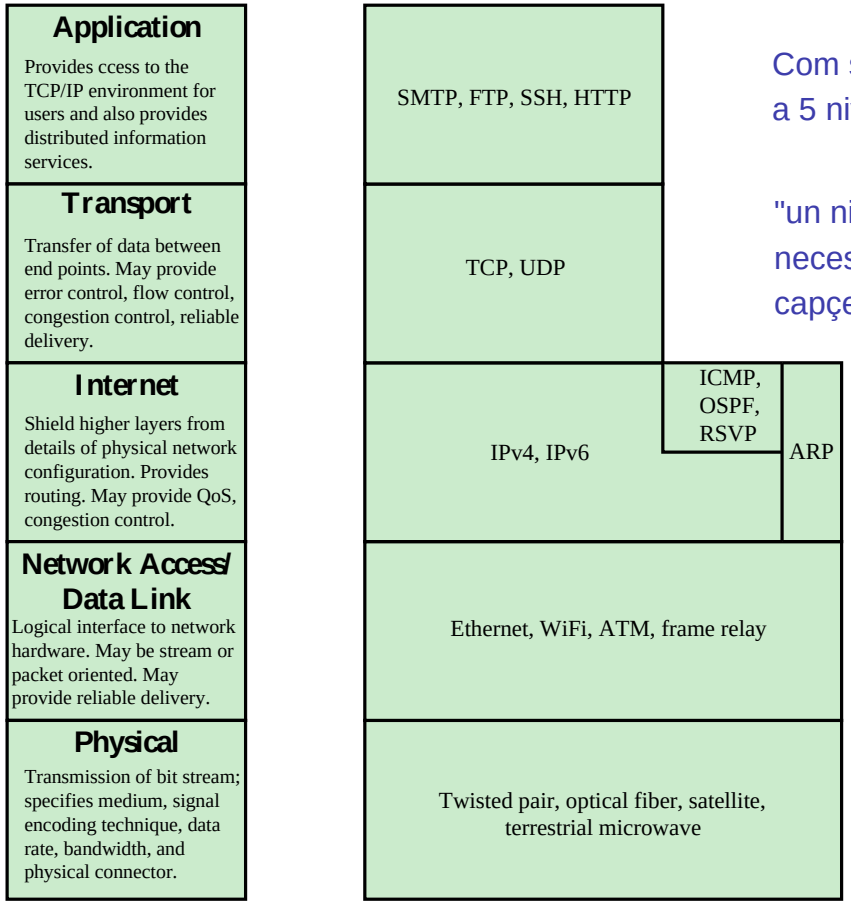
* diferència entre les funcions que fa el nivell 4 i el 2: el nivell treballa entre terminals que exuten aplicacions, i el 2 entre elements de la xarxa.

TCP/IP

Nivell 4: és el nivell que comunica extrem a extrem de les aplicacions.
TCP defineix la aplicació a través dels ports, i fa control d'errors i flux

Nivell3: funció principal --> routing
un paquet IP no té res per indicar on comencen i acaben els paquets.,
per tant no té sincrnintzació

funcions del nivell 2
-sincronització
-control d'errors
-control de flux



Com s'ha imposat TCP/IP s'ha simplificat el model a 5 nivells

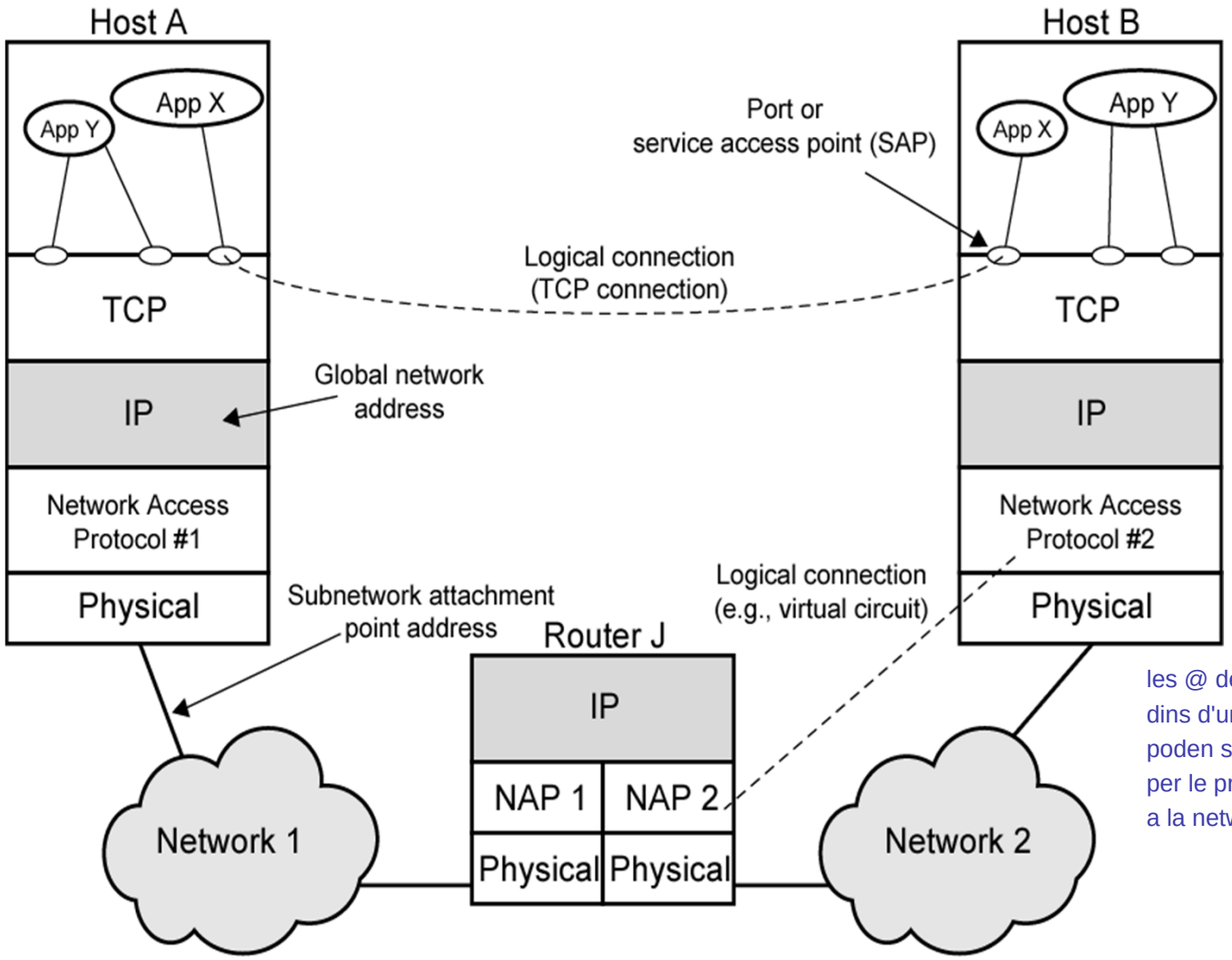
"un nivell executa funcións per oferir serveis, i necessita la informació que li arriba de les capçeleres"

tots els nivells (excepte el 3) fan sincronitació: s'ha de determinar on comencen i on acaben les unitats de dades.

* raó per la que no fem que el nivell 2 enruti : les direccions IP han de ser uniques, i quan es va fer ethernet no es va evitar que es repetissin direccions, i per això es necessita IP

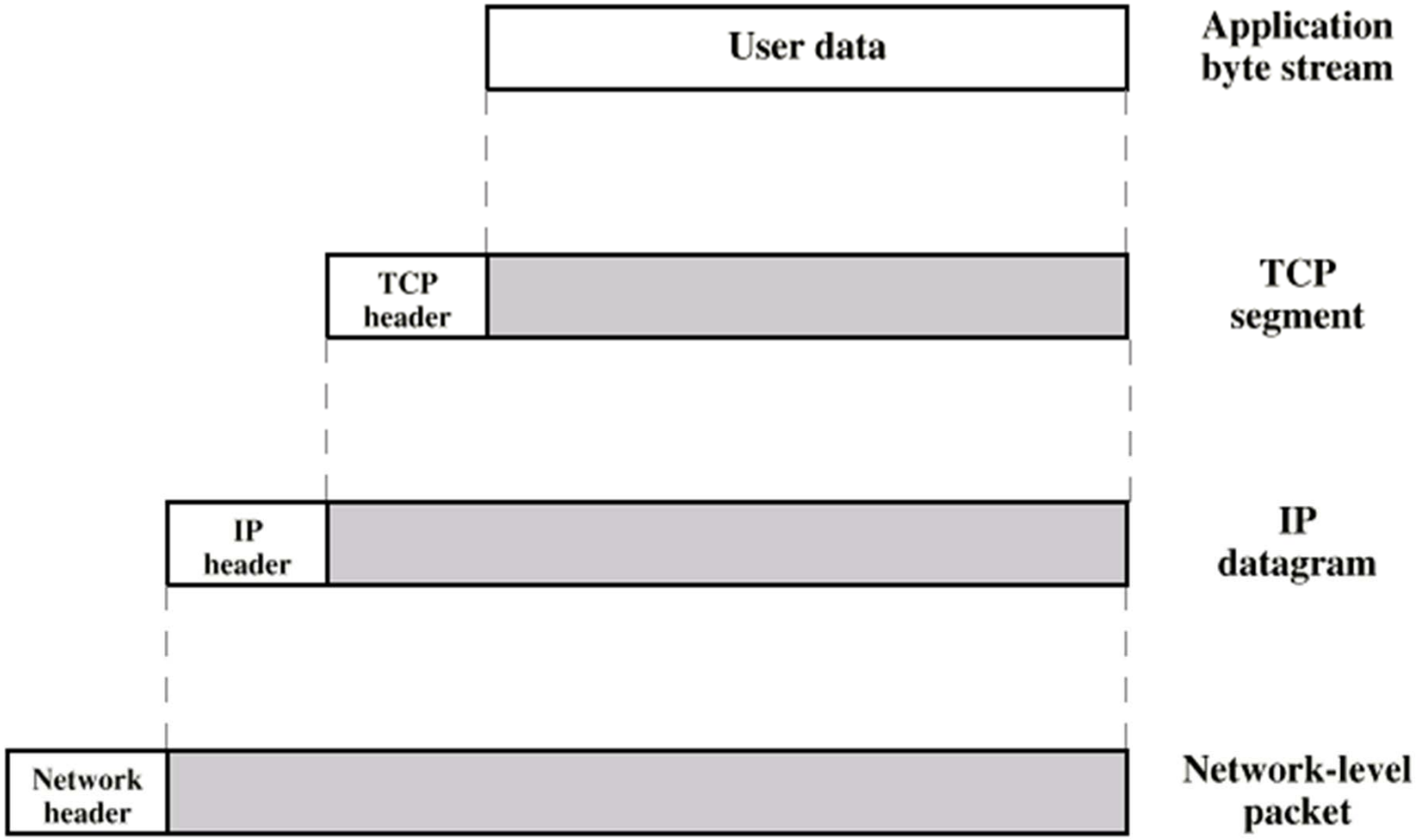
Figure 2.3 The TCP/IP Layers and Example Protocols

Operation of TCP/IP



les @ del nivell 2 han de ser diferents dins d'una network (ex: el telefons poden ser iguals pero es diferèncien per le prefix) per tant pot estar una @ a la network1 i a la network 2

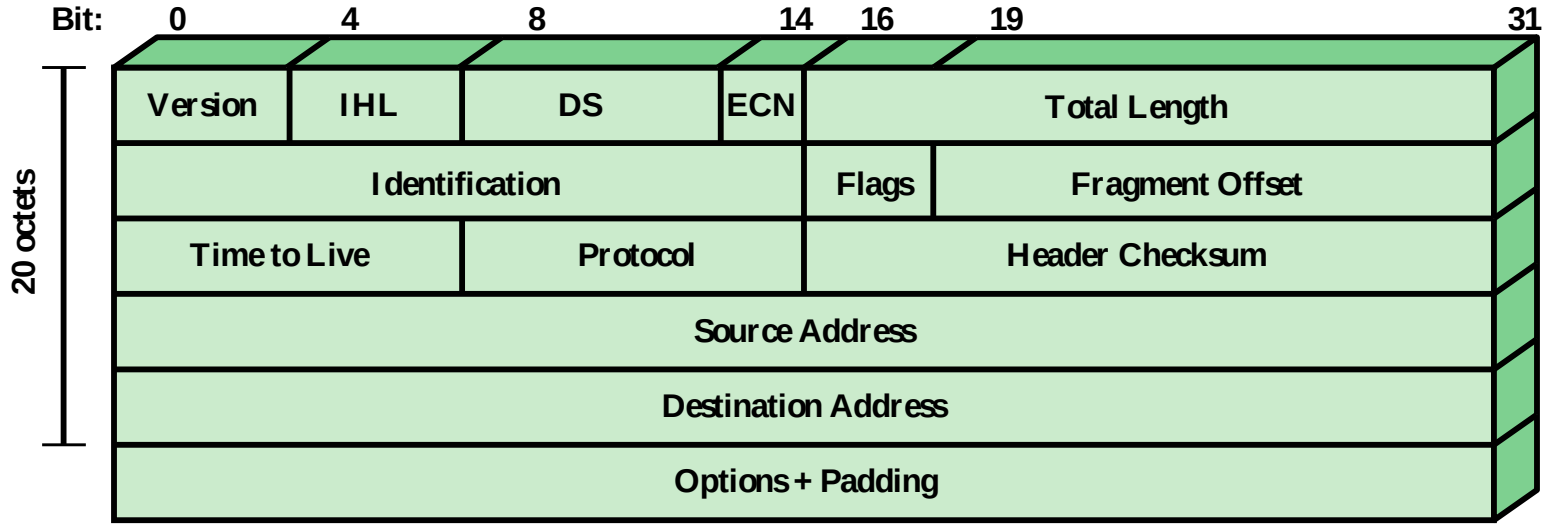
Operation of TCP/IP



IPv4 header

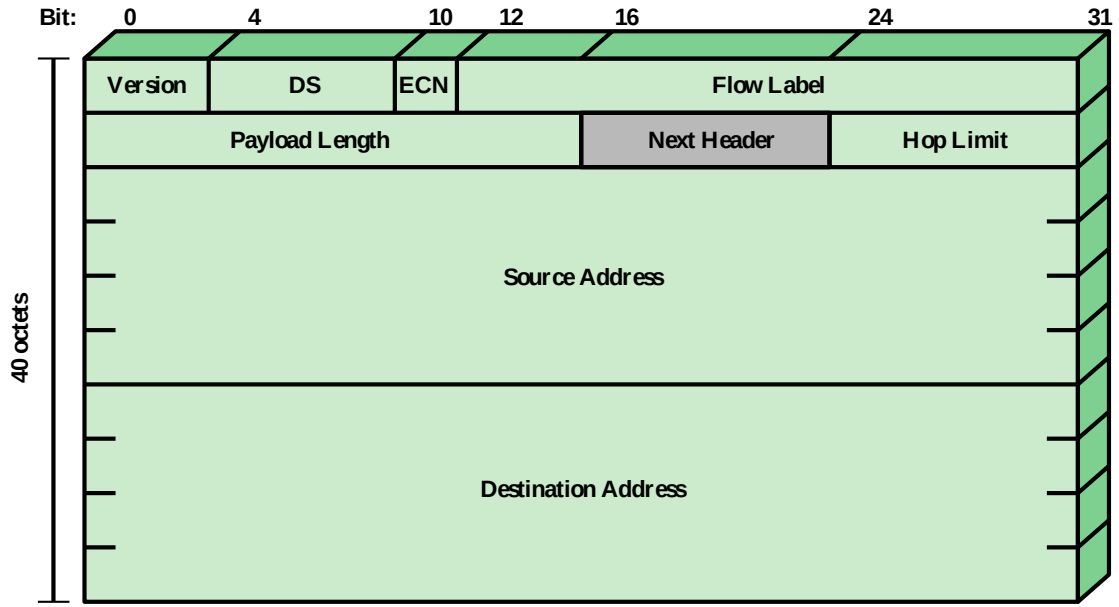
IPv4 s'està quedant sense adreçes, sobretot perquè est'a mal distribuhit

IoT és la justificació per la qual s'hagin reservat tantes @



(a) IPv4 Header

IPv6 header



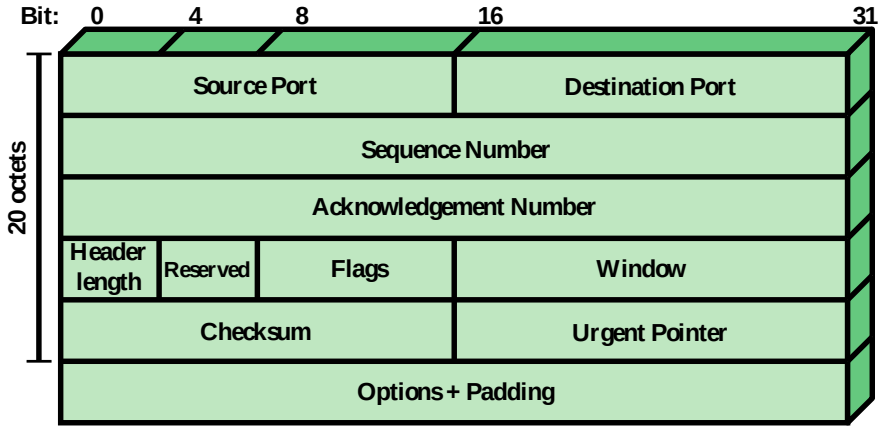
(b) IPv6 Header

DS = Differentiated services field
ECN = Explicit congestion notification field

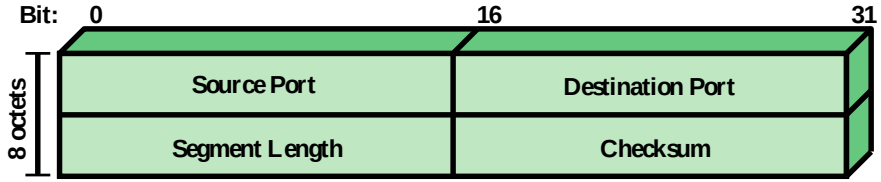
Note: The 8-bit DS/ECN fields were formerly known as the Type of Service field in the IPv4 header and the Traffic Class field in the IPv6 header.

Figure 2.7 IP Headers

TCP/UDP headers



(a) TCP Header

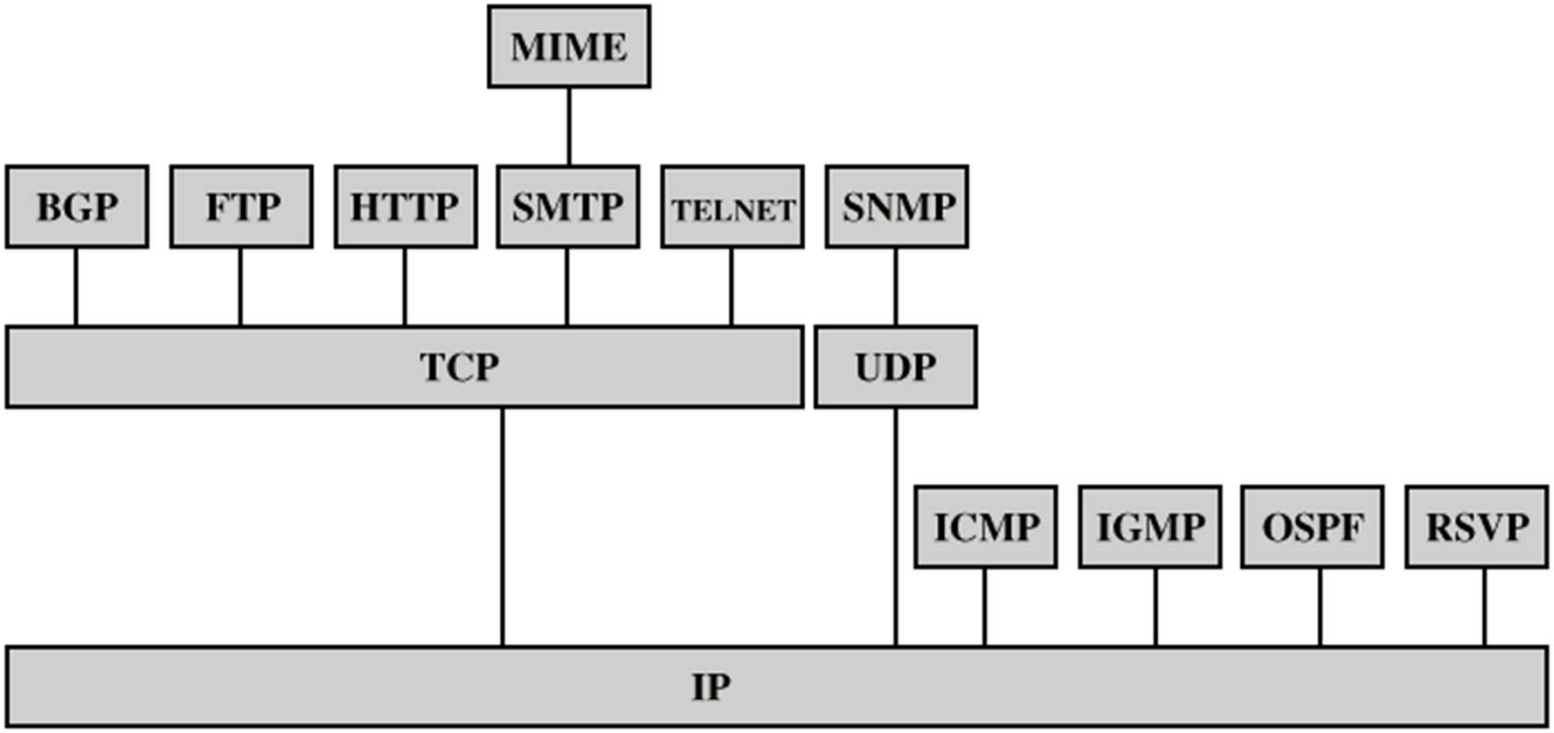


(b) UDP Header

Figure 2.6 TCP and UDP Headers

UDP a diferència de TCP és que UDP no controla erors.
UDP millora el "rendiment"

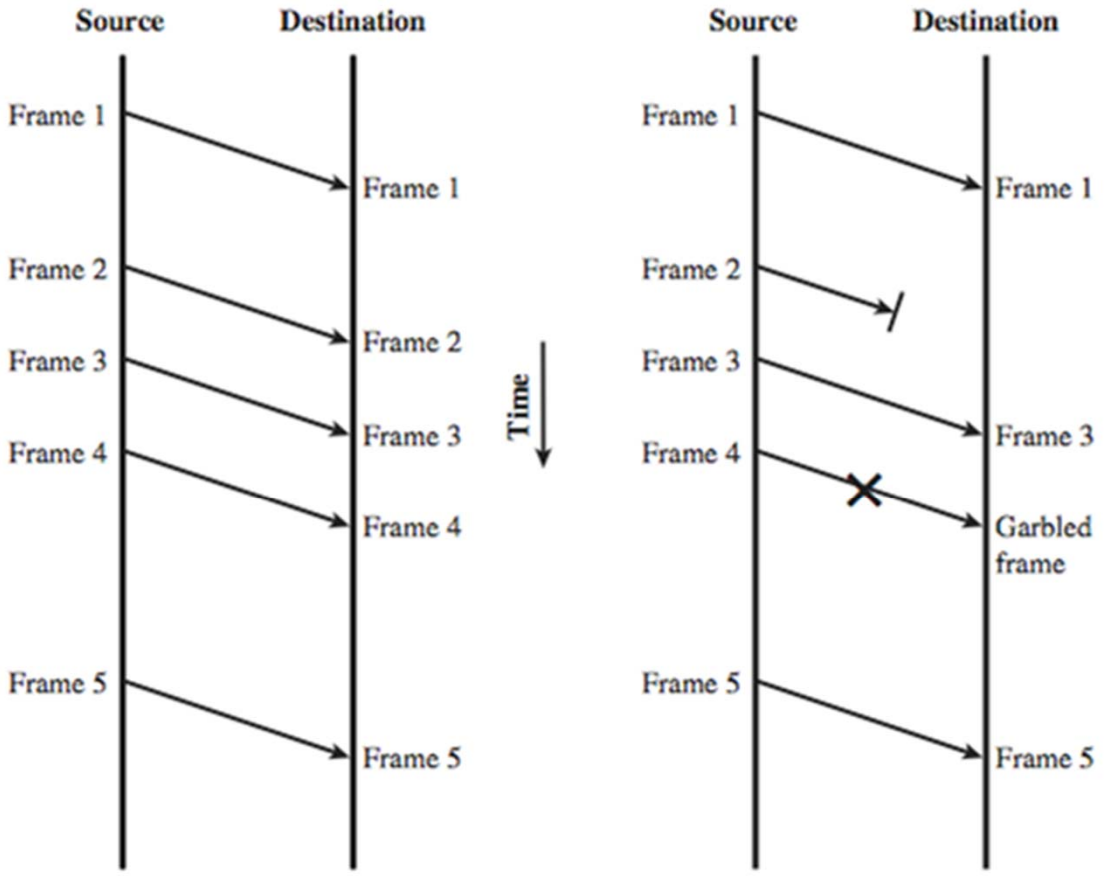
TCP/IP Protocols



BGP = Border Gateway Protocol
FTP = File Transfer Protocol
HTTP = Hypertext Transfer Protocol
ICMP = Internet Control Message Protocol
IGMP = Internet Group Management Protocol
IP = Internet Protocol
MIME = Multi-Purpose Internet Mail Extension
OSPF = Open Shortest Path First
RSVP = Resource ReSerVation Protocol
SMTP = Simple Mail Transfer Protocol
SNMP = Simple Network Management Protocol
TCP = Transmission Control Protocol
UDP = User Datagram Protocol

2.2 Protocols control d'enllaç

Model of Frame Transmission

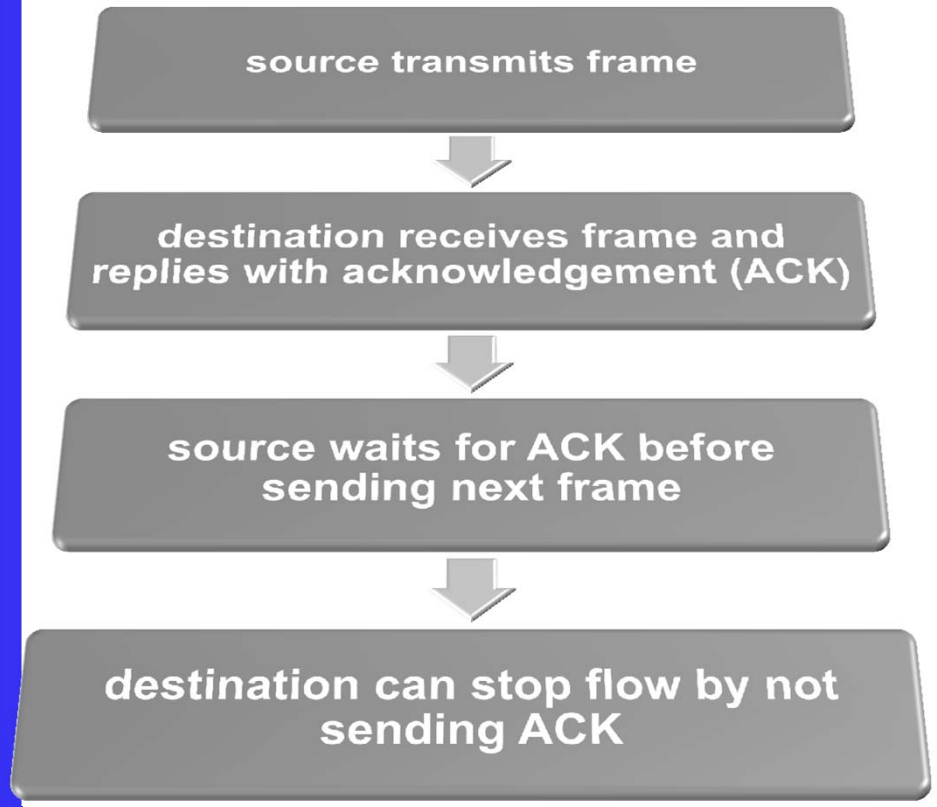


(a) Error-free transmission

(b) Transmission with losses and errors

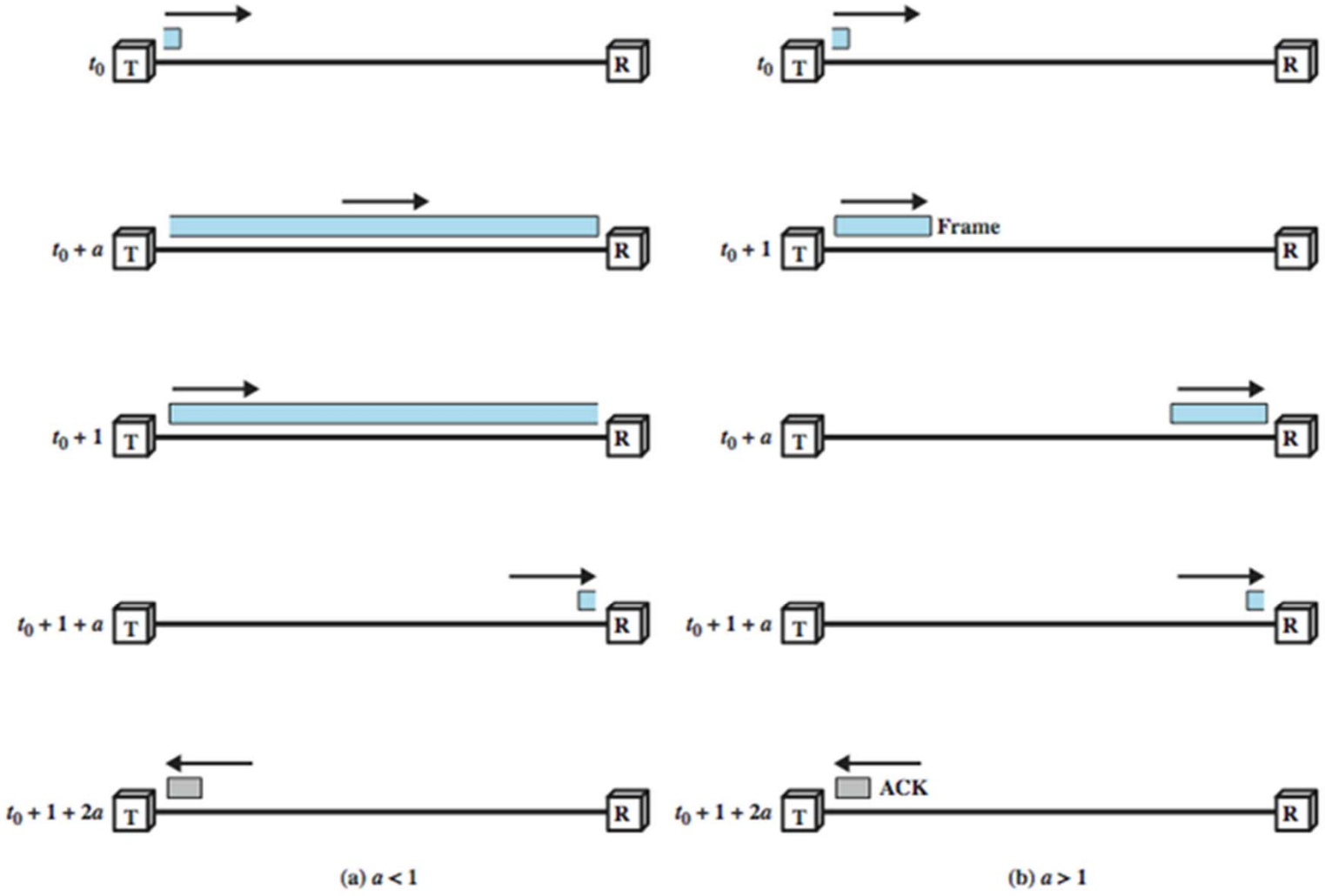
Stop and Wait

- simplest form of flow control

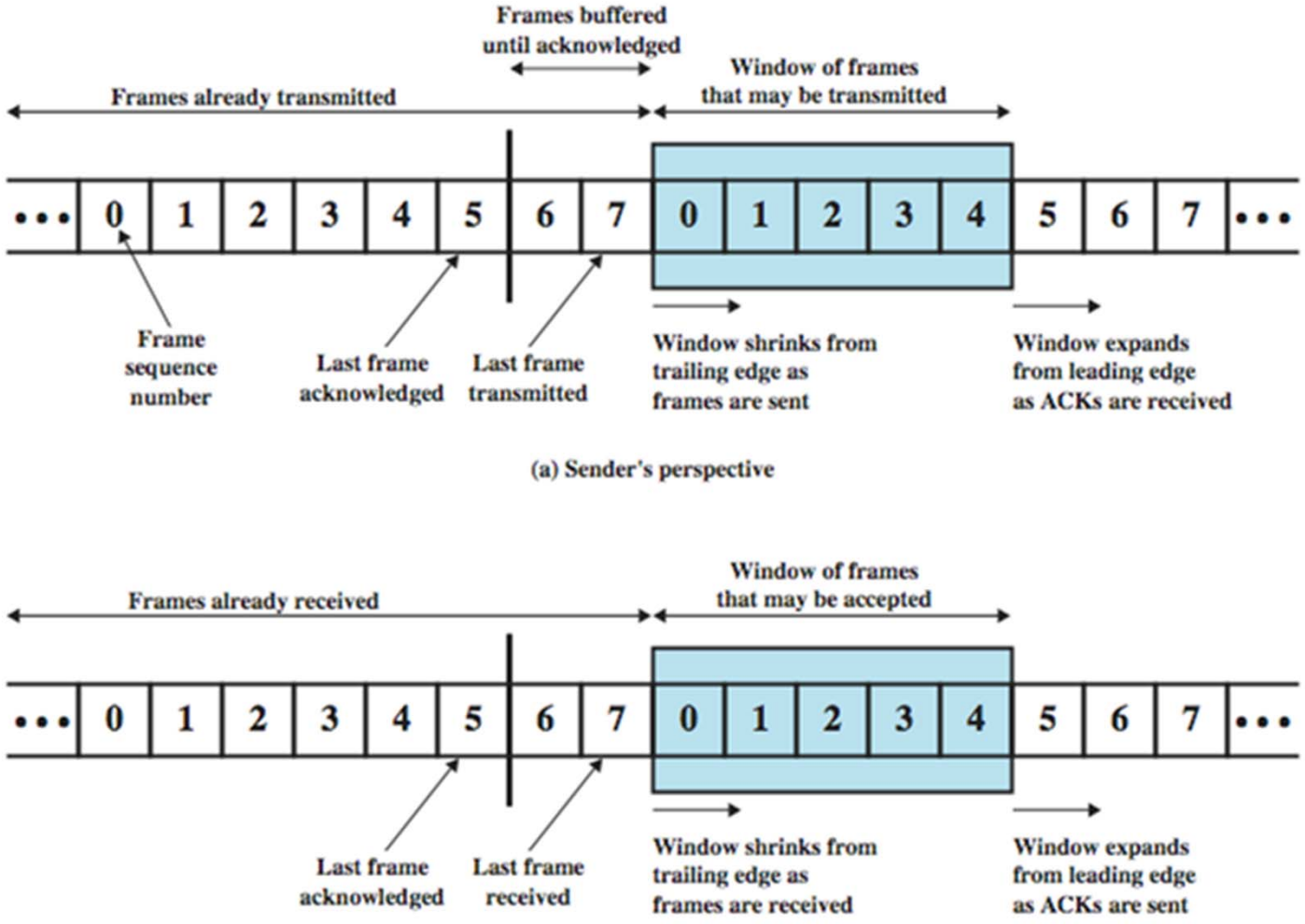


- works well for a message sent in a few large frames
  - stop and wait becomes inadequate if large block of data is split into small frames by source

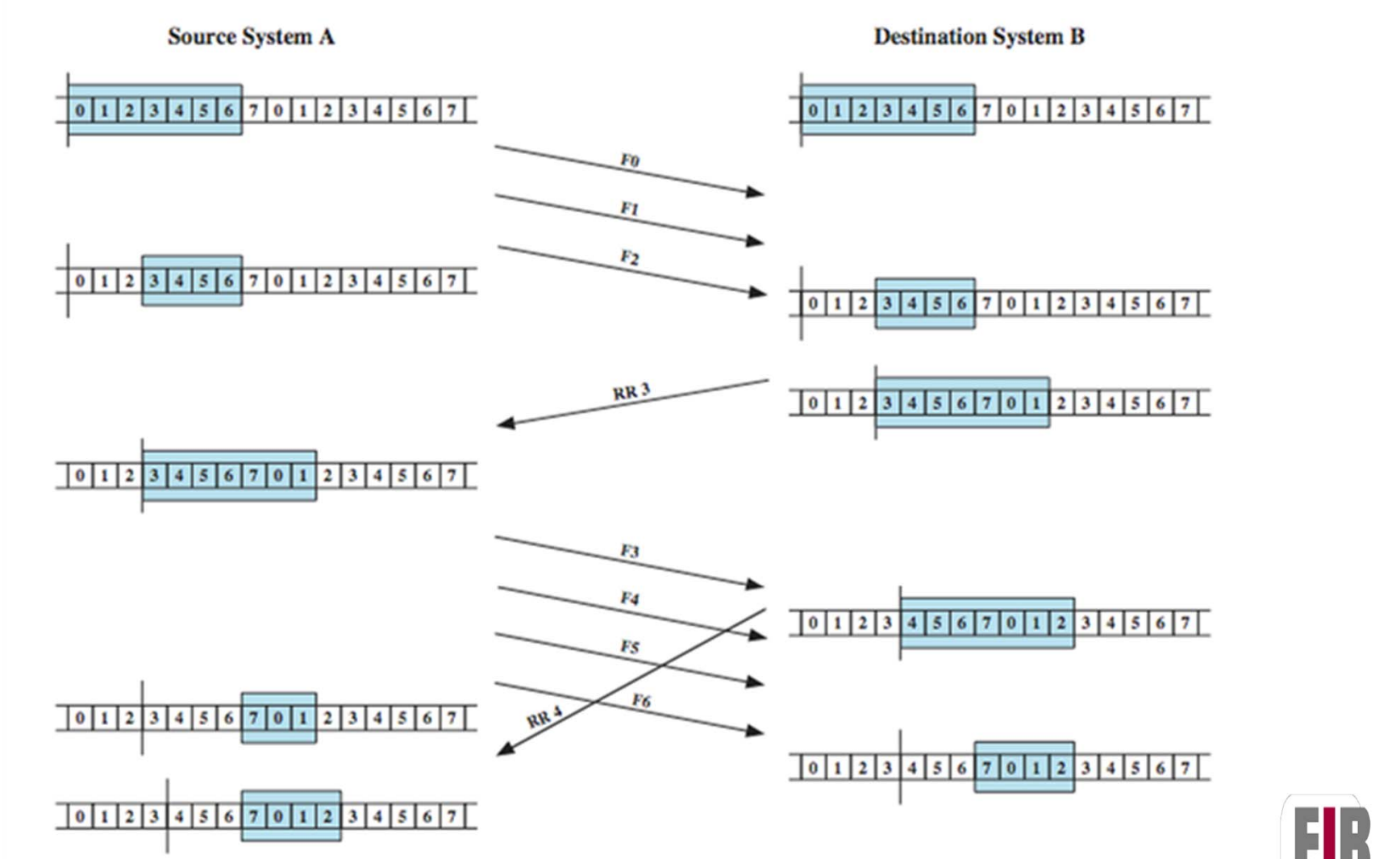
Stop and Wait Link Utilization



Sliding Window Diagram



Sliding Window Example



High Level Data Link Control (HDLC)

most important data link control protocol

- specified as ISO 3009, ISO 4335
- basis for other data link control protocols

station types:

- Primary - controls operation of link
- Secondary - under control of primary station
- Combined - issues commands and responses

link configurations

- Unbalanced - 1 primary, multiple secondary
- Balanced - 2 combined stations

HDLC Transfer Modes

Normal Response Mode (NRM)

- used with an unbalanced configuration
- primary initiates transfer

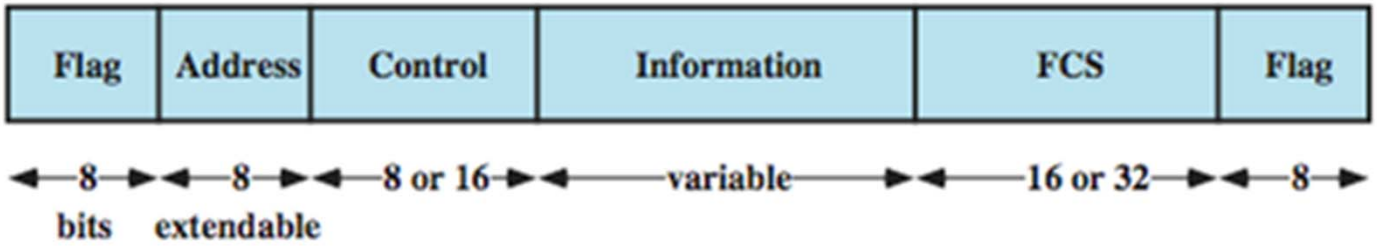
Asynchronous Balanced Mode (ABM)

- used with a balanced configuration
- either station initiates transmission
- has no polling overhead
- most widely used

Asynchronous Response Mode (ARM)

- used with unbalanced configuration
- secondary may transmit without permission from primary
- rarely used

HDLC Frame Structure



(a) Frame format

- uses synchronous transmission
- transmissions are in the form of frames
- single frame format used

Flag Fields and Bit Stuffing

- delimit frame at both ends with 01111110
- receiver hunts for flag sequence to synchronize
- bit stuffing used to avoid confusion with data containing flag sequence 01111110
  - 0 inserted after every sequence of five 1s
  - if receiver detects five 1s it checks next bit
  - if next bit is 0, it is deleted (was stuffed bit)
  - if next bit is 1 and seventh bit is 0, accepted as flag
  - if sixth and seventh bits 1, sender is indicating abort

Original Pattern:

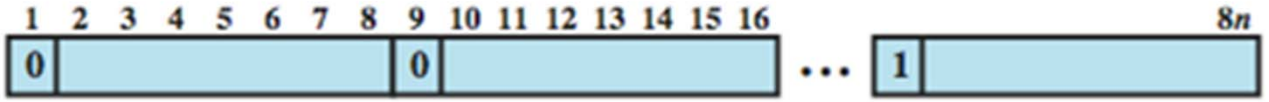
111111111111011111101111110

After bit-stuffing

111110111110110111110**0**1011111010

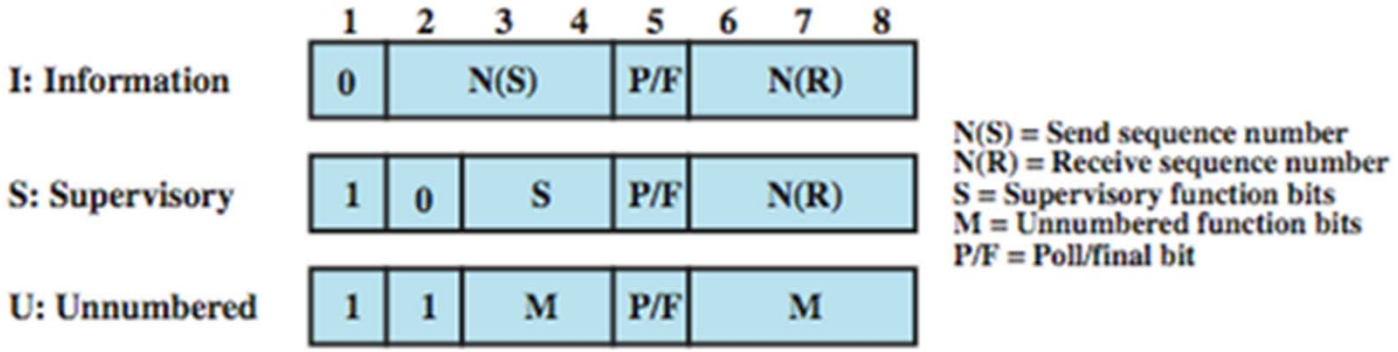
Address Field

- identifies secondary station that transmitted or will receive frame
- usually 8 bits long
- may be extended to multiples of 7 bits
  - leftmost bit indicates if is the last octet (1) or not (0)
- address 11111111 allows primary to broadcast



(b) Extended Address Field

Control Field

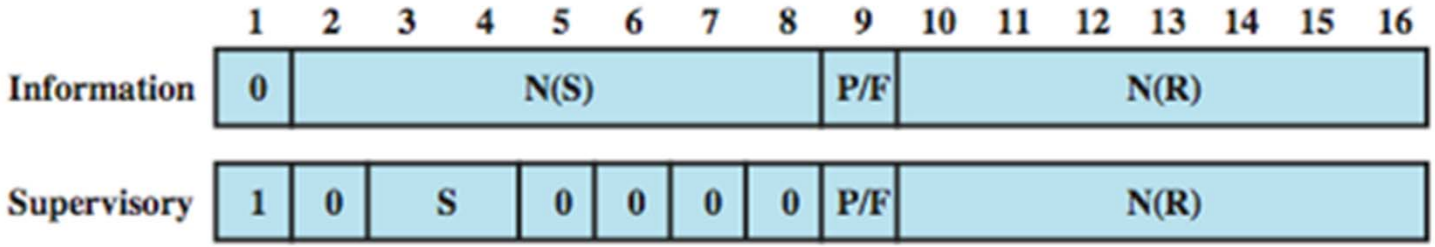


(c) 8-bit control field format

- different frame types
  - Information - data transmitted to user (next layer up)
    - *flow and error control piggybacked on information frames*
  - Supervisory - ARQ when piggyback is not used
  - Unnumbered - supplementary link control functions
- first 1-2 bits of control field identify frame type

Control Field

- use of Poll/Final (P/F) bit depends on context
- in command frame P bit set to 1 to solicit (poll) response from peer
- in response frame F bit set to 1 to indicate response to soliciting command
- sequence number usually 3 bits
  - can extend to 8 bits as shown below



(d) 16-bit control field format

Information and Frame Check Sequence (FCS) Fields

Information Field

- **in I-frames and some U-frames**
- **must contain integral number of octets**
- **variable length**

Frame Check Sequence Field (FCS)

- **used for error detection**
- **either 16 bit CRC or 32 bit CRC**

HDLC Operation

- consists of exchange of I-frames, S-frames and U-frames
- involves three phases

Initialization	Data Transfer	Disconnect
• either side may request by issuing one of the six set-mode commands	• with flow and error control • using both I and S-frames (RR, RNR, REJ, SREJ)	• when fault noted or at request of higher-layer user • sends a disconnect (DISC) frame

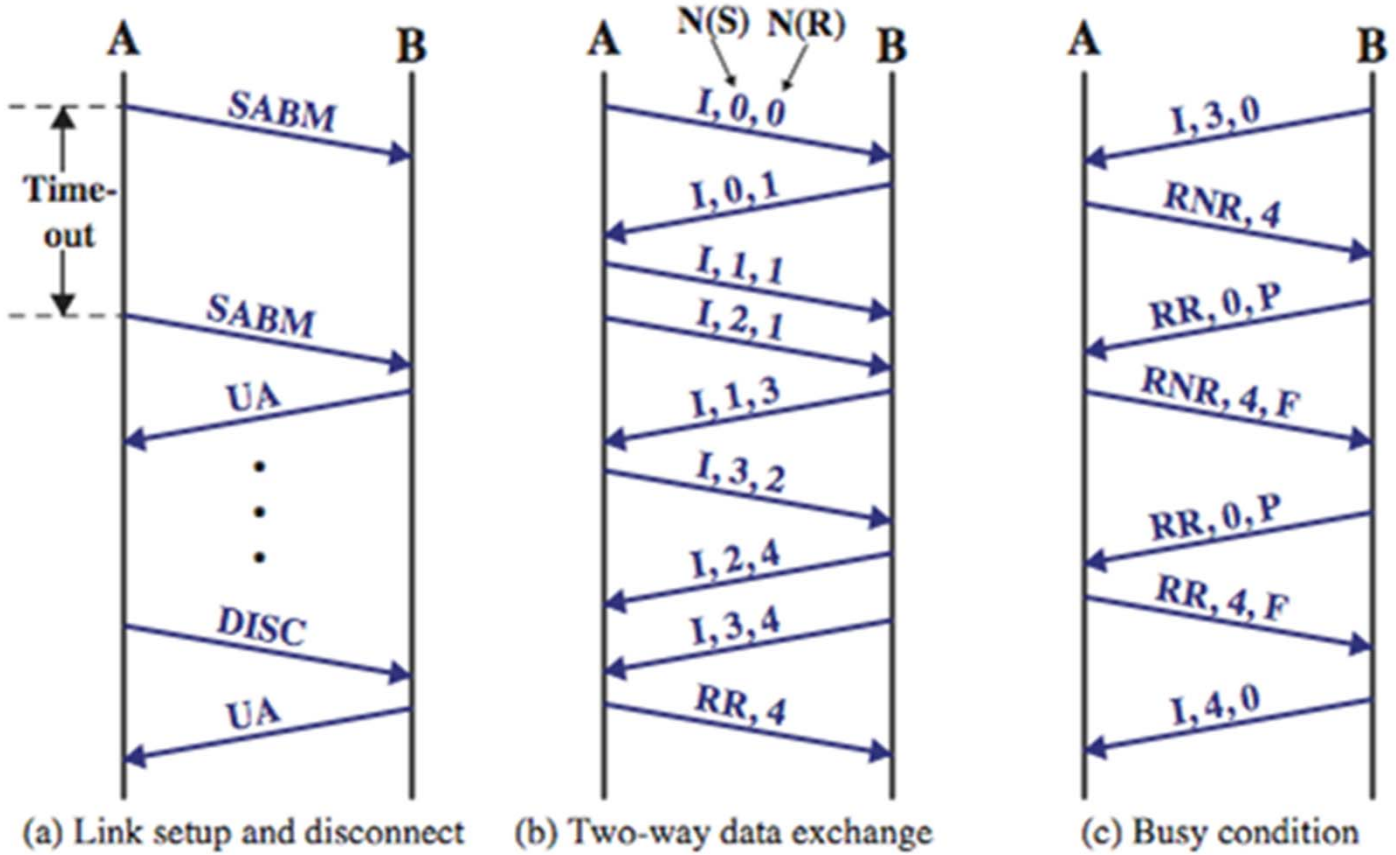
Commands and Responses (1)

Name	Command/ Response	Description
Information (I)	C/R	Exchange user data
Supervisory (S)		
Receive ready (RR)	C/R	Positive acknowledgment; ready to receive I-frame
Receive not ready (RNR)	C/R	Positive acknowledgment; not ready to receive
Reject (REJ)	C/R	Negative acknowledgment; go back N
Selective reject (SREJ)	C/R	Negative acknowledgment; selective reject

Commands and Responses (2)

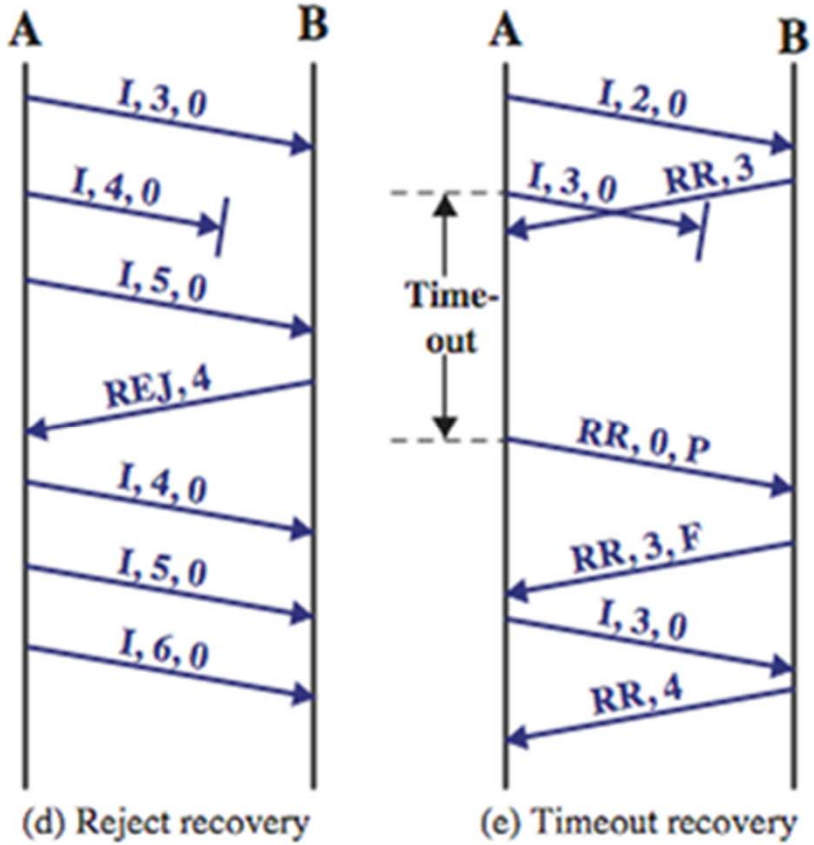
Unnumbered (U)		
Set normal response/extended mode (SNRM/SNRME)	C	Set mode; extended = 7-bit sequence numbers
Set asynchronous response/extended mode (SARM/SARME)	C	Set mode; extended = 7-bit sequence numbers
Set asynchronous balanced/extended mode (SABM, SABME)	C	Set mode; extended = 7-bit sequence numbers
Set initialization mode (SIM)	C	Initialize link control functions in addressed station
Disconnect (DISC)	C	Terminate logical link connection
Unnumbered Acknowledgment (UA)	R	Acknowledge acceptance of one of the set-mode commands
Disconnected mode (DM)	R	Responder is in disconnected mode
Request disconnect (RD)	R	Request for DISC command
Request initialization mode (RIM)	R	Initialization needed; request for SIM command
Unnumbered information (UI)	C/R	Used to exchange control information
Unnumbered poll (UP)	C	Used to solicit control information
Reset (RSET)	C	Used for recovery; resets N(R), N(S)
Exchange identification (XID)	C/R	Used to request/report status
Test (TEST)	C/R	Exchange identical information fields for testing
Frame reject (FRMR)	R	Report receipt of unacceptable frame

HDLC Operation Example



(a) Link setup and disconnect (b) Two-way data exchange (c) Busy condition

HDLC Operation Example



(d) Reject recovery (e) Timeout recovery

2.3 Mitjans de transmissió

Frequency, Spectrum and Bandwidth

Time Domain Concepts

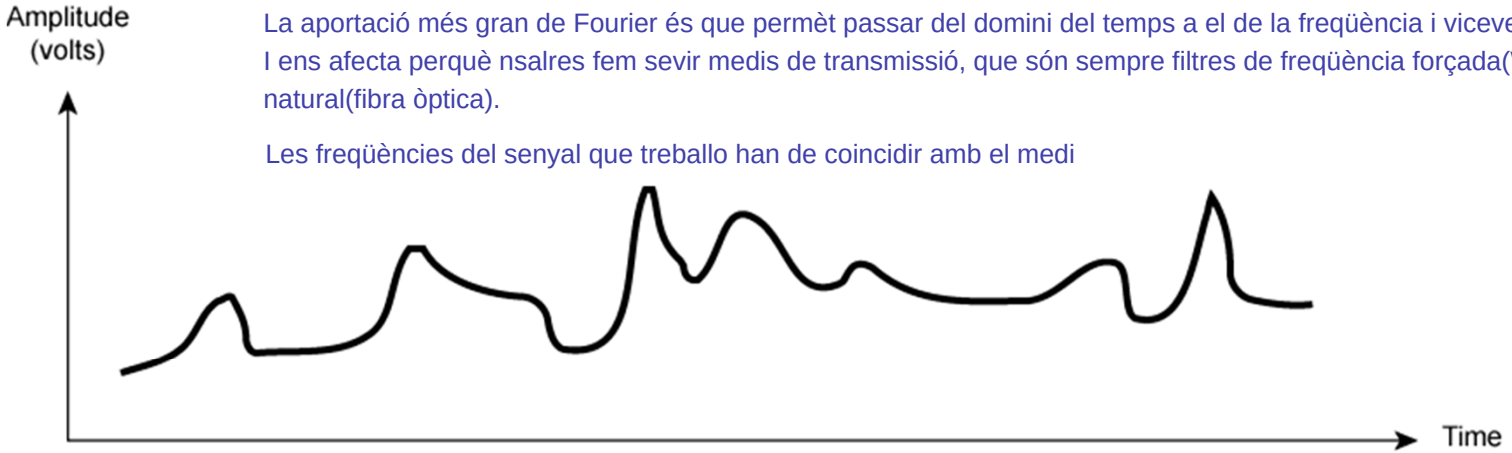
- **analog signal** passa progressivament en el temps d'un valor a un altre
  - *signal intensity varies smoothly with no breaks*
- **digital signal** passa bruscament d'un valor a un altre (ex: de 0 a 1 sense 0.5 i tal)
  - *signal intensity maintains a constant level and then abruptly changes to another level*
- **periodic signal**
  - *signal pattern repeats over time*
- **aperiodic signal**
  - *pattern not repeated over time*

la teoiria de Fourier distingeix entre seyals periòdics i no periodics

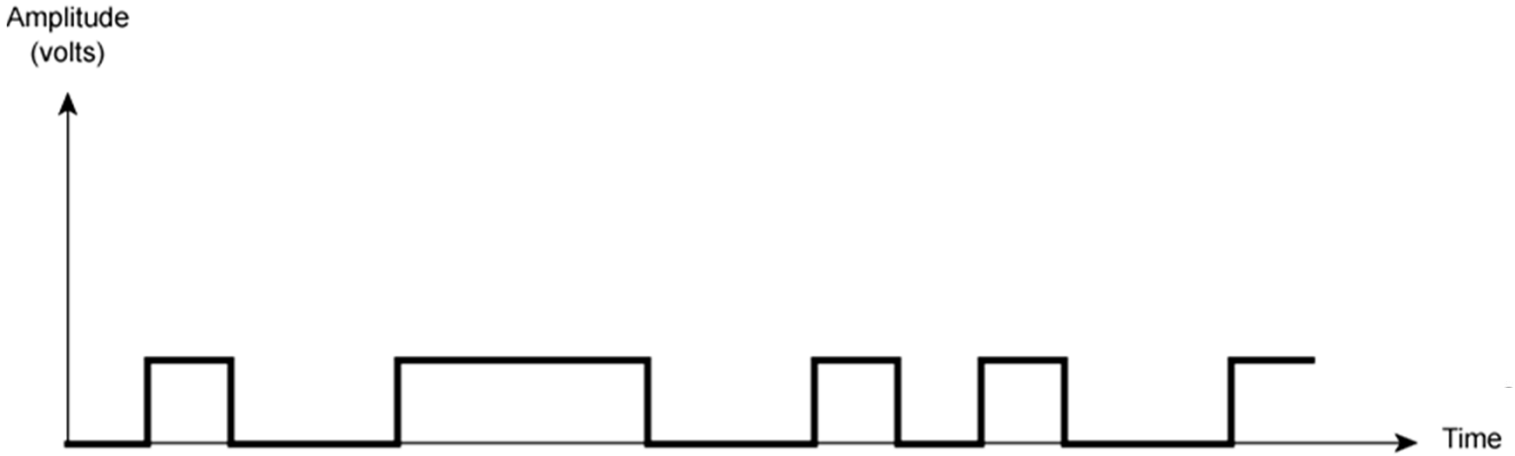
Analog and Digital Signals

La aportació més gran de Fourier és que permèt passar del domini del temps a el de la freqüència i viceversa.
I ens afecta perquè nsalres fem sevir medis de transmissió, que són sempre filtres de freqüència forçada(WiFi, o la telefonia mòbil) o natural(fibra òptica).

Les freqüències del senyal que treballo han de coincidir amb el medi



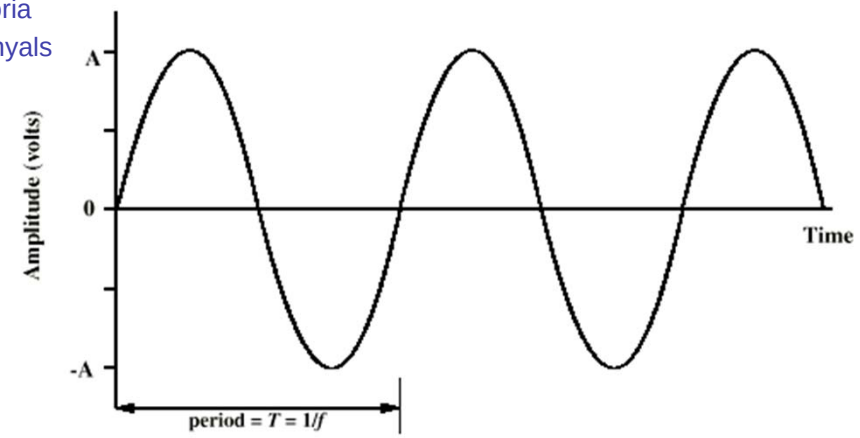
(a) Analog



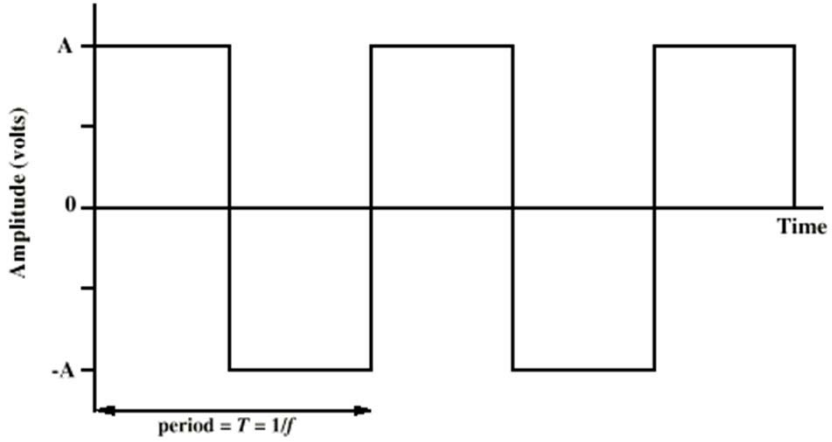
(b) Digital

Periodic Signals

Són la millor manera per entendre la teoria però en realitat mai treballarem amb senyals no periòdics.



(a) Sine wave



(b) Square wave

Sine Wave

a la natura tot tendeix a seguir una senyal sinusoidal

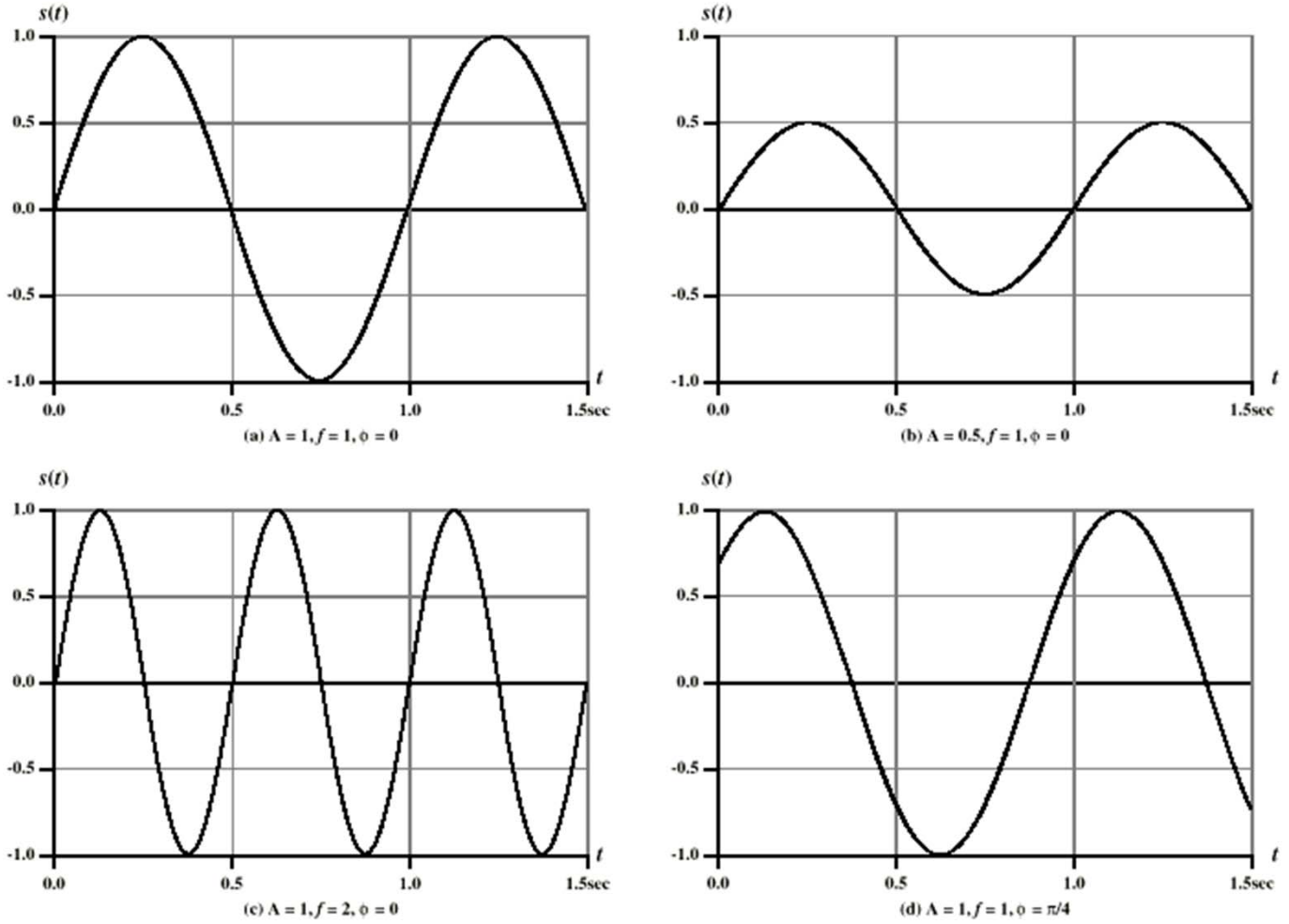
(periodic continuous signal)

- **peak amplitude (A)**
  - maximum strength of signal
  - typically measured in volts
- **frequency (f)** nombre de vegades que es repeteix en un periode de temps
  - rate at which the signal repeats
  - Hertz (Hz) or cycles per second
  - period (T) is the amount of time for one repetition
  - T = 1/f
- **phase (ϕ)**
  - relative position in time within a single period of signal

Varying Sine Waves

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

els receptors estàn sintonitzats a unes freqüències determinades, i igoren les altres



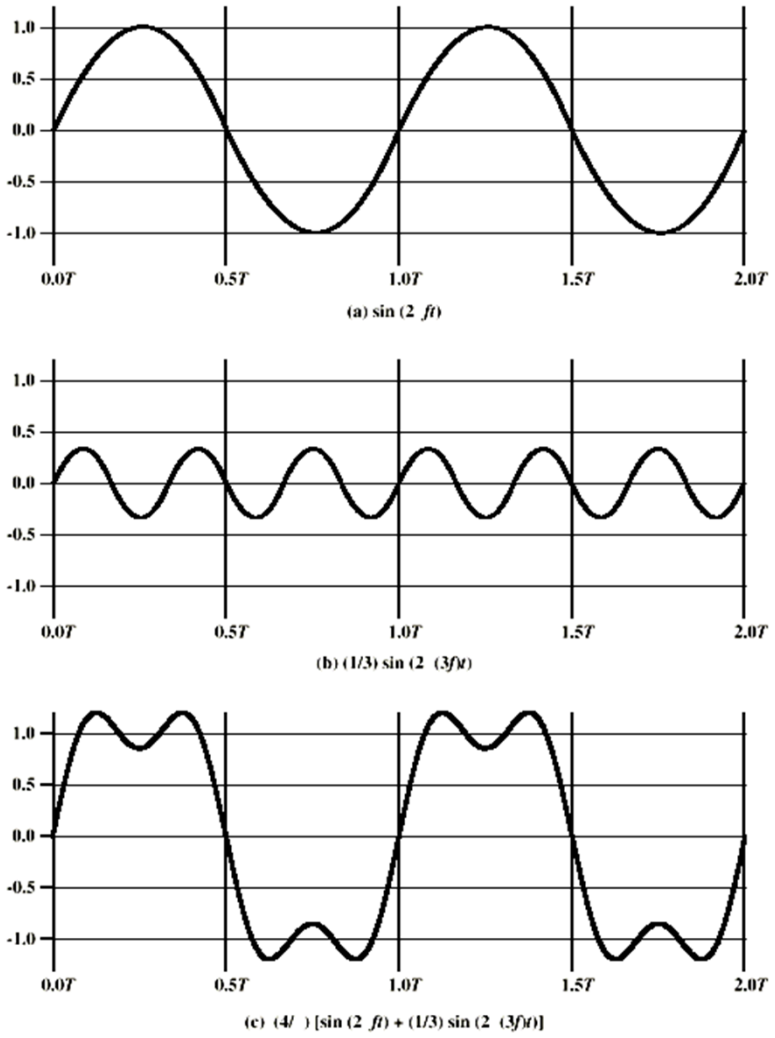
+ freq = + velocitat de transmissió

Frequency Domain Concepts

- signals are made up of many frequencies
- components are sine waves (tons purs)
- Fourier analysis can show that any signal is made up of components at various frequencies, in which each component is a sinusoid
- can plot frequency domain functions

Addition of Frequency Components (T=1/f)

c is sum of *f & 3f*

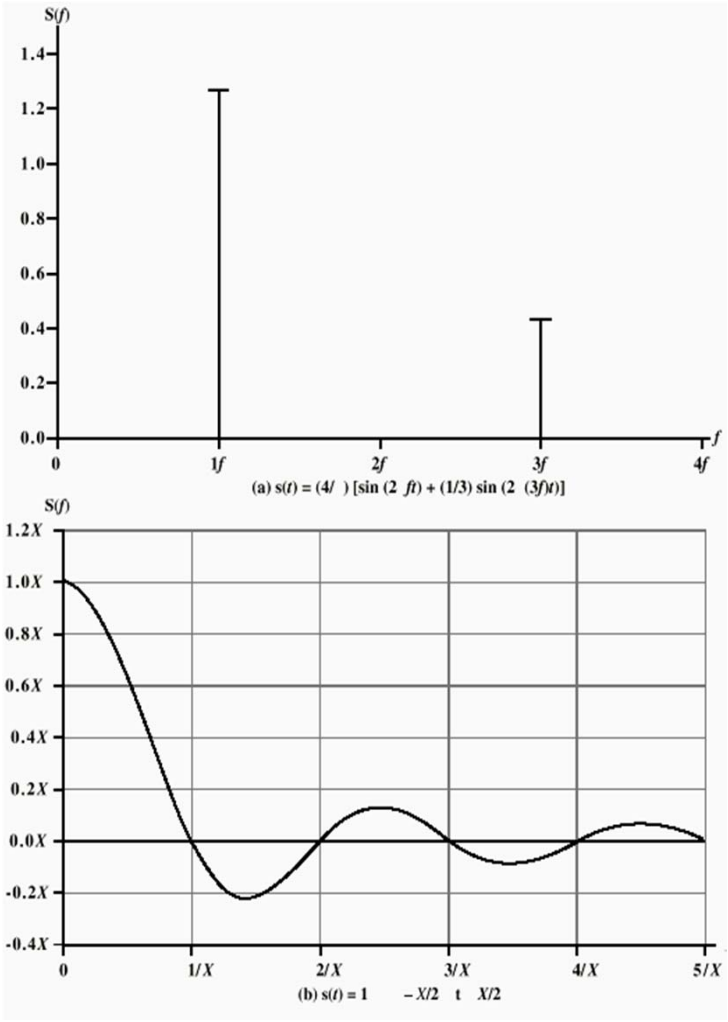


en senyals periodics : la freqüencia fonamental és l'invers del periode, i la resta de freqüències són múltiples de la freq fonamental (full1)

Fourier ens permet anaitzar la requencia tante de senyals contínus, com no continus, com codis

Frequency Domain Representations

- frequency domain function of Fig 3.4c
- frequency domain function of single square pulse



Spectrum & Bandwidth

spectrum

- *range of frequencies contained in signal*

absolute bandwidth

- *width of spectrum*

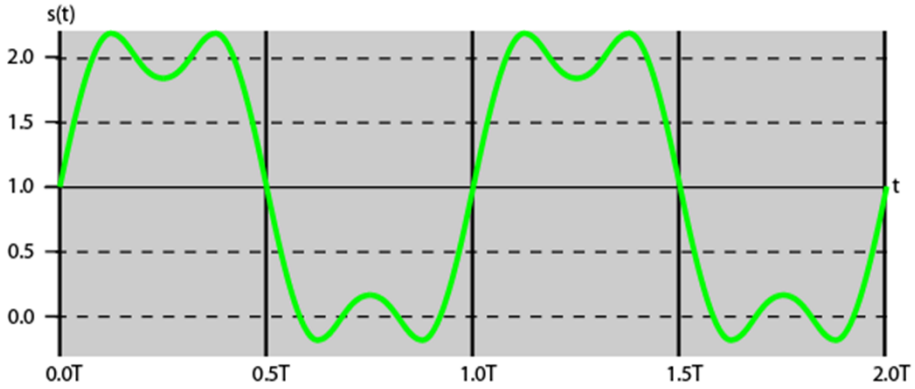
effective bandwidth

- *often just bandwidth*
- *narrow band of frequencies containing most energy*

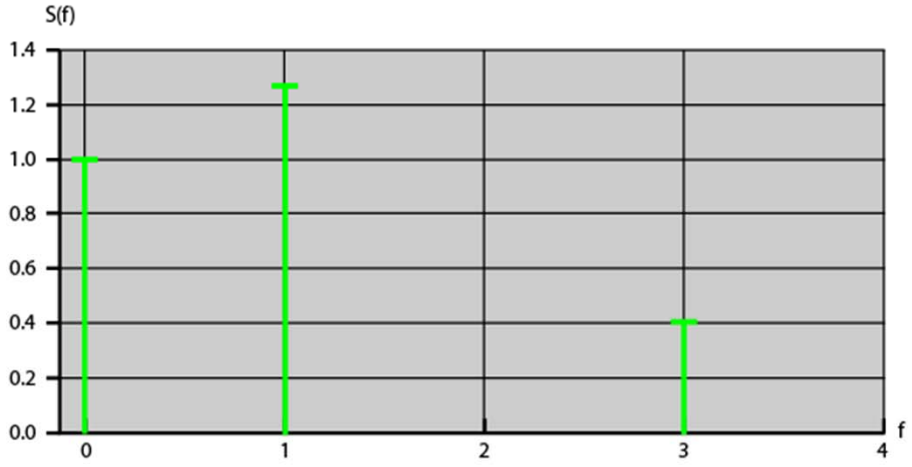
dc component

- *component of zero frequency*

Signal with dc Component



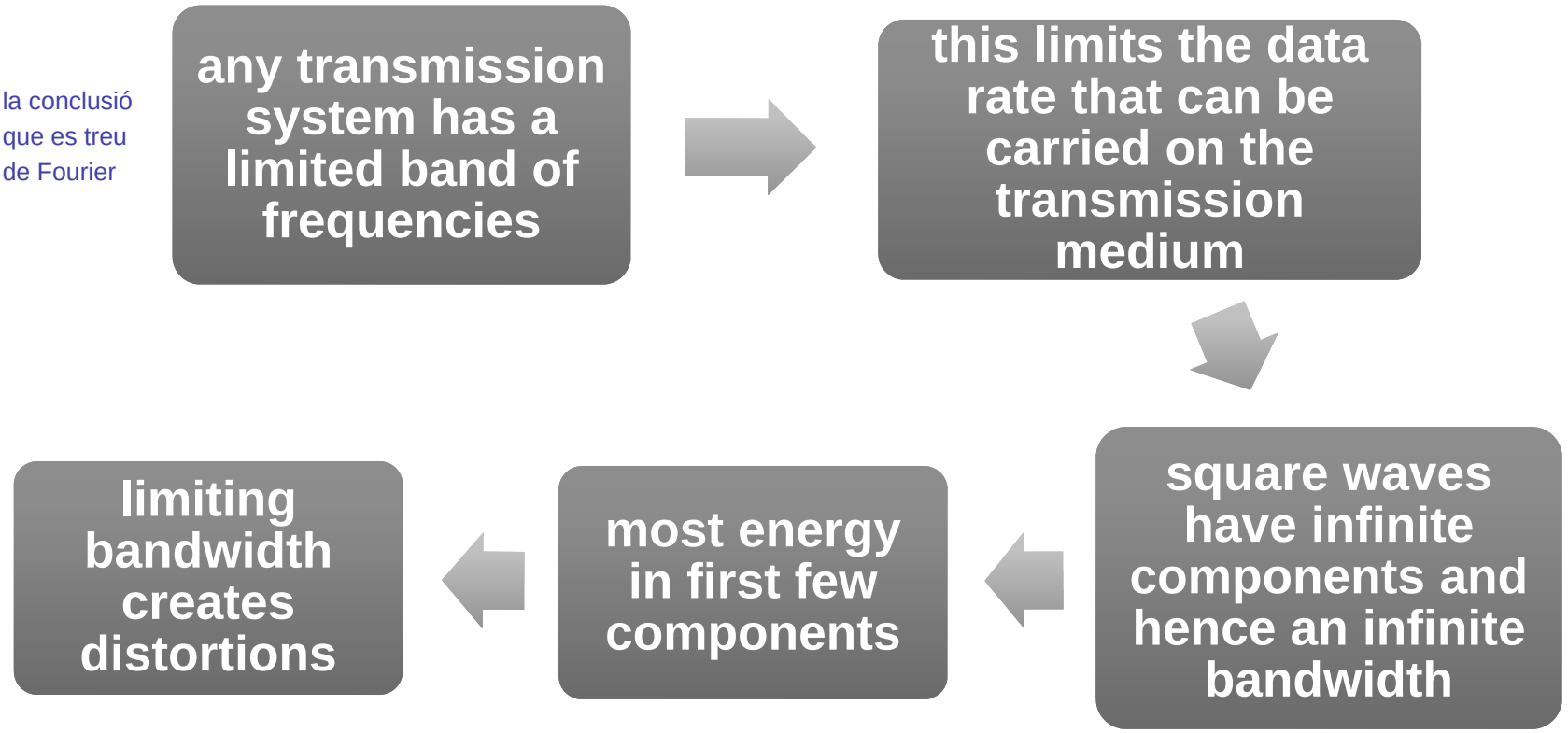
(a) $s(t) = 1 + (4/p)\,[\sin(2pft) + (1/3)\sin(2p(3f)t)]$



(b) S(f)

Data Rate and Bandwidth

la conclusió que es treu de Fourier

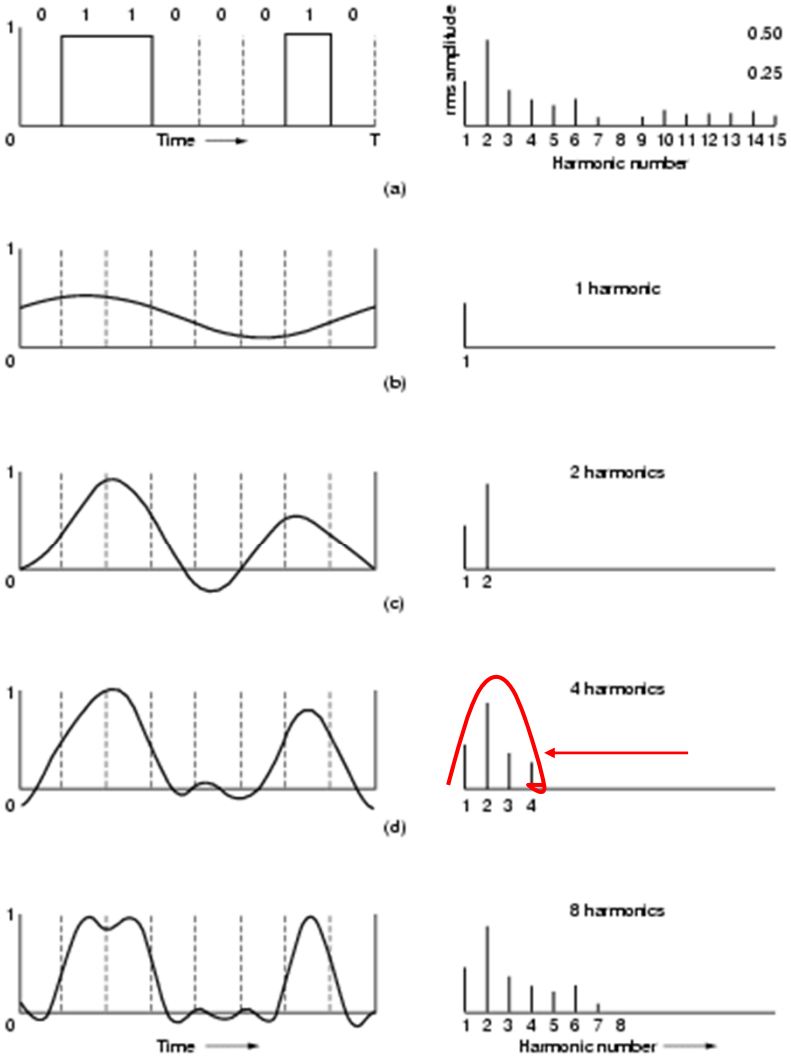


There is a direct relationship between data rate and bandwidth.

Example spectral analysis

"només es representa la part positiva perquè no existeixen freqs negatives"

señal original -->



cada cop van passant més freqs i cada cop s'assembla més a l'original.

+freq --> + ample de bnda

per exemple aquí amb 4 freqs ja m'aniria bé

Design Factors Determining Data Rate and Distance

bandwidth

- **higher bandwidth gives higher data rate**

+ ample de banda -->+ velocitat de transmissió

transmission impairments

- **impairments, such as attenuation, limit the distance**

limitacions dels mitjans de transmissió

interference

- **overlapping frequency bands can distort or wipe out a signal**

només té sentit en el punt de recepció: que rep senyal de diferents fonts a la mateixa freq.

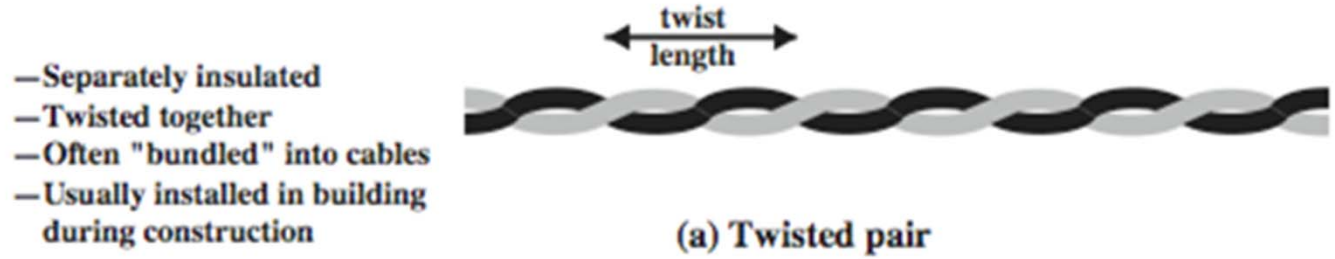
number of receivers

- **more receivers introduces more attenuation**

ypus de mitjans de medis de transmissió

Twisted Pair

EL fet de cargolar-lo fa que per "algún fenòmen físic", augmenti l'ample de banda màxim



Twisted pair is the least expensive and most widely used guided transmission medium.

- **consists of two insulated copper wires arranged in a regular spiral pattern**
- **a wire pair acts as a single communication link**
- **pairs are bundled together into a cable**
- **most commonly used in the telephone network and for communications within buildings**

Unshielded vs. Shielded Twisted Pair

tipus de parells trenats:

Unshielded Twisted Pair (UTP)

+barat

- ordinary telephone wire
- cheapest
- easiest to install
- suffers from external electromagnetic interference

Shielded Twisted Pair (STP)

- has metal braid or sheathing that reduces interference
- provides better performance at higher data rates
- more expensive
- harder to handle (thick, heavy)

porta un malla metàlica que fa 'gàbia de Faraday', perquè no perdi tanta energia degut a radiació

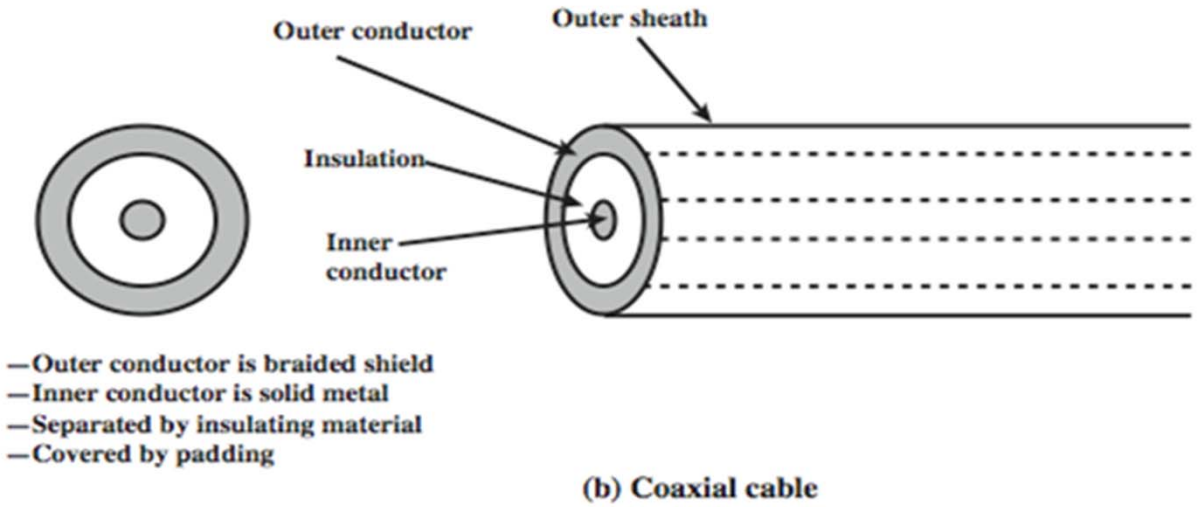
UTP Categories

El qiue diferència les categories, és el nombre de girs que té el coble +cargolat --> més ample de banda

el més econòmic estàndar el més car

	Category 3 Class C	Category 5 Class D	Category 5E	Category 6 Class E	Category 7 Class F
Bandwidth	16 MHz	100 MHz	100 MHz	200 MHz	600 MHz
Cable Type	UTP	UTP/FTP	UTP/FTP	UTP/FTP	SSTP
Link Cost (Cat 5 =1)	0.7	1	1.2	1.5	2.2

Coaxial Cable



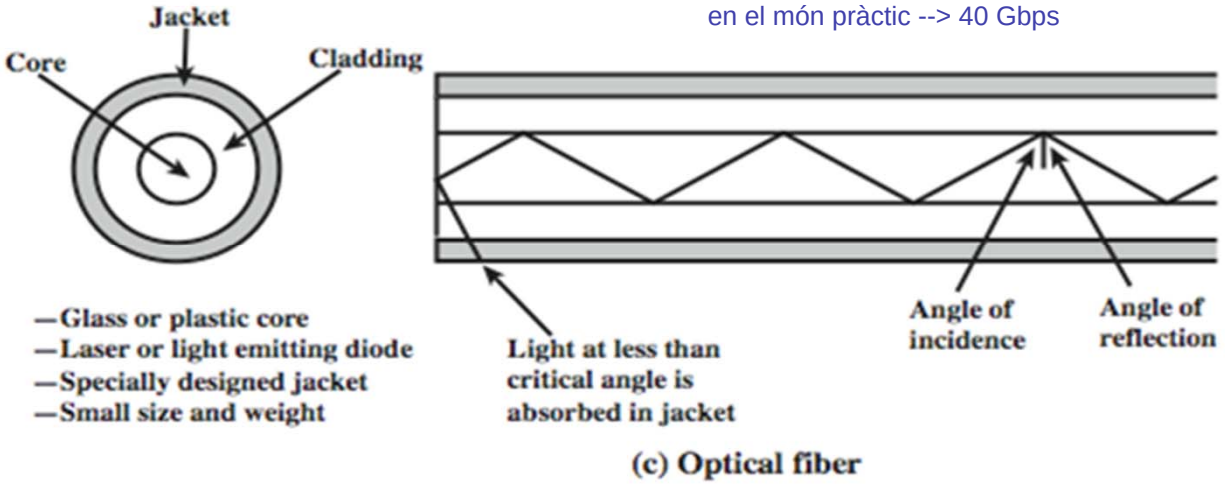
(b) Coaxial cable

Coaxial cable can be used over longer distances and support more stations on a shared line than twisted pair.

- **consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor**
- **is a versatile transmission medium used in a wide variety of applications**
- **used for TV distribution, long distance telephone transmission and LANs**

Optical Fiber

Actualment es pot arribar mab fibra optica són:
en el món exeprimental --> 100 Gbps
en el món pràctic --> 40 Gbps



(c) Optical fiber

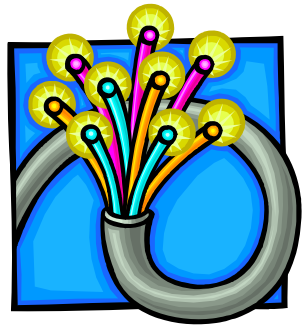
es propaga el senyal per una combinació entre reflexió i refracció

Optical fiber is a thin flexible medium capable of guiding an optical ray.

- **various glasses and plastics can be used to make optical fibers**
- **has a cylindrical shape with three sections – core, cladding, jacket**
- **widely used in long distance telecommunications**
- **performance, price and advantages have made it popular to use**

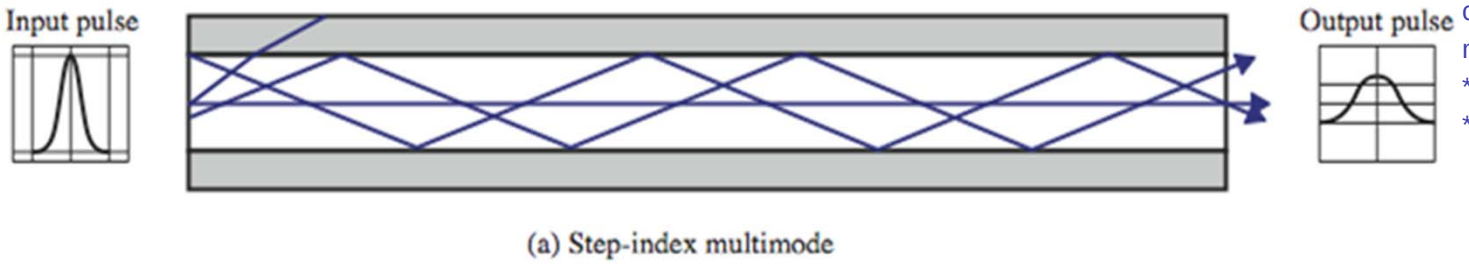
Optical Fiber - Benefits

- greater capacity
  - data rates of hundreds of Gbps (teòricament)
- smaller size and lighter weight
  - considerably thinner than coaxial or twisted pair cable
  - reduces structural support requirements

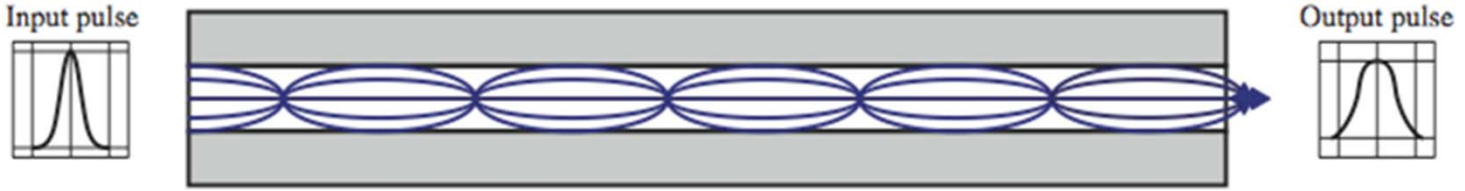


- lower attenuation això vol dir que podem fer tirades llargues sense amplificadors (o amps. cada molt)
- electromagnetic isolation
  - not vulnerable to interference, impulse noise, or crosstalk
  - high degree of security from eavesdropping això fa que es puguin passar per qualsevol lloc: ex vies de tren, on no es podría posar un sistema elèctric.
- greater repeater spacing
  - lower cost and fewer sources of error

Optical Fiber Transmission Modes



(a) Step-index multimode



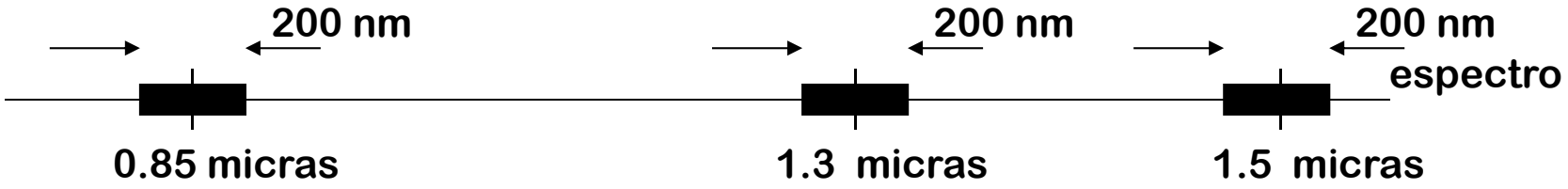
(b) Graded-index multimode

(c) Single mode

canviant el diametre del conductor interior, tenim 2 modes:
* single-mode
* multi-mode

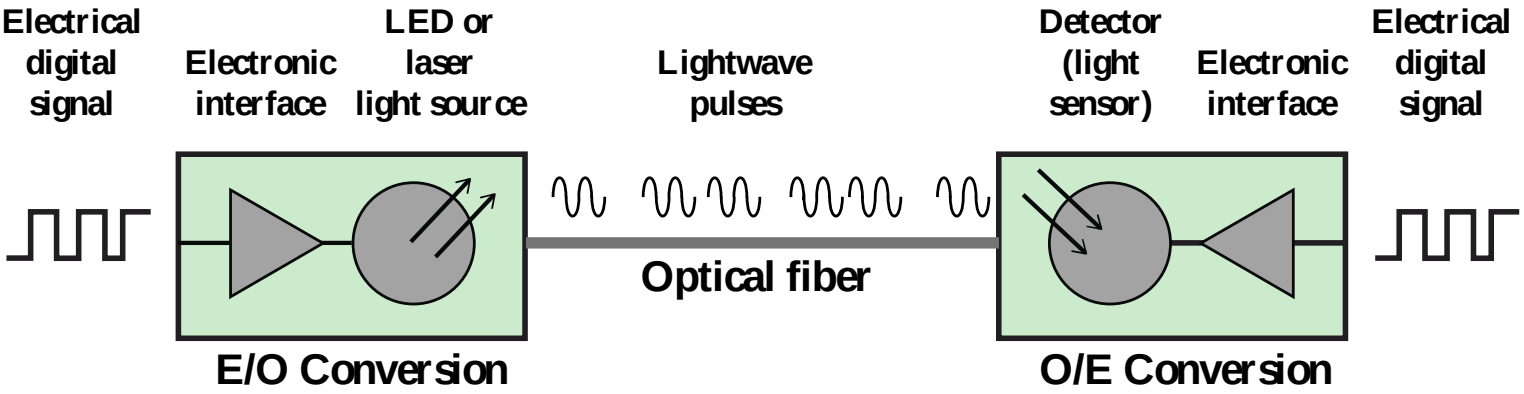
les de les grans operadores són single-mde, perque són molt grans i necessiten menys repetidors.

Frequency Utilization for Fiber Applications



Wavelength (in vacuum) range (nm)	Frequency Range (THz)	Band Label	Fiber Type	Application
820 to 900	366 to 333		Multimode	LAN
1280 to 1350	234 to 222	S	Single mode	Various
1528 to 1561	196 to 192	C	Single mode	WDM
1561 to 1620	192 to 185	L	Single mode	WDM

Optical communication

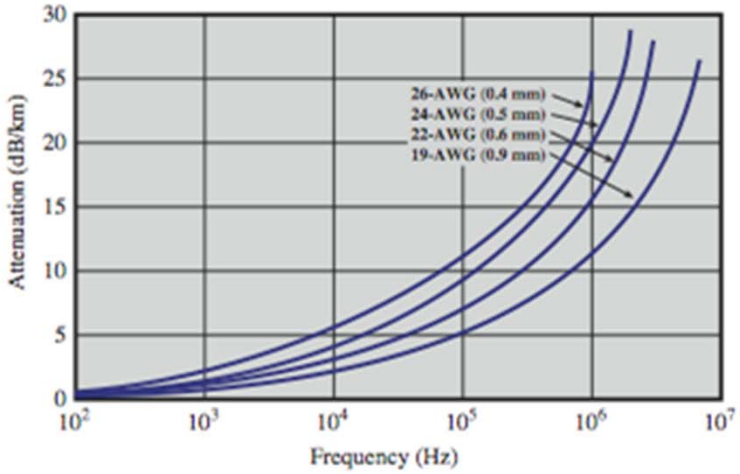


es fan servir diodes emisors i receptors de llum.

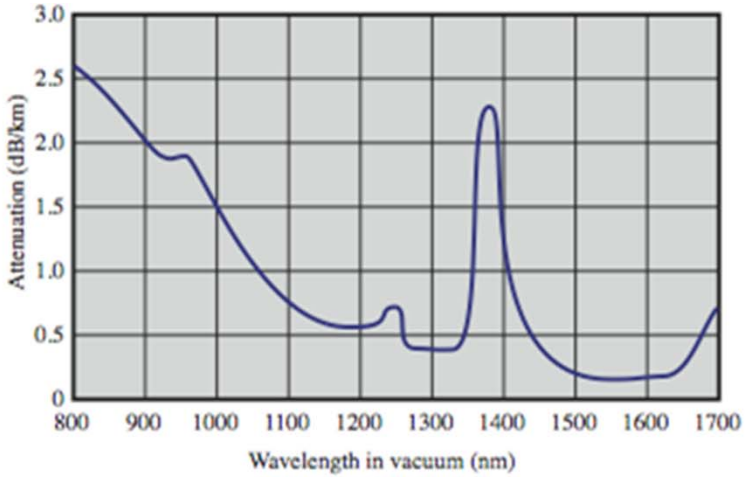
Figure 4.6 Optical Communication

explicació de perquè la fibra òptica nomeés es pot fer servir a unes freqs. APUJNTS

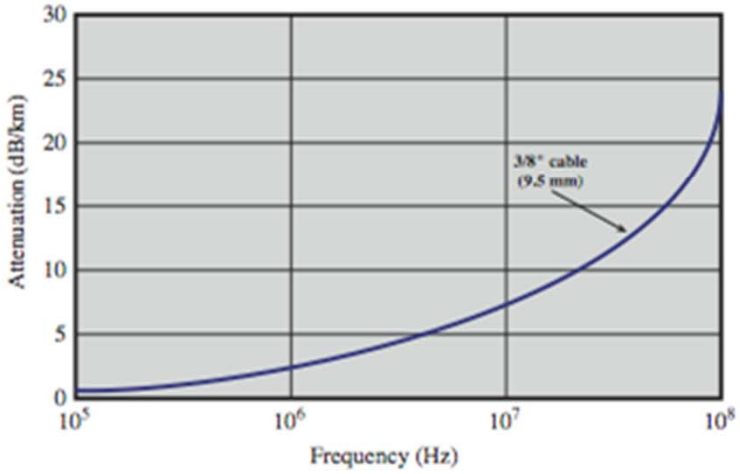
Attenuation in Guided Media



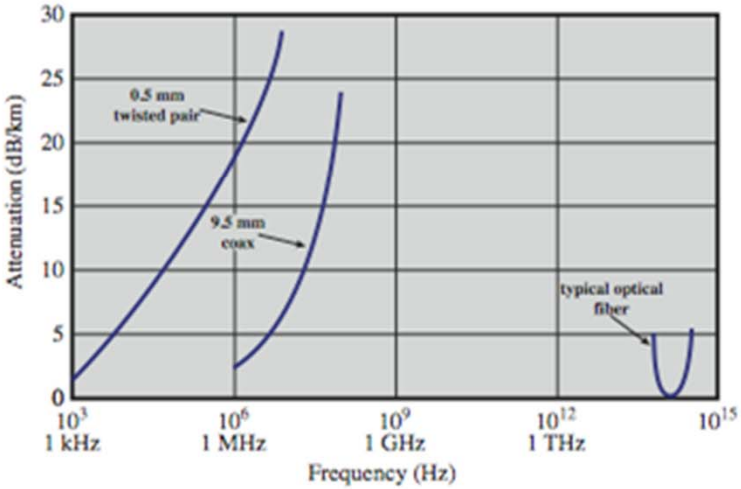
(a) Twisted pair (based on [REEV95])



(c) Optical fiber (based on [FREE02])

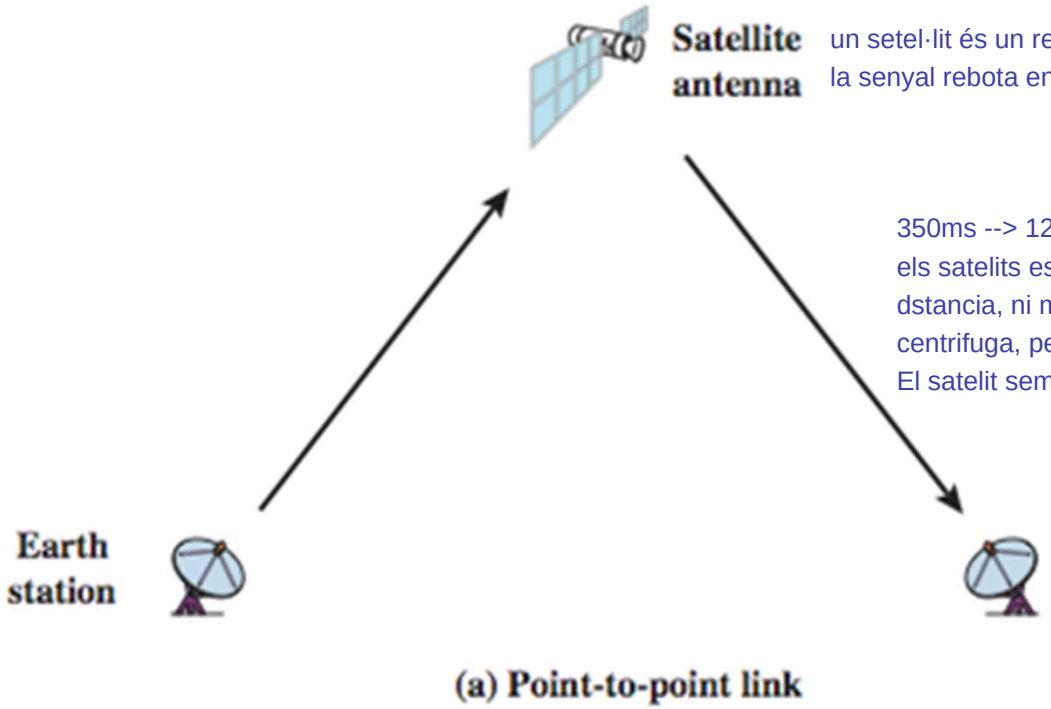


(b) Coaxial cable (based on [BELL90])



(d) Composite graph

Satellite Point-to-Point Link



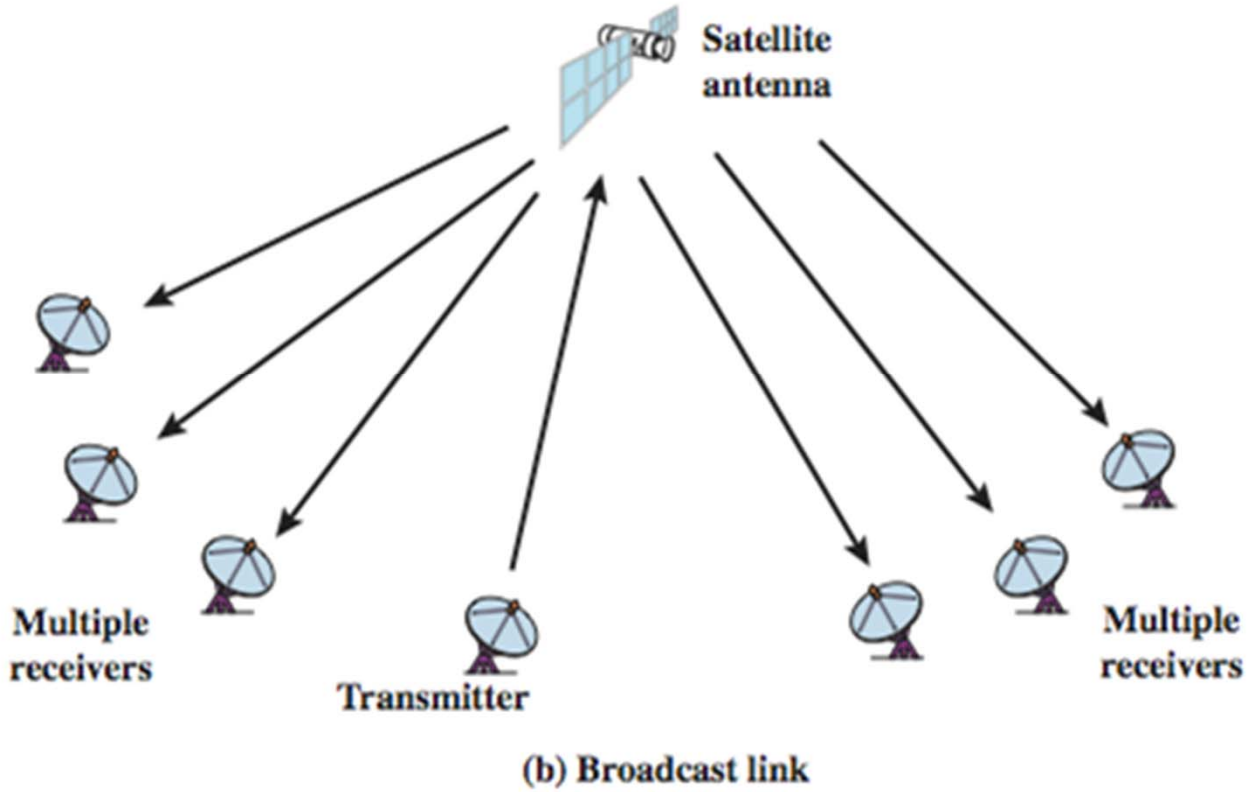
(a) Point-to-point link

un setel·lit és un repetidor.
la senyal rebota en el satelit i torna cap a una altra antena

350ms --> 125ms de pujada i 125 de baixada.
els satelits estan en la orbita geoEstacionaria 36000KM, a aquesta dstancia, ni marxa ni cau. està calculat amb força centrípeta = força centrifuga, per tant, s'anula la massa. ??????
El satelit sempre està al mateix lloc

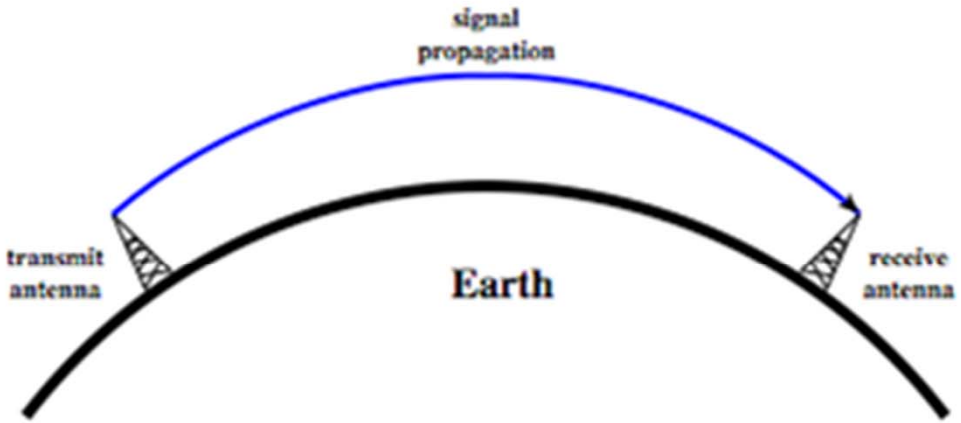
Satellite Broadcast Link

un satelit cubreix 120 graus de corbatura de la terra.



(b) Broadcast link

Wireless Propagation
Ground Wave

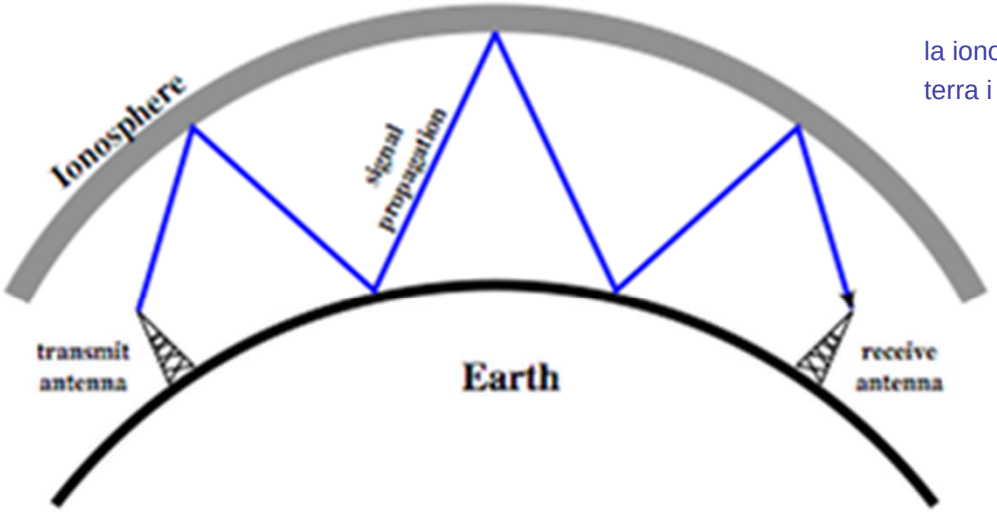


(a) Ground-wave propagation (below 2 MHz)

- ground wave propagation follows the contour of the earth and can propagate distances well over the visible horizon
- this effect is found in frequencies up to 2MHz
- the best known example of ground wave communication is AM radio

Wireless Propagation
Sky Wave

la ionosfera --> ex radio AM, les ones reboten entre el terra i la ionosfera

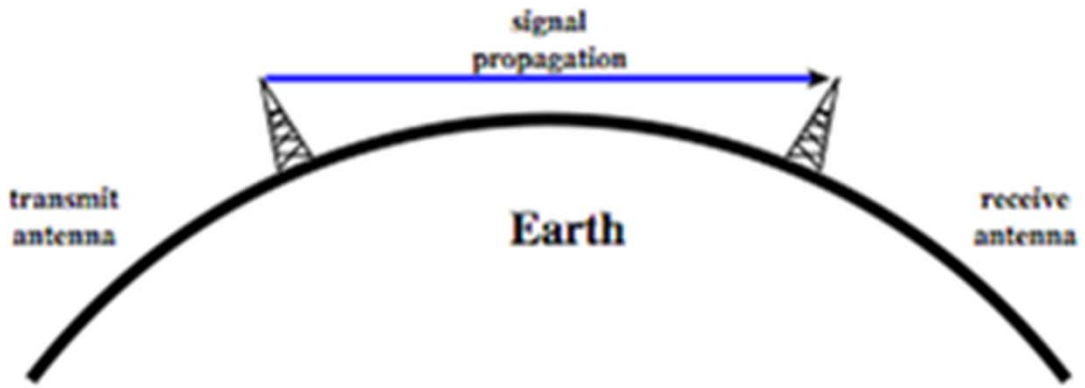


(b) Sky-wave propagation (2 to 30 MHz)

- sky wave propagation is used for amateur radio, CB radio, and international broadcasts such as BBC and Voice of America
- a signal from an earth based antenna is reflected from the ionized layer of the upper atmosphere back down to earth
- sky wave signals can travel through a number of hops, bouncing back and for the between the ionosphere and the earth's surface

Wireless Propagation
Line of Sight

La figura parabolica de la antena, APUNTS

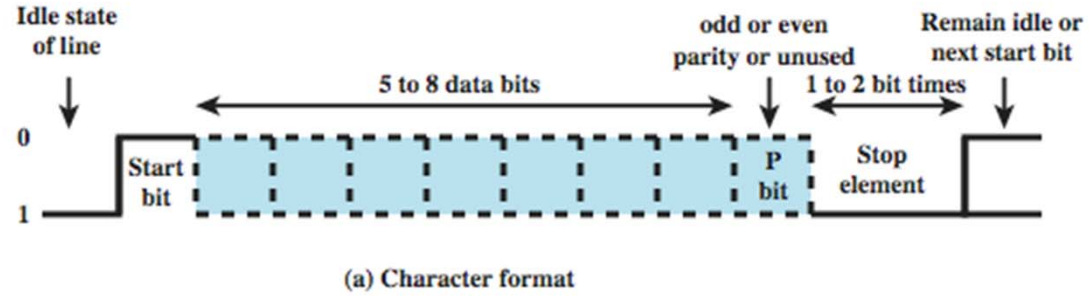


(c) Line-of-sight (LOS) propagation (above 30 MHz)

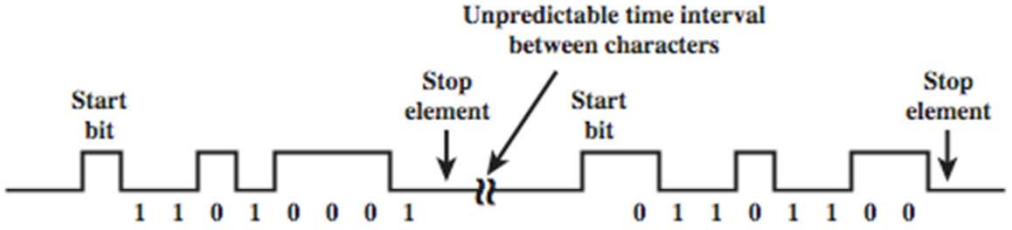
- ground and sky wave propagation modes do not operate above 30 MHz - - communication must be by line of sight

2.4 Tècniques comunicació de dades

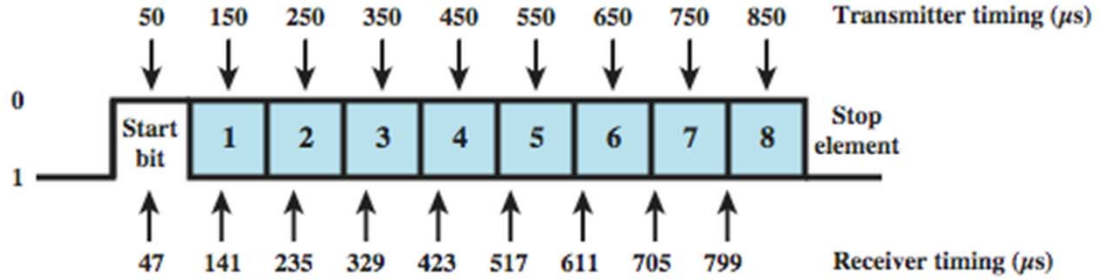
Asynchronous Transmission



(a) Character format



(b) 8-bit asynchronous character stream

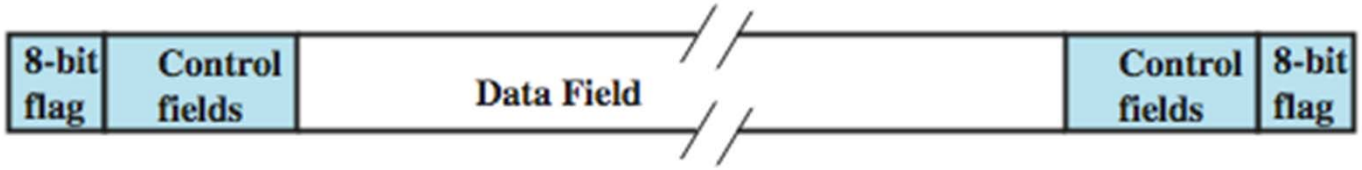


(c) Effect of timing error

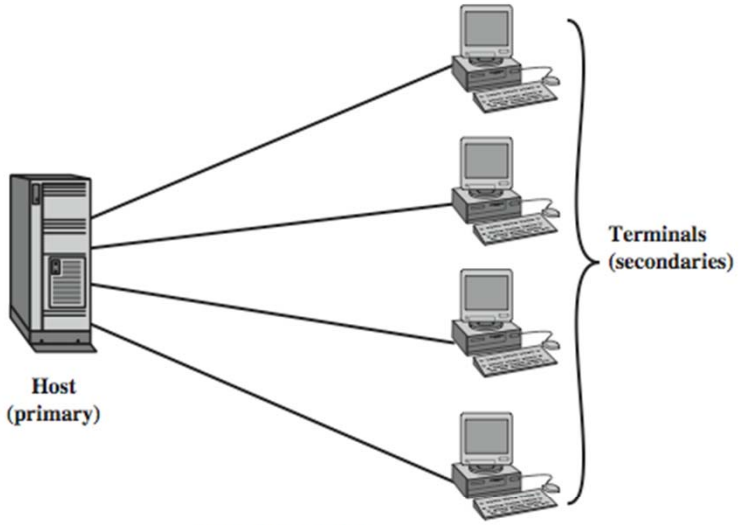
El sincronisme al bit es manté premanentment utilitzant les transicions --> si no hi ha transicions, no es pot sincronitzar en un sneyal continu

Synchronous Transmission

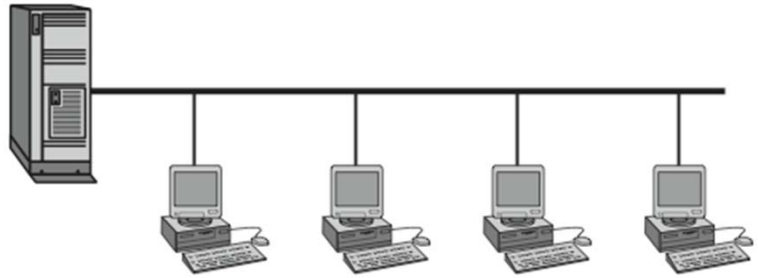
- block of data transmitted sent as a frame
- clocks must be synchronized
  - can use separate clock line
  - or embed clock signal in data
- need to indicate start and end of block
  - use preamble and postamble
- more efficient (lower overhead) than async



Line Configuration - Topology



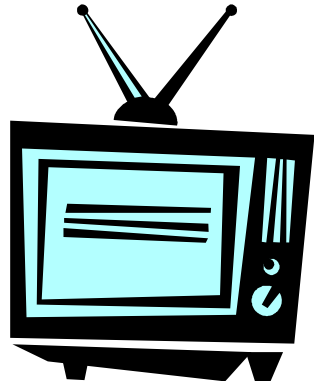
(a) Point-to-point



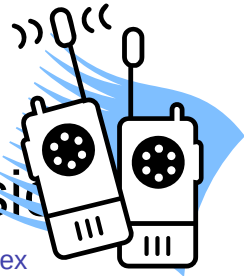
(b) Multipoint

Transmission Terminology

- **Simplex**
  - signals transmitted in one direction
    - *eg. Television*



- **Half duplex**
  - both stations transmit, but only one at a time
    - *eg. police radio* ethernet



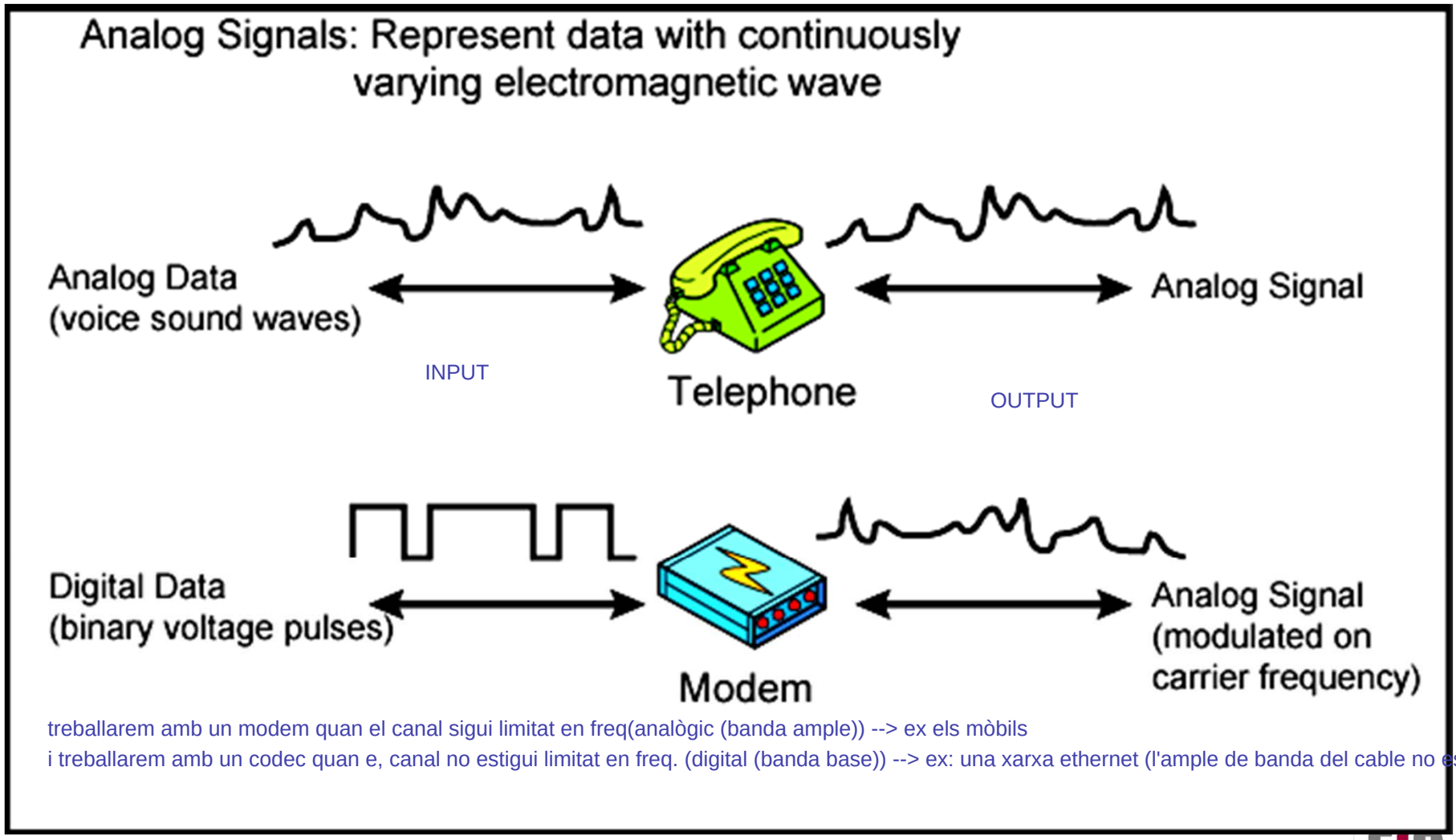
- **Full duplex**
  - simultaneous transmissi
    - *eg. telephone* (el telefon és full-duplex per xarxa, però a la pràctica és half duplex, perque quan es fa servir, la gent parla per torns)

Audio Signals

- frequency range of typical speech is 100Hz-7kHz
- easily converted into electromagnetic signals
- varying volume converted to varying voltage
- can limit frequency range for voice channel to 300-3400Hz

In this graph of a typical analog signal, the variations in amplitude and frequency convey the gradations of loudness and pitch in speech or music. Similar signals are used to transmit television pictures, but at much higher frequencies.

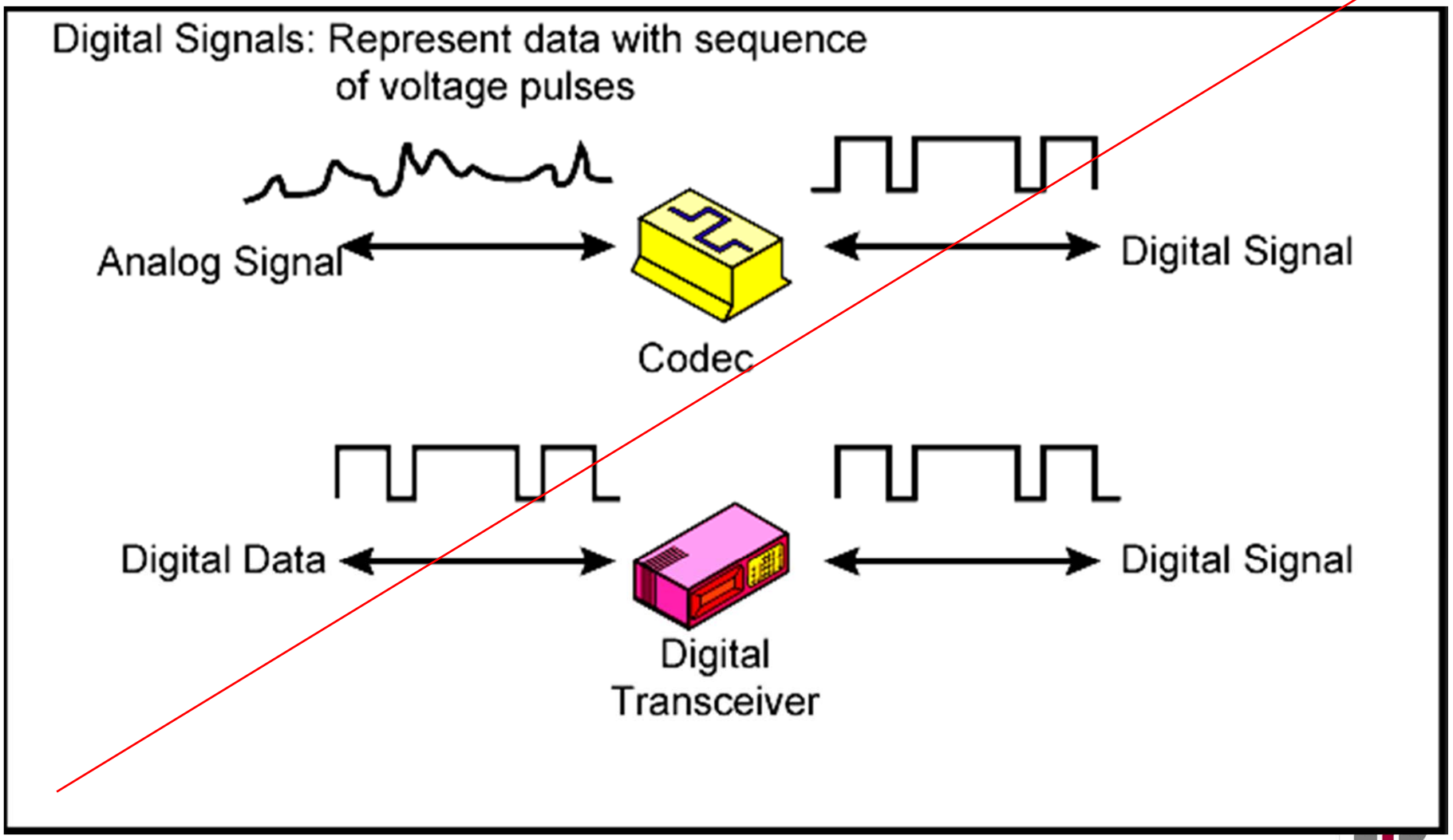
Analog Signals



treballarem amb un modem quan el canal sigui limitat en freq(analògic (banda ample)) --> ex els mòbils
i treballarem amb un codec quan e, canal no estigui limitat en freq. (digital (banda base)) --> ex: una xarxa ethernet (l'ample de banda del cable no esta limitat)

Digital Signals

més detallat que la anterior (a la assignatura no es tindà en compte)



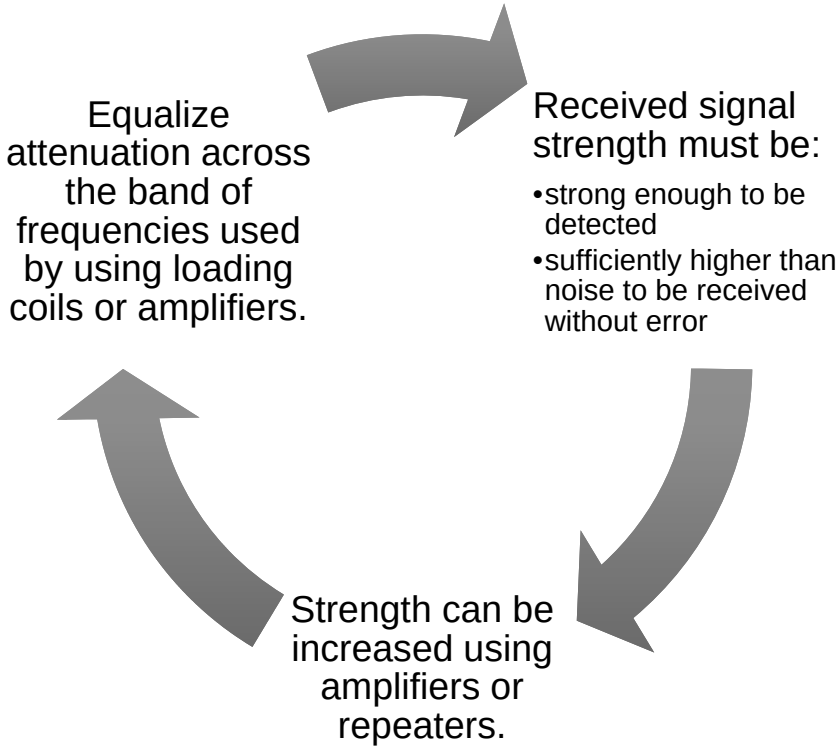
Transmission Impairments

- signal received may differ from signal transmitted causing:
  - analog - degradation of signal quality
  - digital - bit errors
- most significant impairments are
  - attenuation and attenuation distortion
  - delay distortion
  - noise

"Distorsió d'atenuació
el senyal s'atenua de forma diferent en funció de la freq"

APUNTS --> decibels logaritmes

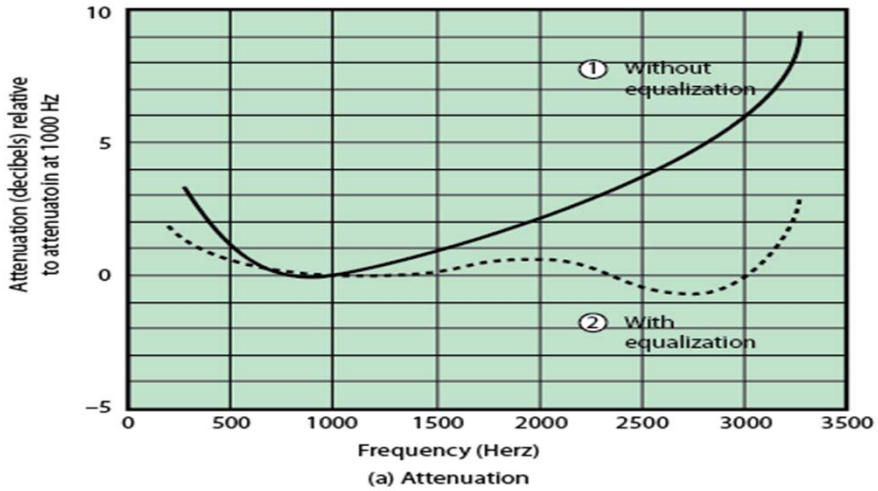
Attenuation

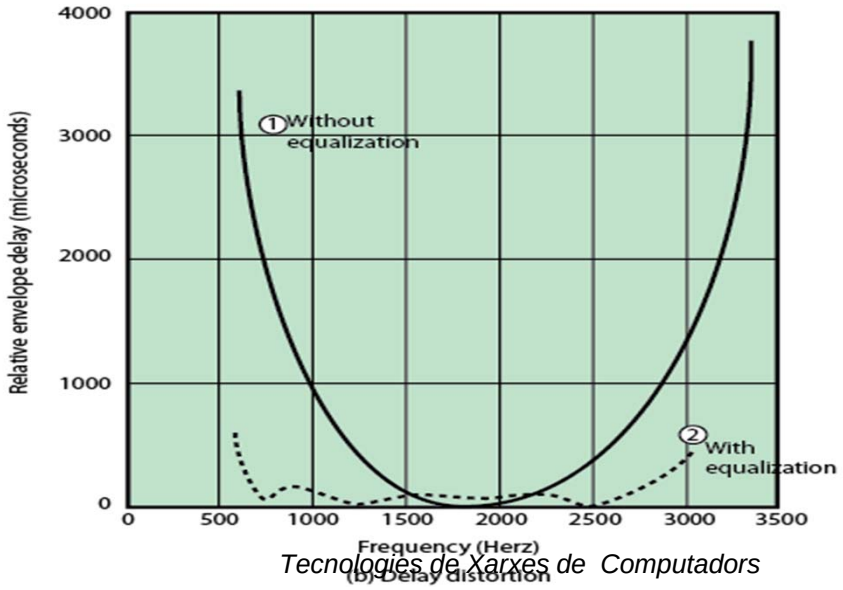


Equalitzador : et permet modificar la atenuació per grups de freq.

- **signal strength falls off with distance over any transmission medium**
- **varies with frequency**

Attenuation Distortion





Delay Distortion

- occurs because propagation velocity of a signal through a guided medium varies with frequency
- various frequency components arrive at different times resulting in phase shifts between the frequencies
- particularly critical for digital data since parts of one bit spill over into others causing intersymbol interference

Categories of Noise

Impulse Noise:

- caused by external electromagnetic interferences
- noncontinuous, consisting of irregular pulses or spikes
- short duration and high amplitude
- minor annoyance for analog signals but a major source of error in digital data

ex: quan s'engega un fluorescent o un motor.

Crosstalk:

- a signal from one line is picked up by another
- can occur by electrical coupling between nearby twisted pairs or when microwave antennas pick up unwanted signals

que la radició d'un cable passi a un altre

APUNTS

Nyquist diu que es poden enviar 2B simbols per segón, sent B l'ample de banda del canal
Vt = 2B log(2, M), sent M el nombre de nivells

Nyquist Bandwidth

In the case of a channel that is noise free:

- if rate of signal transmission is *2B* then can carry signal with frequencies no greater than *B*
  - given bandwidth B, highest signal rate is 2B
- for binary signals, *2B* bps needs bandwidth *B* Hz
- can increase rate by using *M* signal levels
- Nyquist Formula is: $C = 2B \log_2 M$
- data rate can be increased by increasing signals
  - however this increases burden on receiver
  - noise & other impairments limit the value of *M*

+nivells --> + Vt, però com més nivells, menys diferencia hi ha entre ells, però llavors més sensible és al soroll.I arribaun punt en el que és inviable.

va calcular el limit de nyquist en funció del soroll

Shannon Capacity Formula

- considering the relation of data rate, noise and error rate:
  - faster data rate shortens each bit so bursts of noise corrupts more bits
  - given noise level, higher rates mean higher errors
- Shannon developed formula relating these to signal to noise ratio (in decibels)
- $SNR_{db} = 10 \log_{10}$ (signal/noise)
- capacity $C = B \log_2(1+SNR)$
  - theoretical maximum capacity
  - get much lower rates in practice

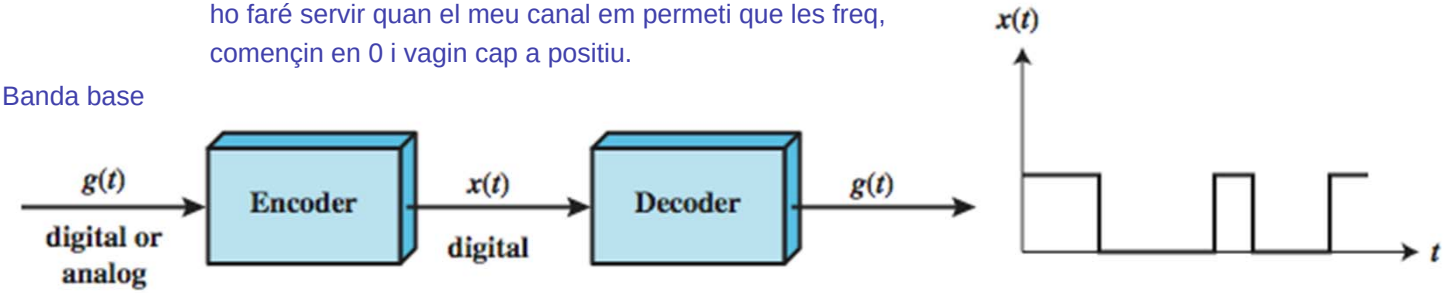
B = ample de banda
SNR = s'ha de fer servir sense db, SNRdb = 10*log(10, (Psenyal / Psoroll)), aillant Psenyal/Psoroll

2.5 Codificació de senyals

Signal Encoding Techniques

Codificació
ho faré servir quan el meu canal em permeti que les freq, comencin en 0 i vagin cap a positiu.

Banda base

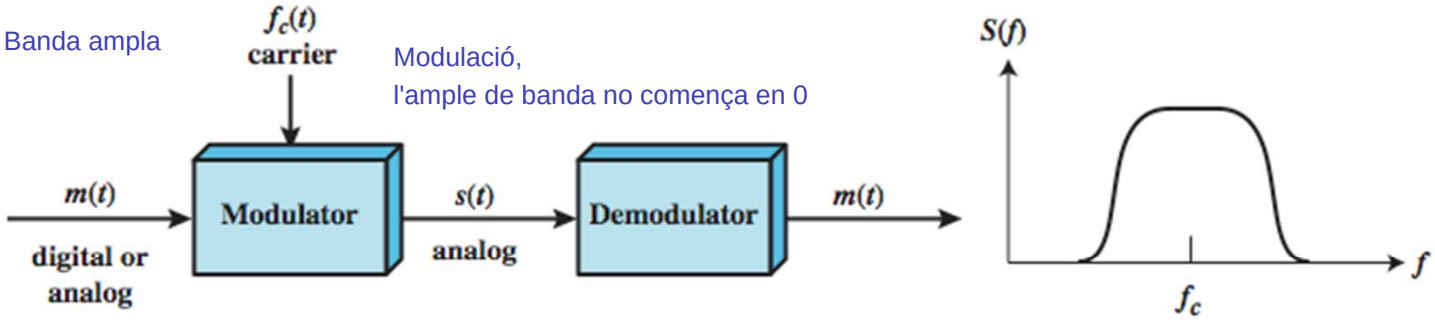


(a) Encoding onto a digital signal

No seria un bon sistema per a la telefonia mobil, perque le canal és compartit

Banda ampla

Modulació,
l'ample de banda no comença en 0



(b) Modulation onto an analog signal

Figure 5.1 Encoding and Modulation Techniques

Terminology

- **unipolar** – all signal elements have the same sign
- **polar** – one logic state represented by positive voltage and the other by negative voltage
- **data rate** – rate of data (R) transmission in bits per second (nombre d'ateracions/bits per segón)
- **duration or length of a bit** – time taken for transmitter to emit the bit (1/R)
- **modulation rate** – rate at which the signal level changes, measured in baud = signal elements per second. nombre de simbols per segón
- **mark and space** – binary 1 and binary 0

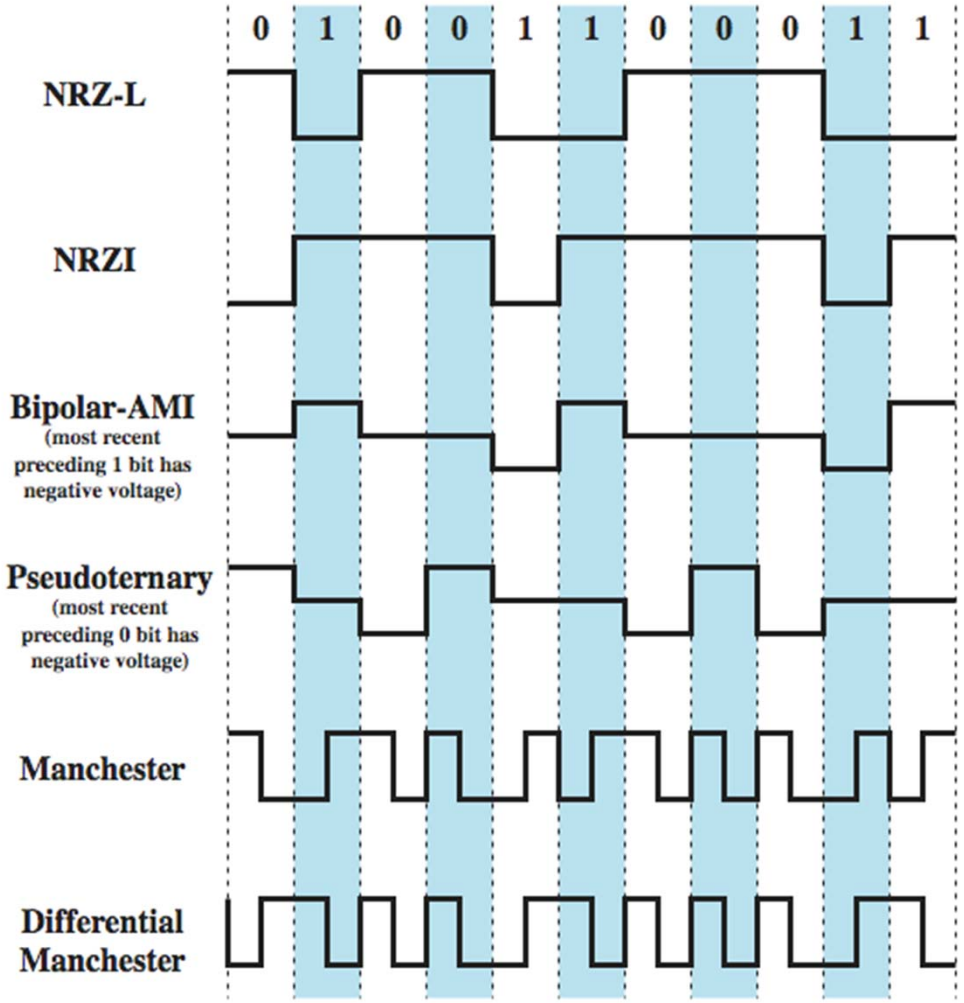
Comparison of Encoding Schemes

- signal spectrum
- clocking
- error detection
- signal interference and noise immunity
- cost and complexity

"característica d'un codi perque permeti sincronitzar: que permèti transicions"

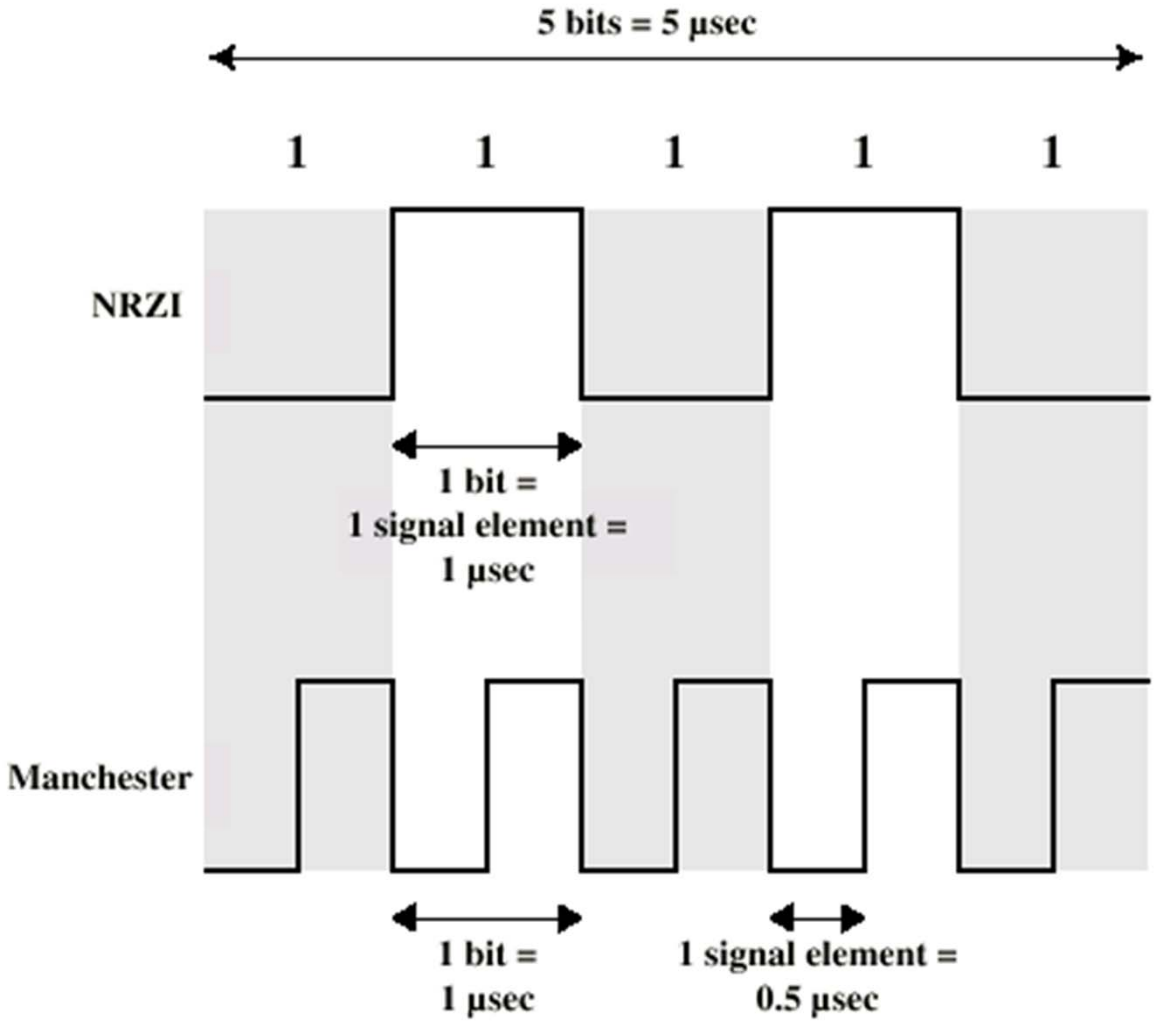
Encoding Schemes

exemples de codis coneguts

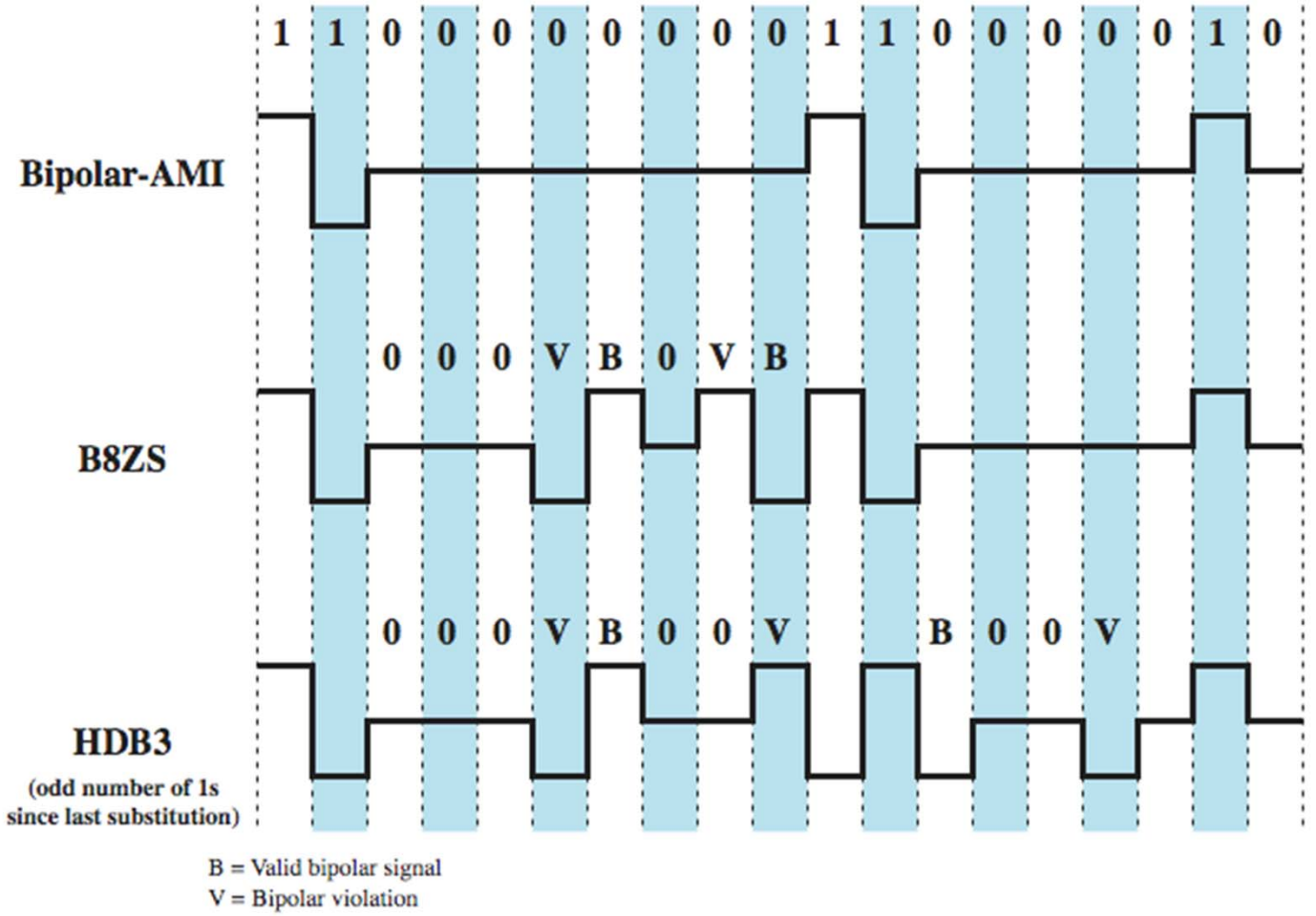


canvia cada cop que vé un 1

Modulation Rate



B8ZS and HDB3



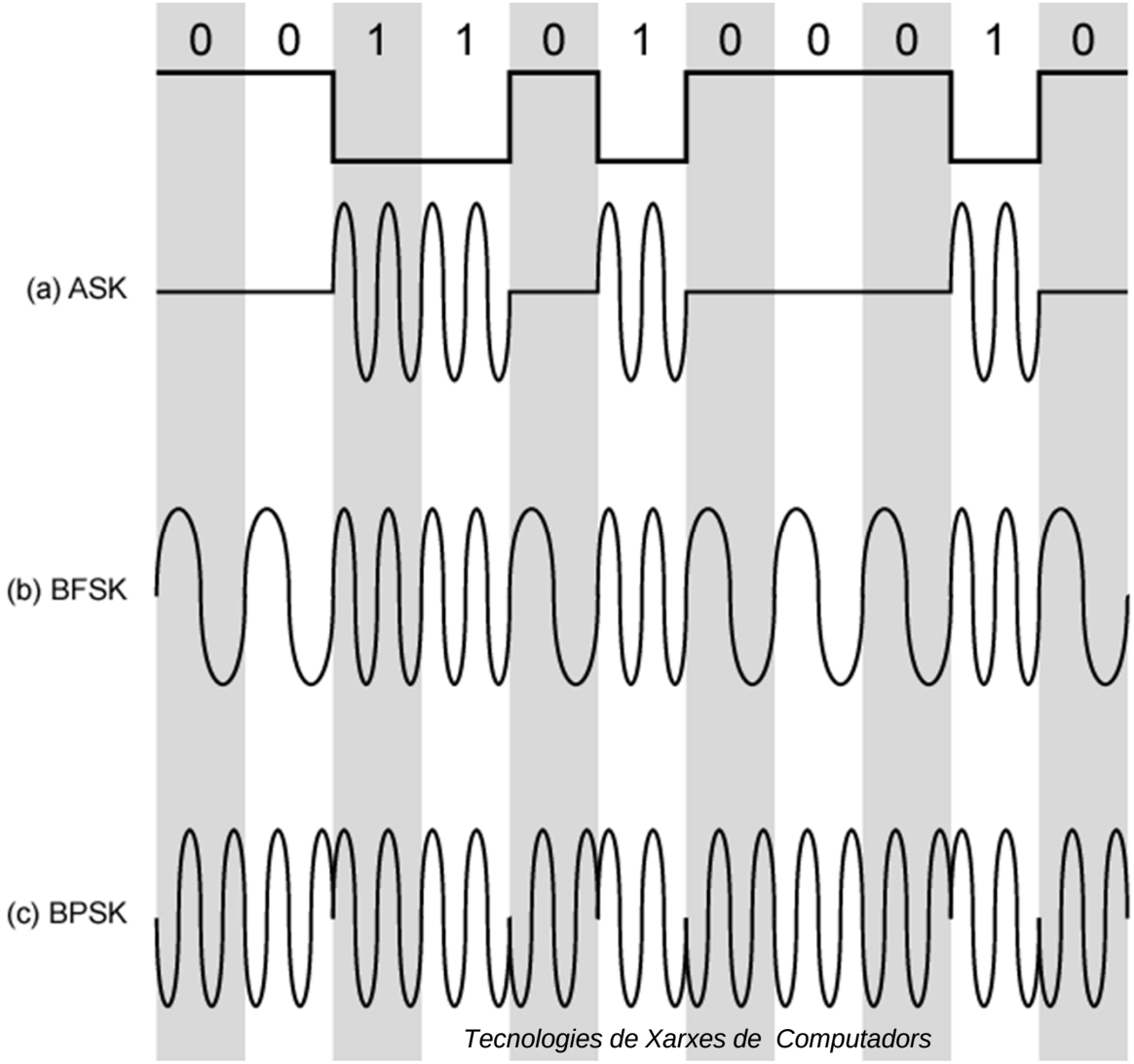
2.6 Modulació

La modulació ens permet concentrar un rang de frequències

Digital Data, Analog Signal

- main use is public telephone system
  - has freq range of 300Hz to 3400Hz
  - use modem (modulator-demodulator)
- encoding techniques
  - Amplitude shift keying (ASK)
  - Frequency shift keying (FSK)
  - Phase shift keying (PK)

Modulation Techniques



1 sola freq per el 0 i l 1

q freq per l'1 i una altra per el 0

mateixa freq, i mateixa maplada per el 0 i per l'1 però diferenta fase

Tots els sitemes no codificats fan servir QAM

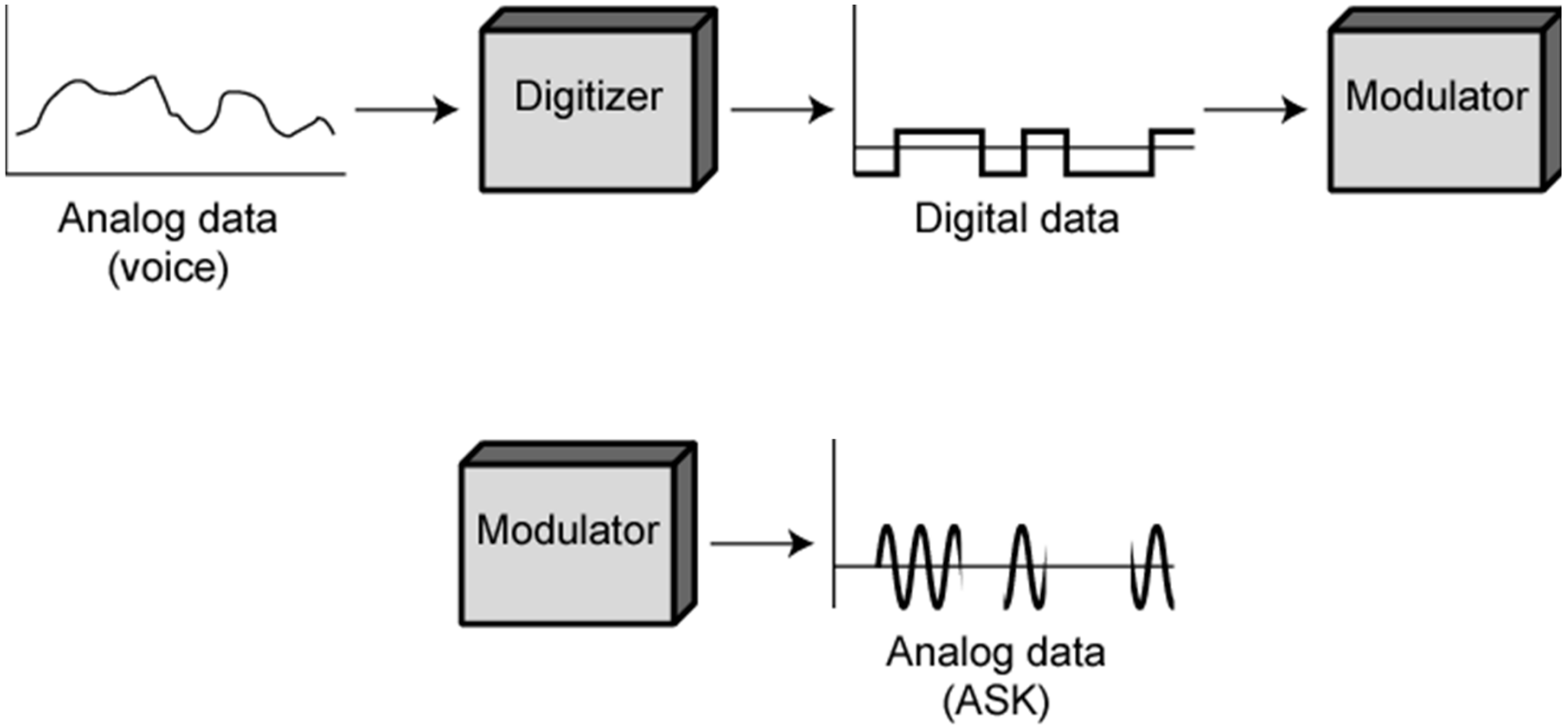
Quadrature Amplitude Modulation

- QAM used on asymmetric digital subscriber line (ADSL) and some wireless
- combination of ASK and PSK

és una varicaió de la amplada i de la fase per codificar 0s i 1s

- send two different signals simultaneously on same carrier frequency
  - use two copies of carrier, one shifted 90˚
  - each carrier is ASK modulated
  - two independent signals over same medium
  - demodulate and combine for original binary output

Digitizing Analog Data

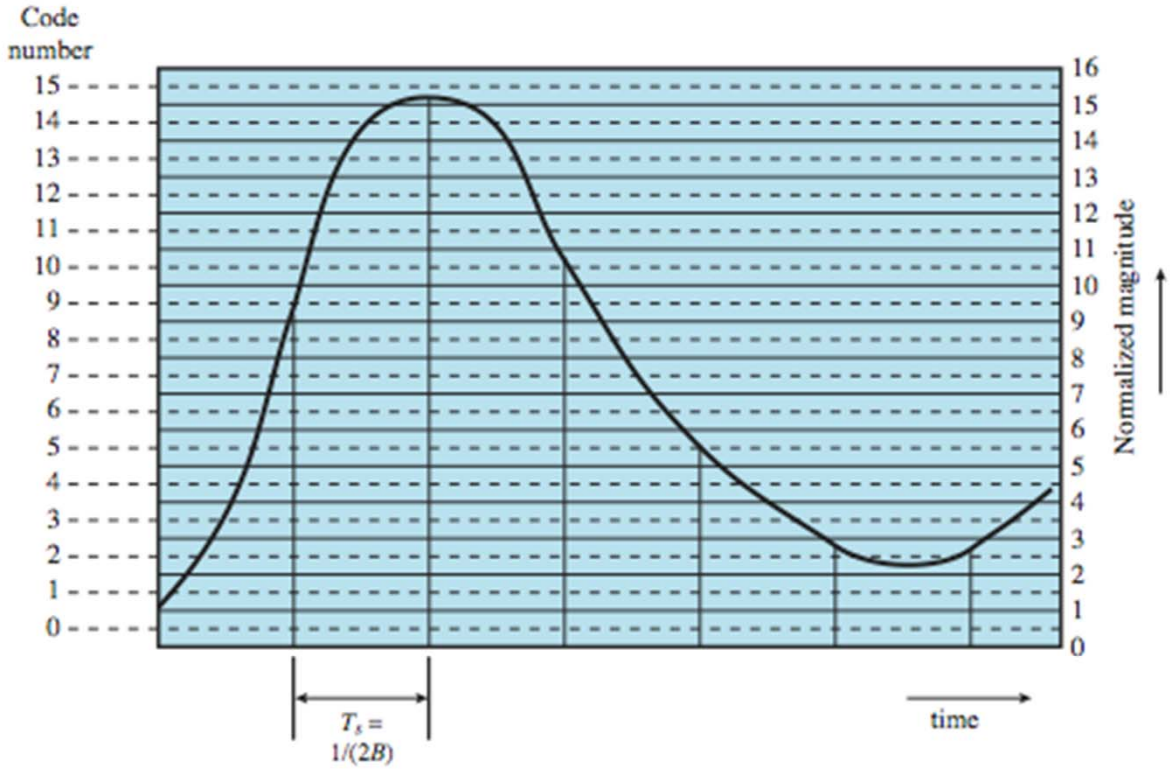


procediment per digitalitzar un sistema analògic: el que dóna millor resultat és el PCM.

Pulse Code Modulation (PCM)

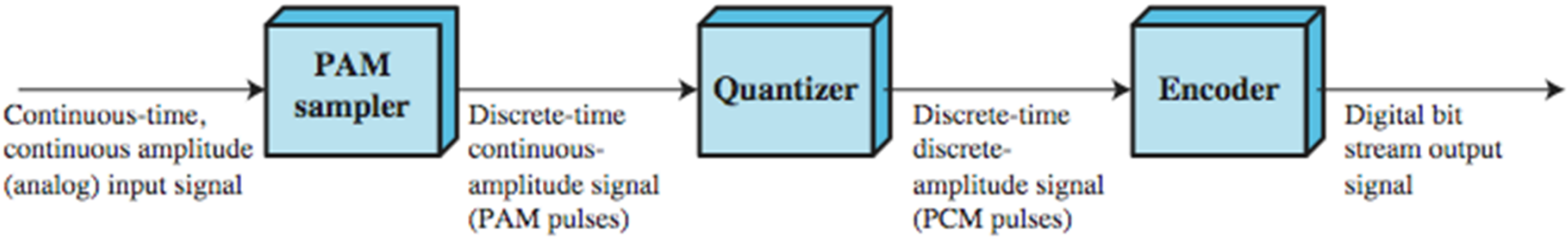
- sampling theorem: si un senyal és mostrejat a com a minim, el doble de la freq maxim del senyal, tenim la garantia de que no es perd informació
  - "If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all information in original signal"
  - eg. 4000Hz voice data, requires 8000 sample per sec
- strictly have analog samples
  - Pulse Amplitude Modulation (PAM)
- so assign each a digital value

PCM Example

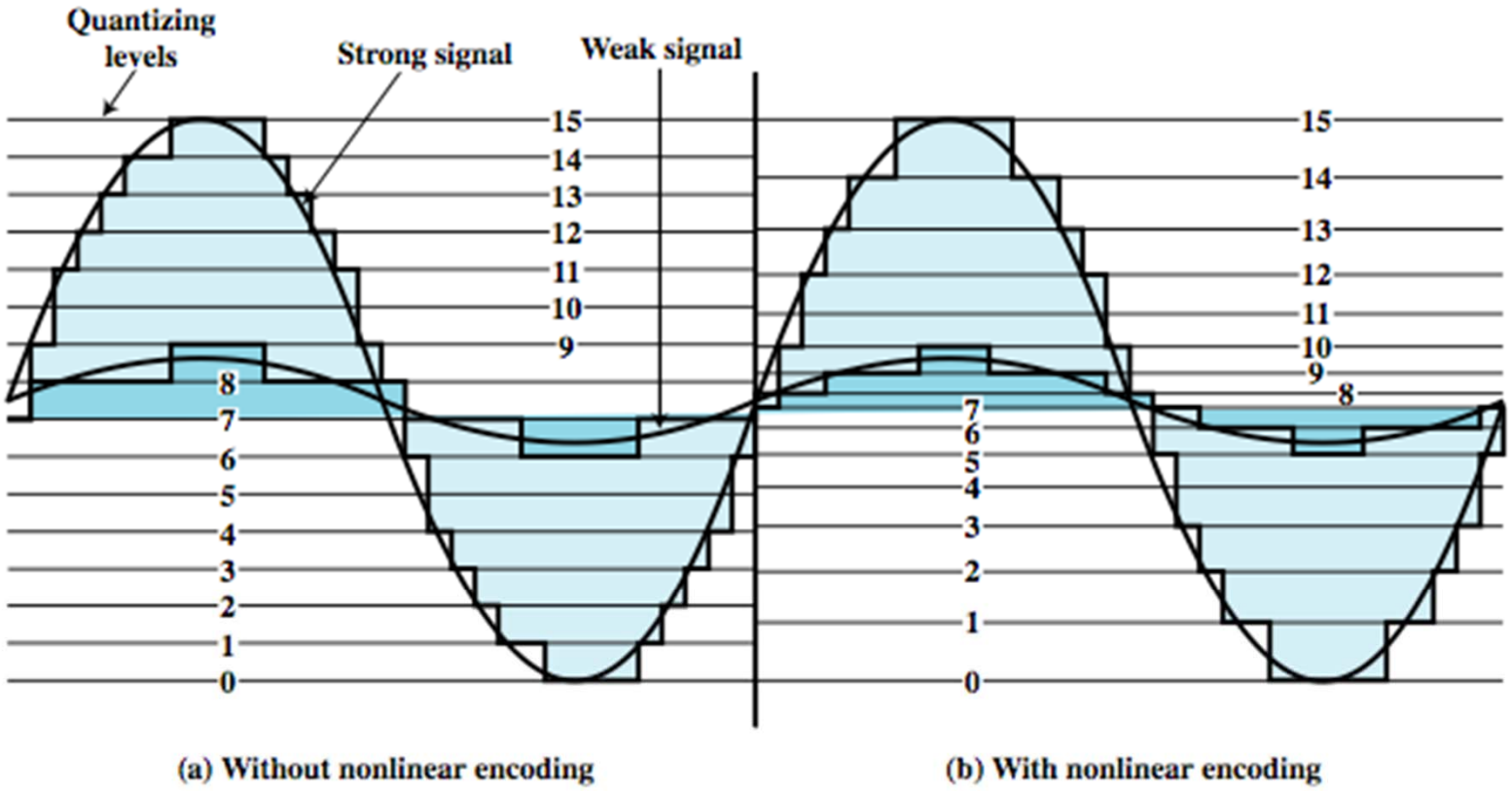


PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

PCM Block Diagram



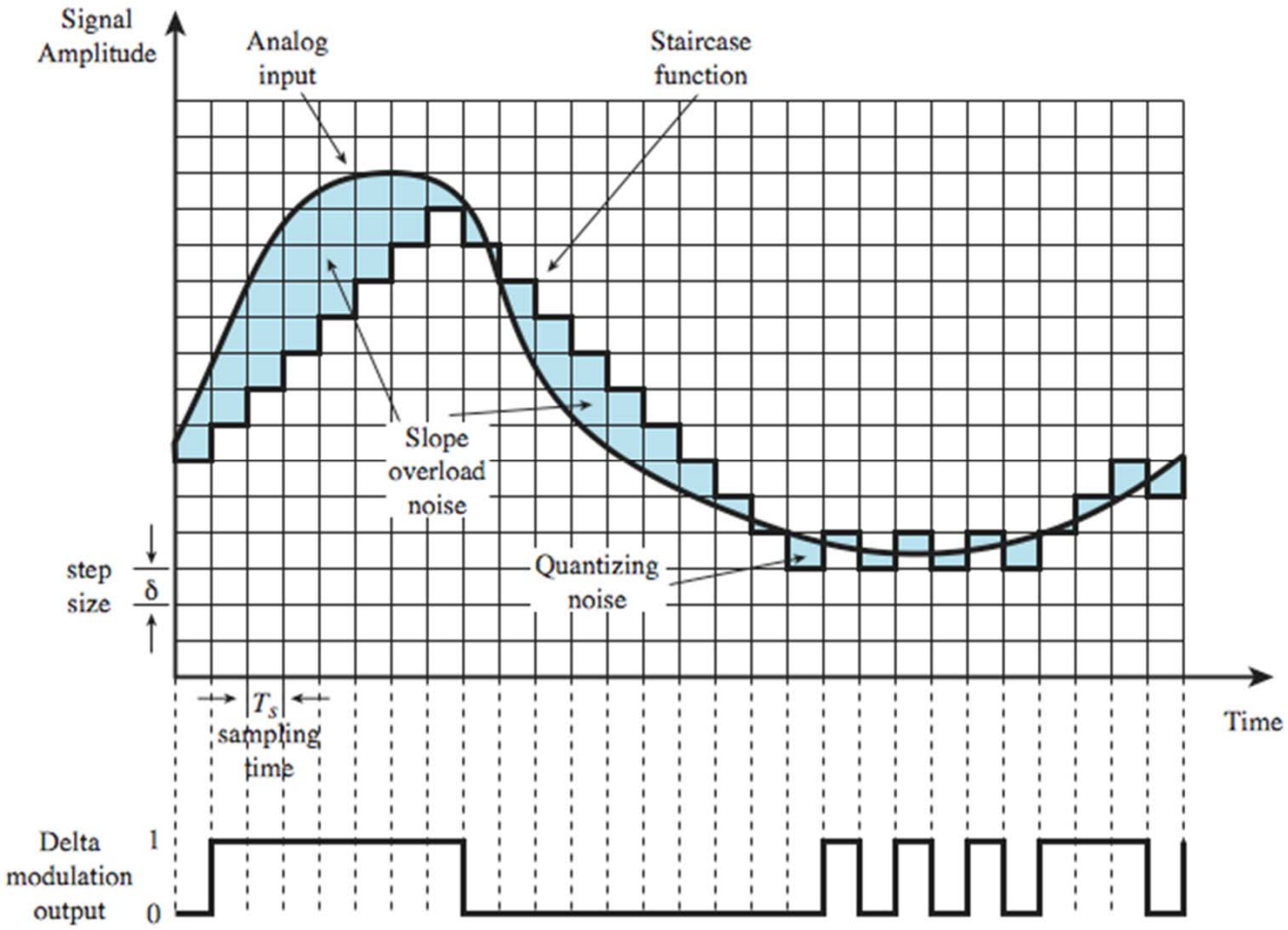
Non-Linear Coding



Delta Modulation

- analog input is approximated by a staircase function
  - can move up or down one level (δ) at each sample interval
- has binary behavior
  - since function only moves up or down at each sample interval
  - hence can encode each sample as single bit
  - 1 for up or 0 for down

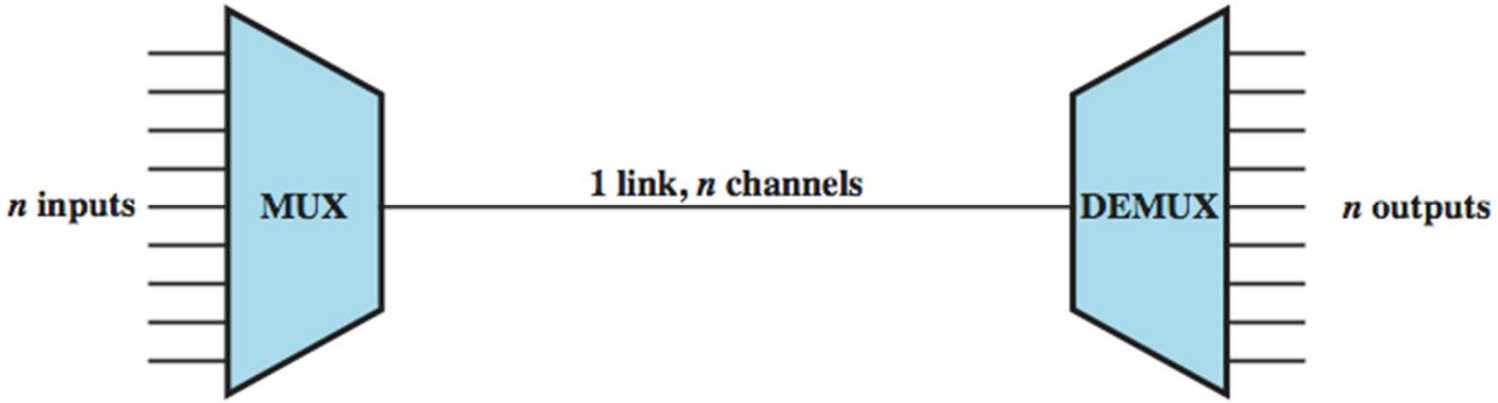
Delta Modulation Example



2.7 Multiplexació

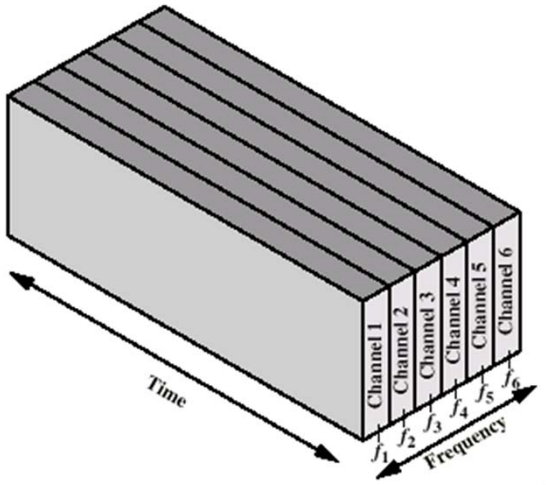
Multiplexing

- multiple links on 1 physical line
- common on long-haul, high capacity, links
- have FDM, TDM, STDM alternatives



Frequency Division Multiplexing

- FDM
- Useful bandwidth of medium exceeds required bandwidth of channel
- Each signal is modulated to a different carrier frequency
- Carrier frequencies separated so signals do not overlap (guard bands)
- e.g. broadcast radio
- Channel allocated even if no data

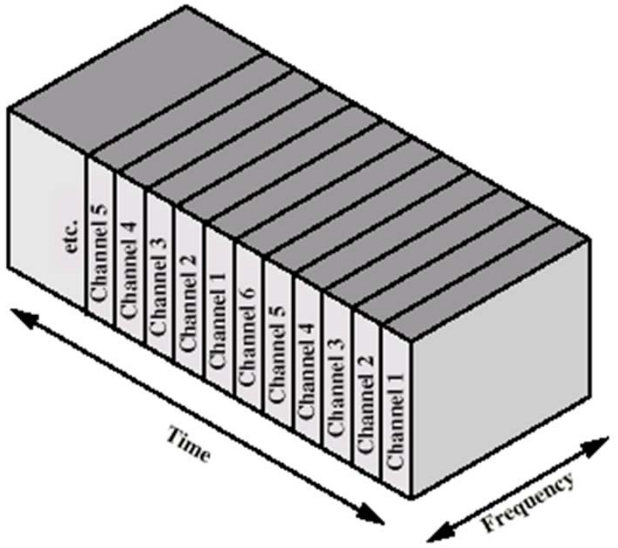


Wavelength Division Multiplexing

- Multiple beams of light at different frequency
- Carried by optical fiber
- A form of FDM
- Each color of light (wavelength) carries separate data channel
- 1997 Bell Labs
  - 100 beams
  - Each at 10 Gbps
  - Giving 1 terabit per second (Tbps)
- Commercial systems of 160 channels of 10 Gbps now available
- Lab systems (Alcatel) 256 channels at 39.8 Gbps each
  - 10.1 Tbps
  - Over 100 km

Synchronous Time Division Multiplexing

- Data rate of medium exceeds data rate of digital signal to be transmitted
- Multiple digital signals interleaved in time
- May be at bit level of blocks
- Time slots preassigned to sources and fixed
- Time slots allocated even if no data
- Time slots do not have to be evenly distributed amongst sources



Statistical TDM

- In Synchronous TDM many slots are wasted
- Statistical TDM allocates time slots dynamically based on demand
- Multiplexer scans input lines and collects data until frame full
- Data rate on line lower than aggregate rates of input lines

Statistical TDM Frame Formats

(a) Overall frame

(b) Subframe with one source per frame

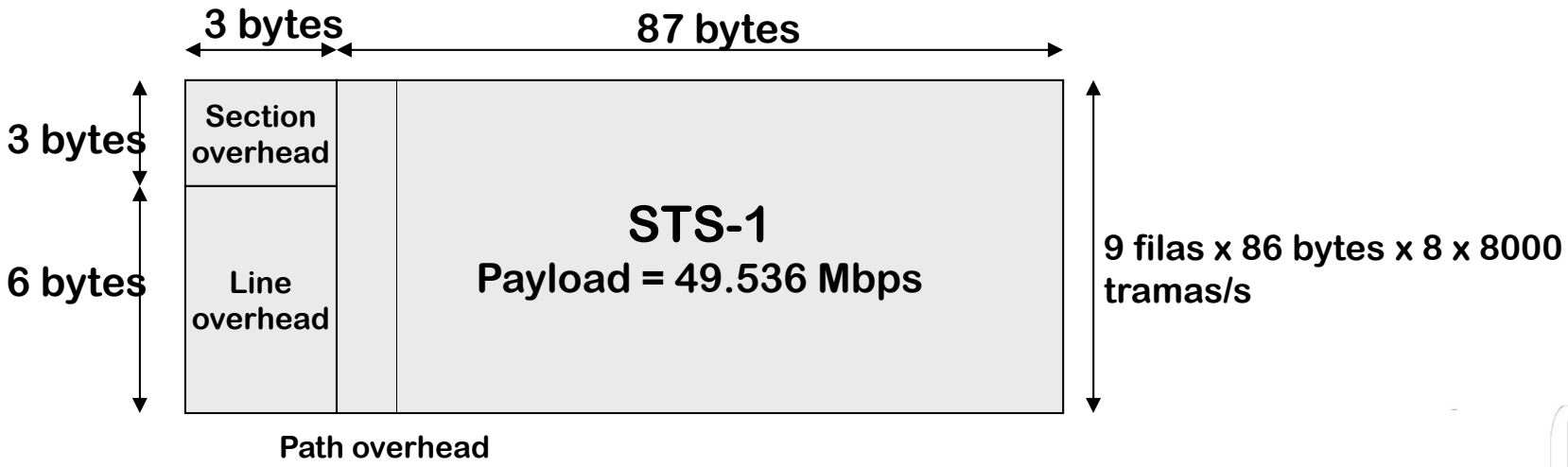
(c) Subframe with multiple sources per frame

SDH

- SDH: Synchronous Digital Hierarchy
- SDH/Sonet es una tecnología de transmisión (G.707-G.709)
  - la forma en que los datos están codificados
  - velocidades
  - esquemas de multiplexación
  - técnicas de codificación
  - medios de transmisión

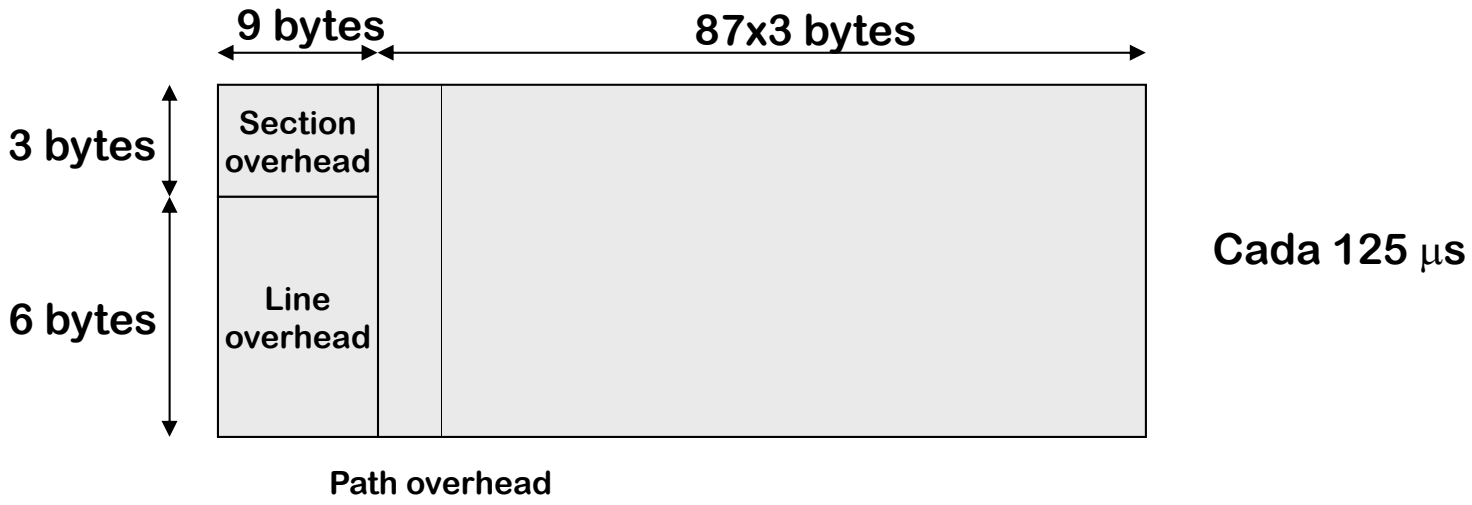
SONET

- SONET transmite datos en tramas:
  - La trama OC-1 es un conjunto bidimensional de 90 columnas por 9 filas de octetos (bytes).
    - *Las primeras 3 columnas (27 bytes) son el overhead de transporte*
    - *La velocidad es 8000 tramas por segundo (cada 125 microsegundos):*
    - *90 x 9 x 8 x 8000=90 x 9 x 64 kbps = 51.84 Mbps*
  - La trama de OC-n son n tramas de OC-1

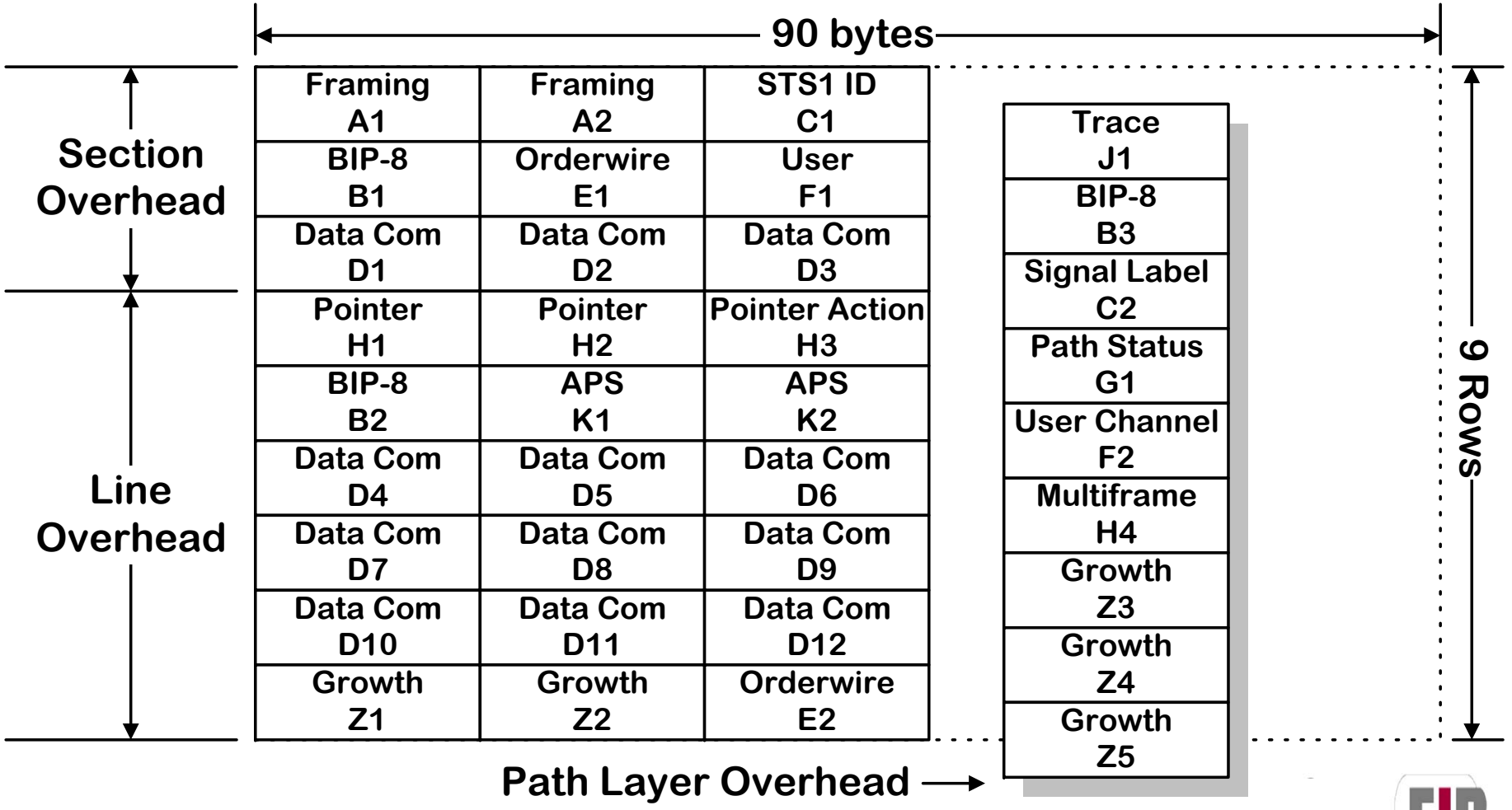


STS-3c

- 3 tramas STS-1 forman una STS-3c
- 3 x 51.84 Mbps = 155.52 Mbps

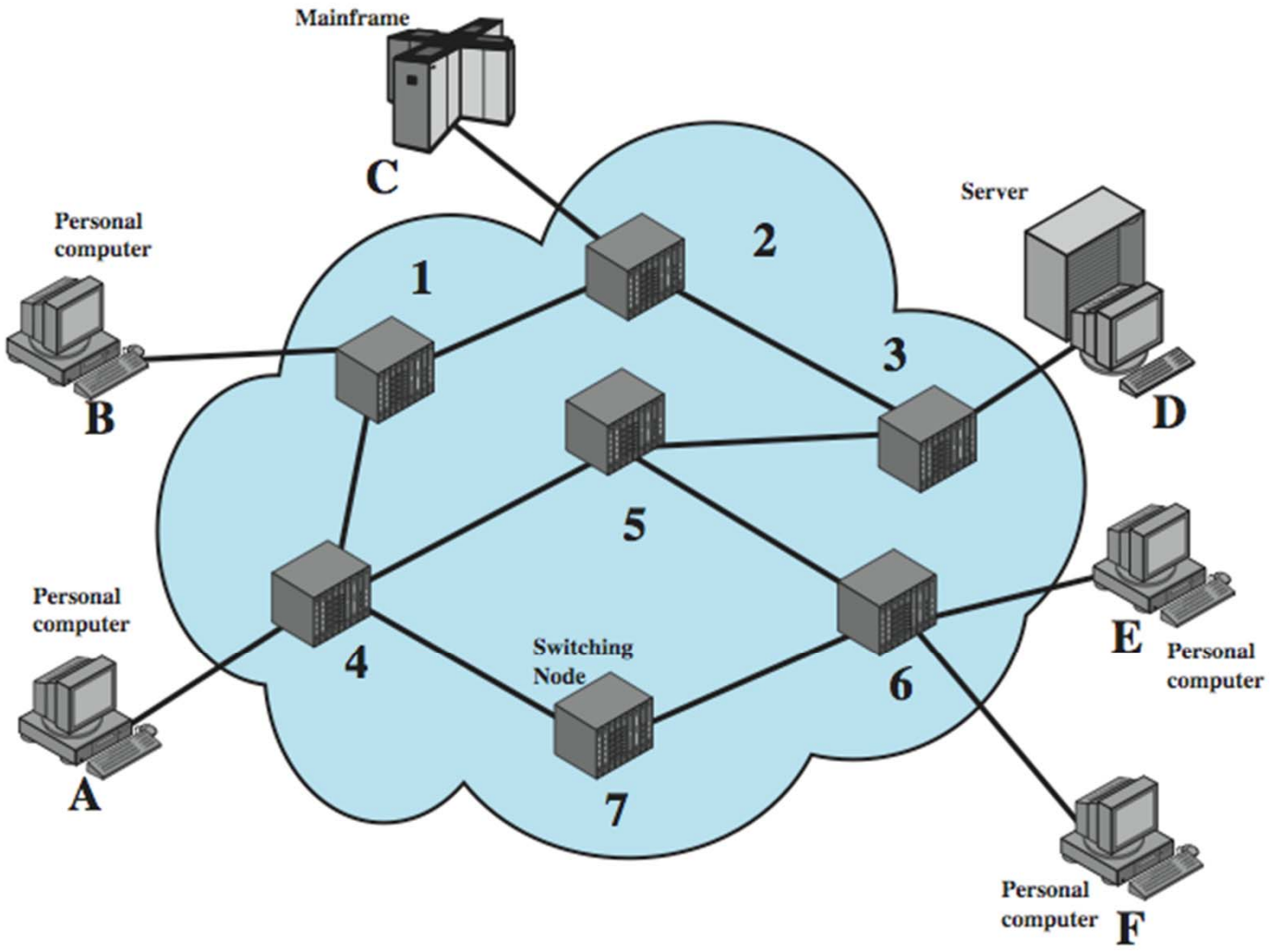


SONET Overhead



2.8 Commutació

Switched Network



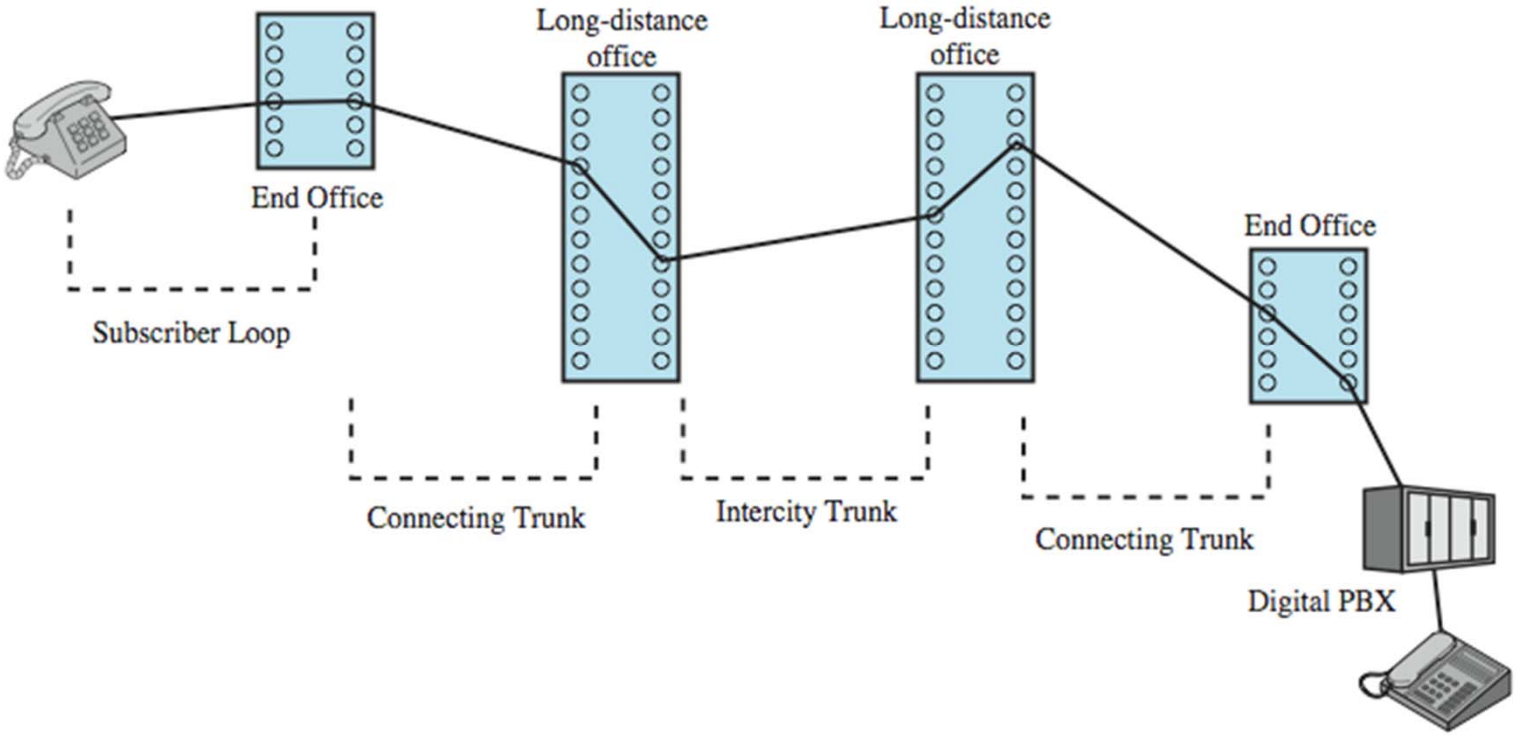
Nodes

- a collection of nodes and connections is a communications network
- nodes may connect to other nodes only, or to stations and other nodes
- network is usually partially connected
  - some redundant connections are desirable
- have two different switching technologies
  - circuit switching
  - packet switching

Circuit Switching

- uses a dedicated path between two stations
- has three phases
  - establish
  - transfer
  - disconnect
- inefficient
  - channel capacity dedicated for duration of connection
  - if no data, capacity wasted
- set up (connection) takes time
- once connected, transfer is transparent

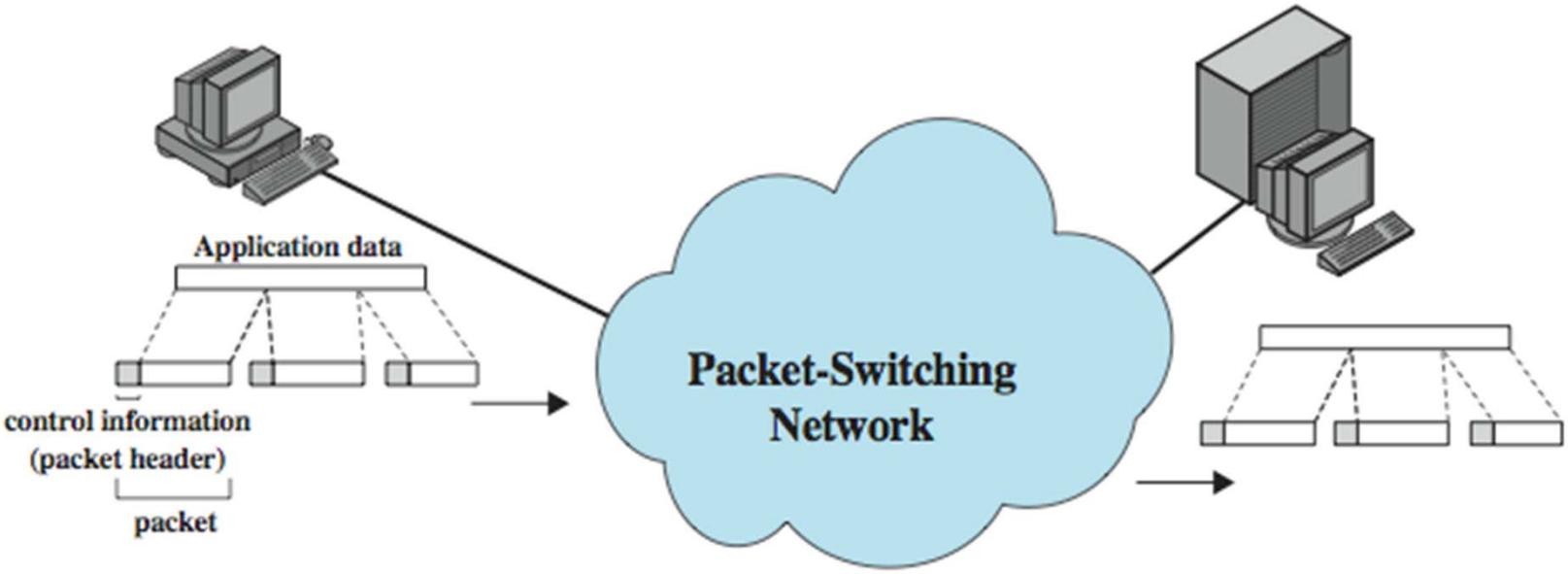
Public Circuit Switched Network



Packet Switching

- circuit switching was designed for voice
- packet switching was designed for data
- transmitted in small packets
- packets contains user data and control info
  - user data may be part of a larger message
  - control info includes routing (addressing) info
- packets are received, stored briefly (buffered) and past on to the next node

Packet Switching



Advantages

- line efficiency
  - single link shared by many packets over time
  - packets queued and transmitted as fast as possible
- data rate conversion
  - stations connects to local node at own speed
  - nodes buffer data if required to equalize rates
- packets accepted even when network is busy
- priorities can be used

Datagram Diagram

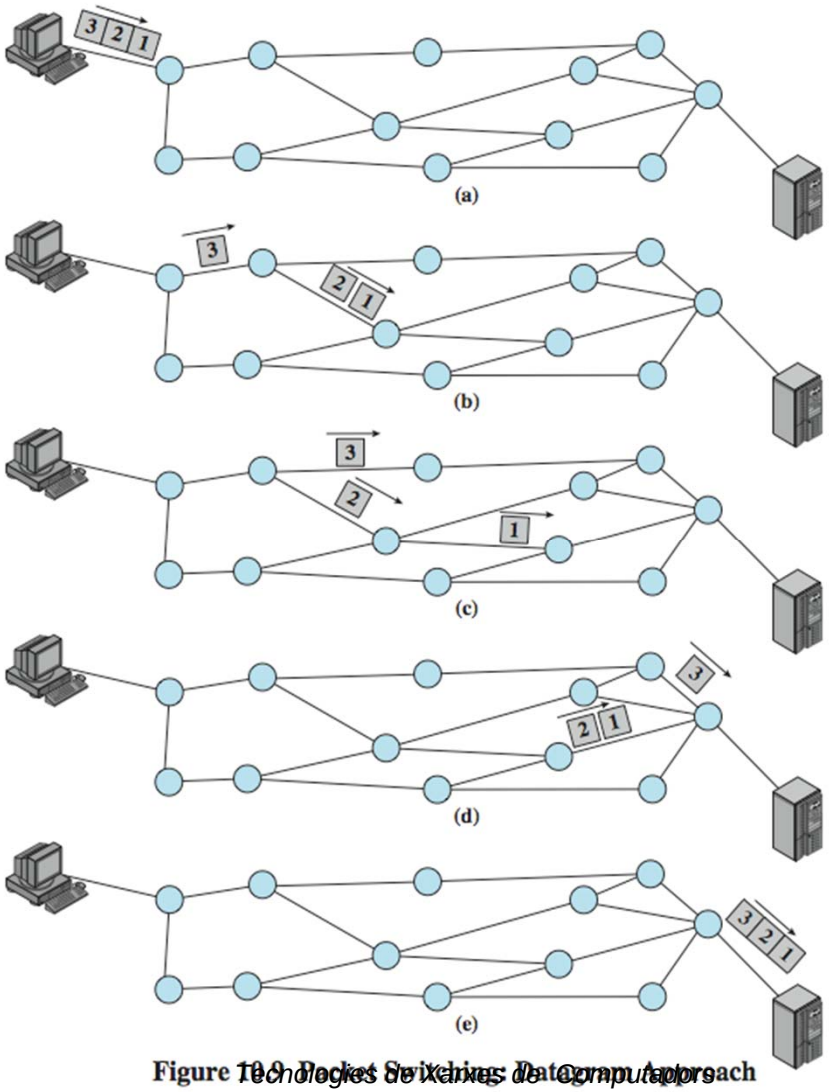


Figure 10.9 Packet Switching: Datagram Approach

Virtual Circuit Diagram

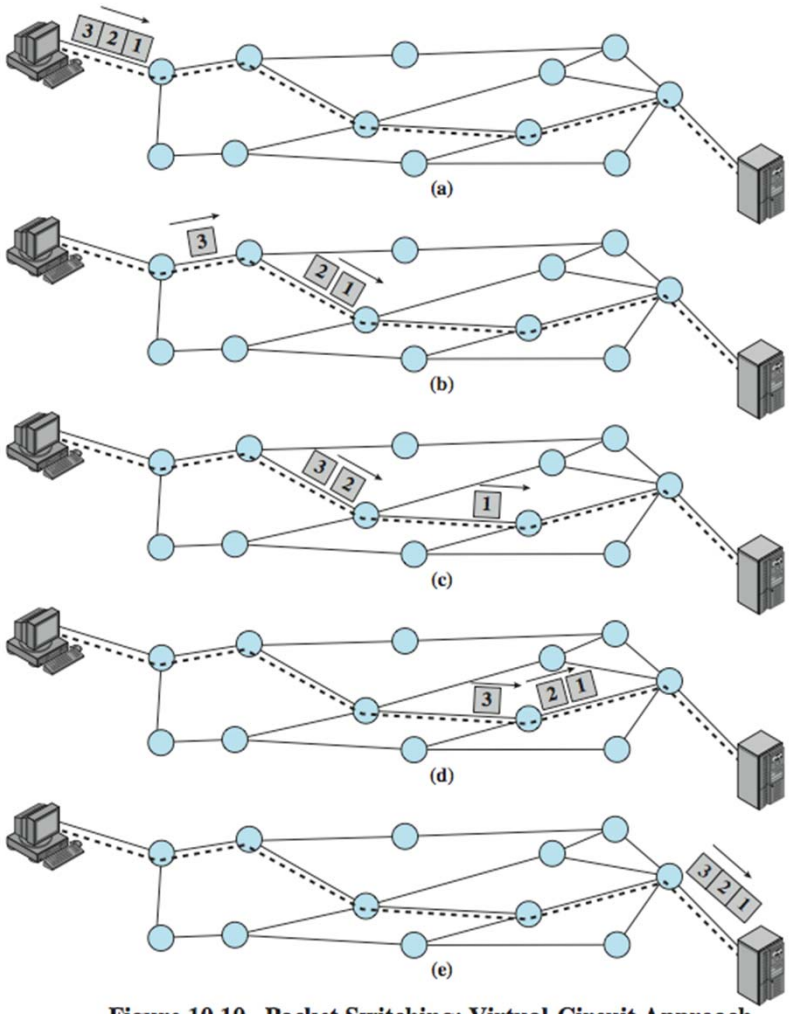
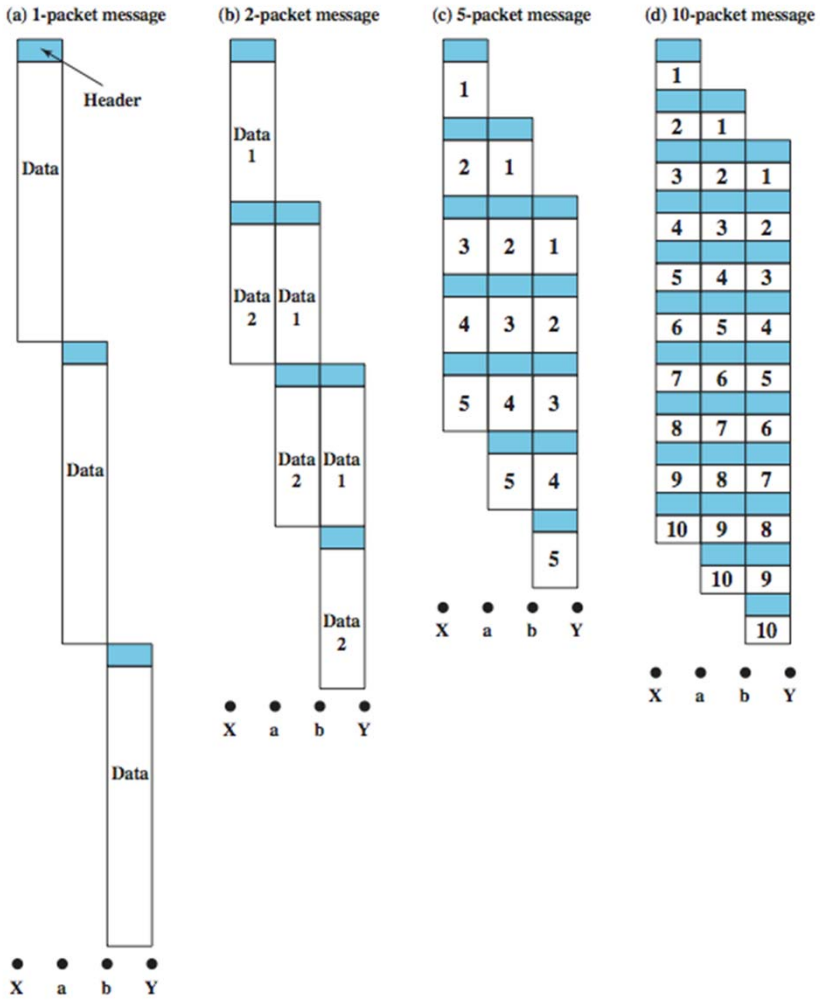


Figure 10.10 Packet Switching: Virtual-Circuit Approach

Virtual Circuits v Datagram

- virtual circuits
  - network can provide sequencing and error control
  - packets are forwarded more quickly
  - less reliable
- datagram
  - no call setup phase
  - more flexible
  - more reliable

Packet Size


(a) 1-packet message
Header
Data
Data
Data
X a b Y
(b) 2-packet message
Data 1
Data 2
Data 1
Data 2
Data 1
Data 2
X a b Y
(c) 5-packet message
1
2 1
3 2 1
4 3 2
5 4 3
5 4
5
X a b Y
(d) 10-packet message
1
2 1
3 2 1
4 3 2
5 4 3
6 5 4
7 6 5
8 7 6
9 8 7
10 9 8
10 9
10
X a b Y

Event Timing