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

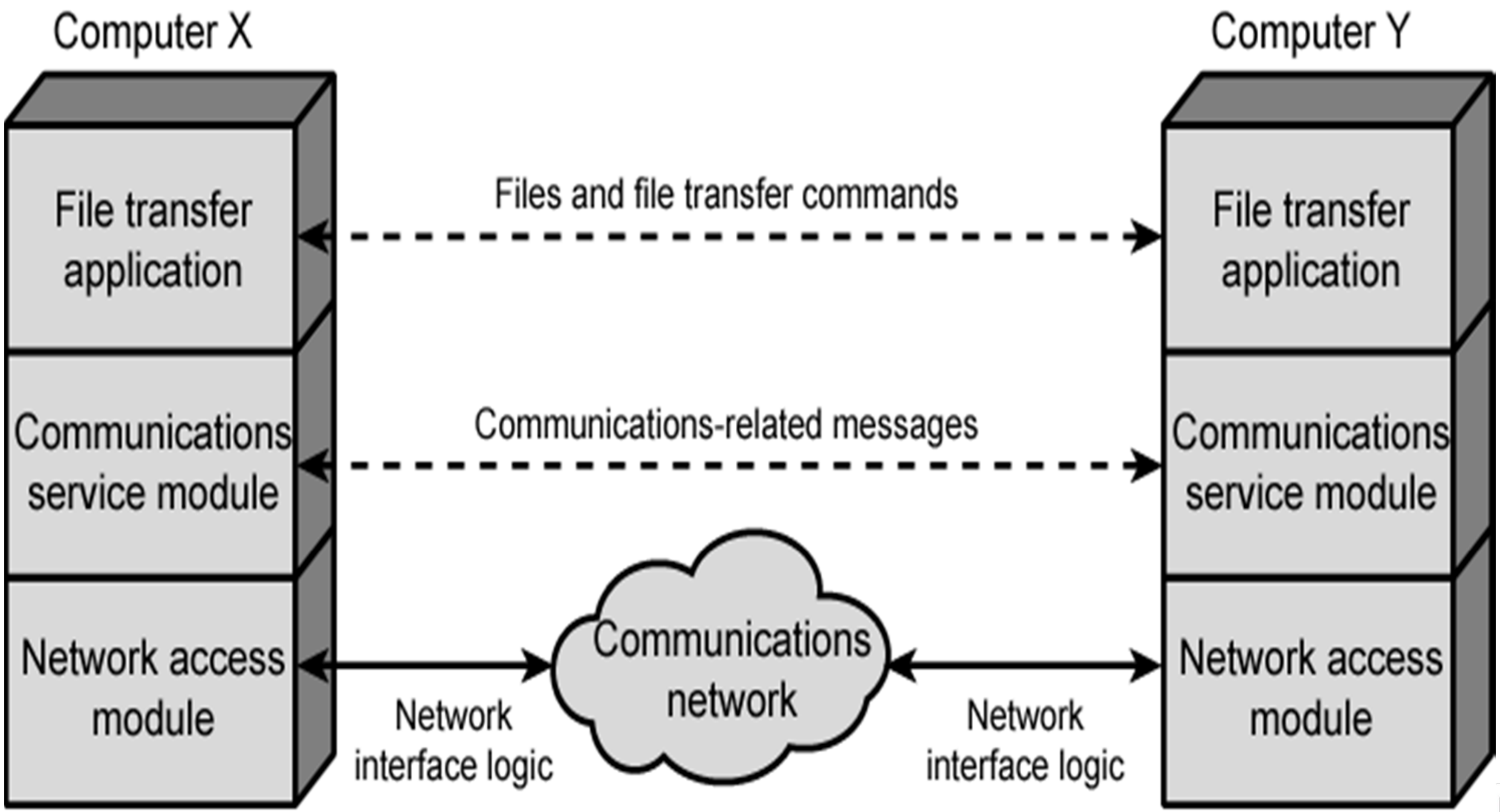
2.6 Modulació

2.7 Multiplexació

2.8 Commutació

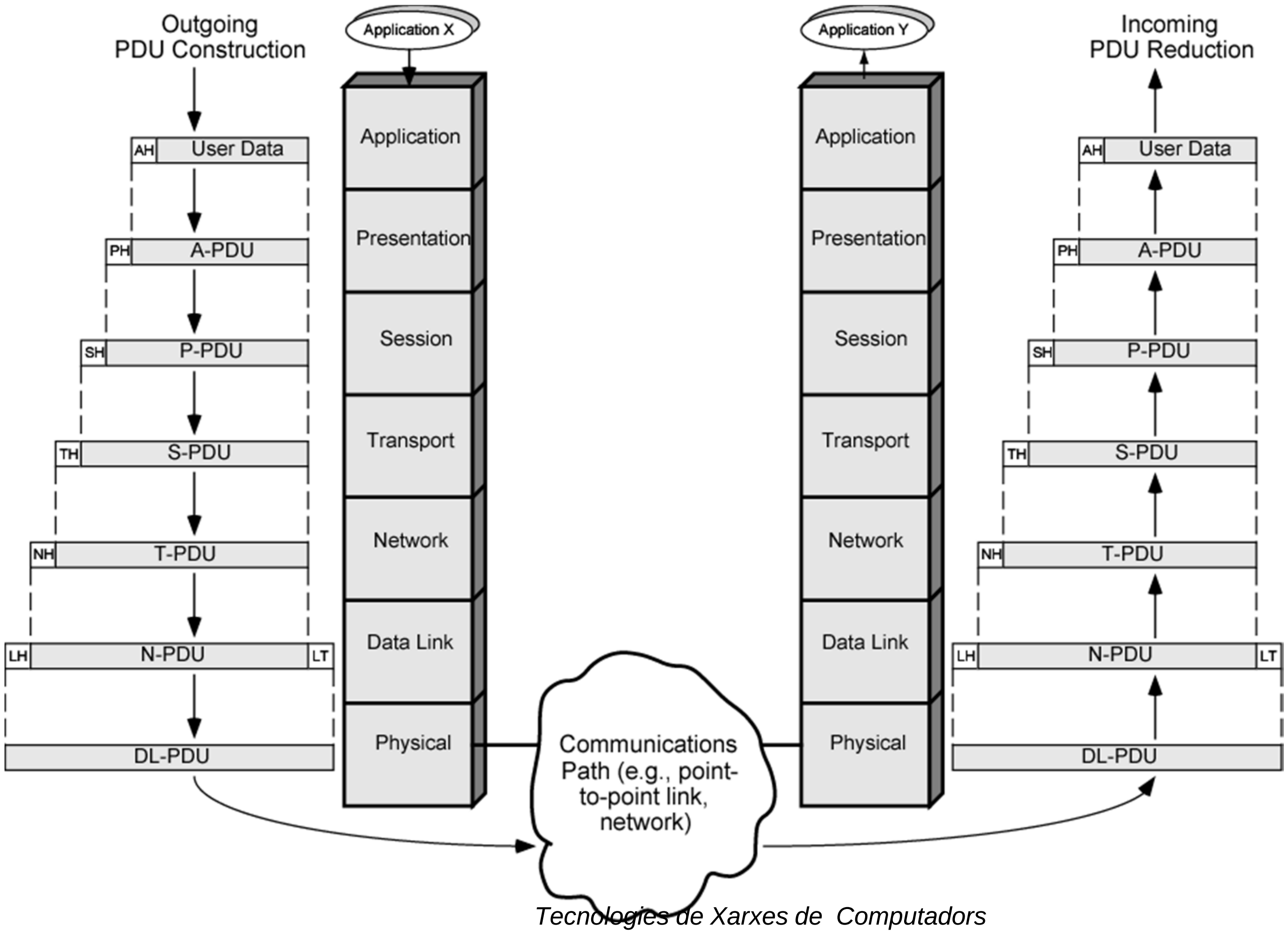
2.1 Model arquitectònic d'Internet.

Simplified Network Architecture

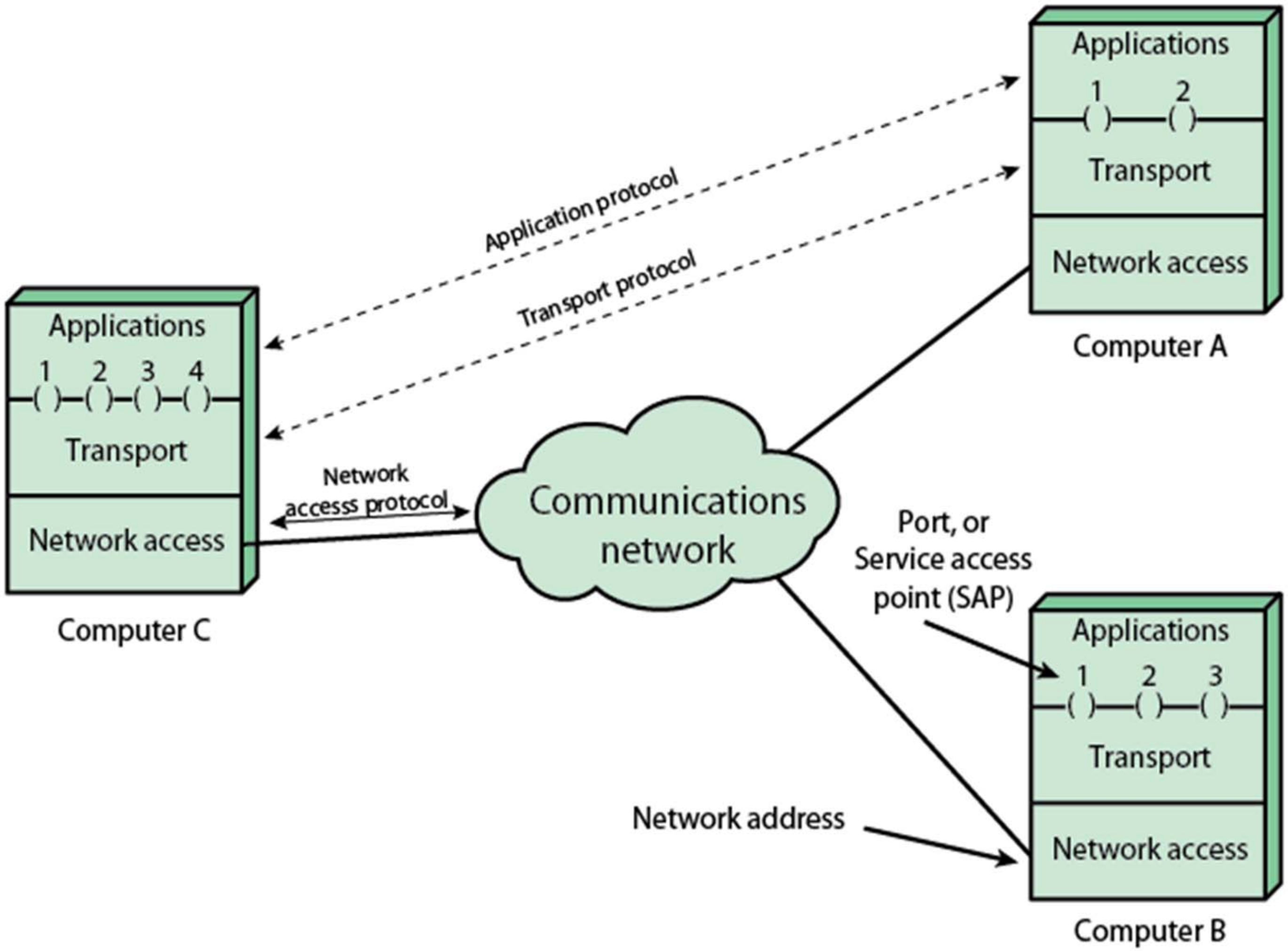


OSI model

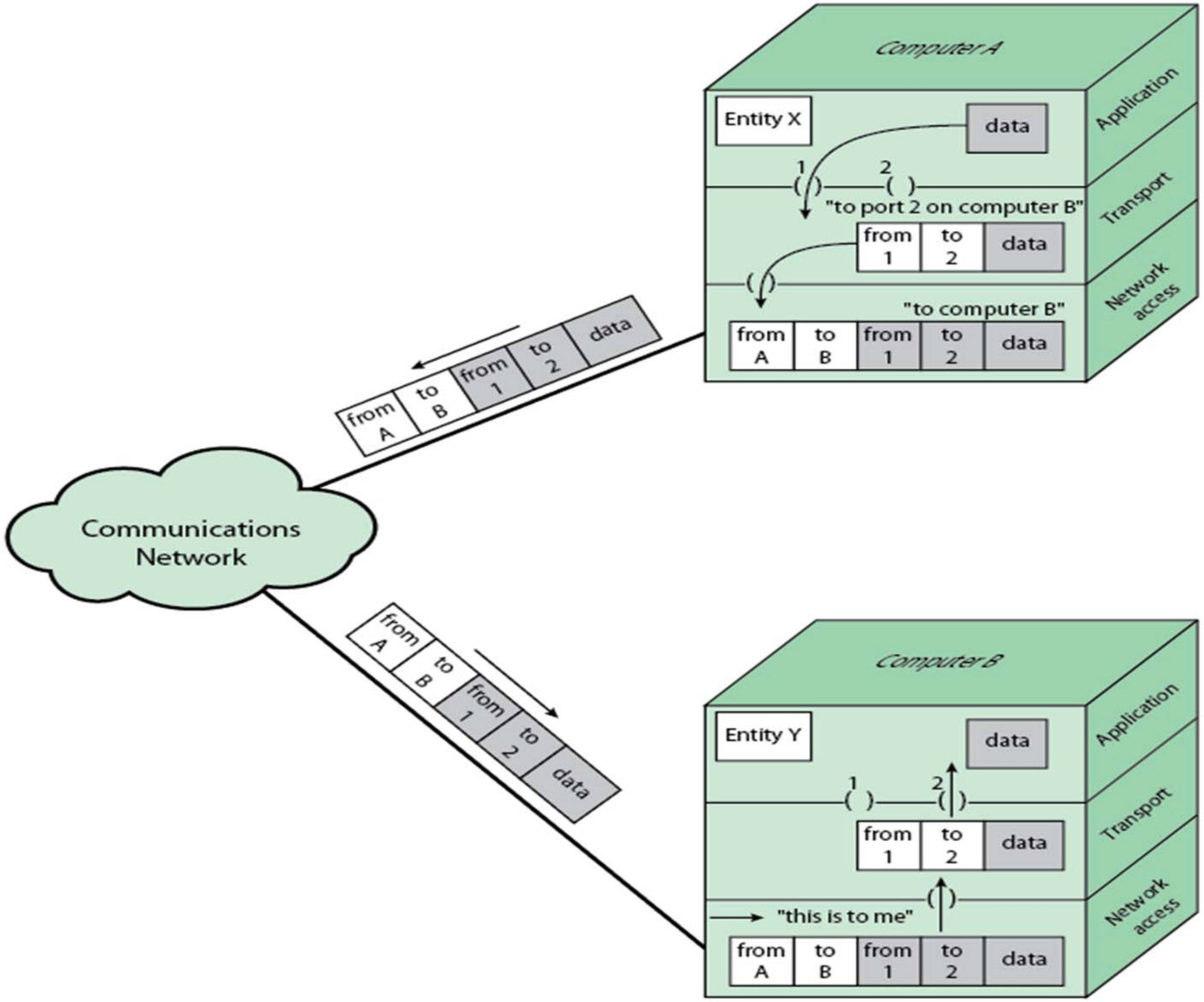
- Arquitectura ISO/OSI



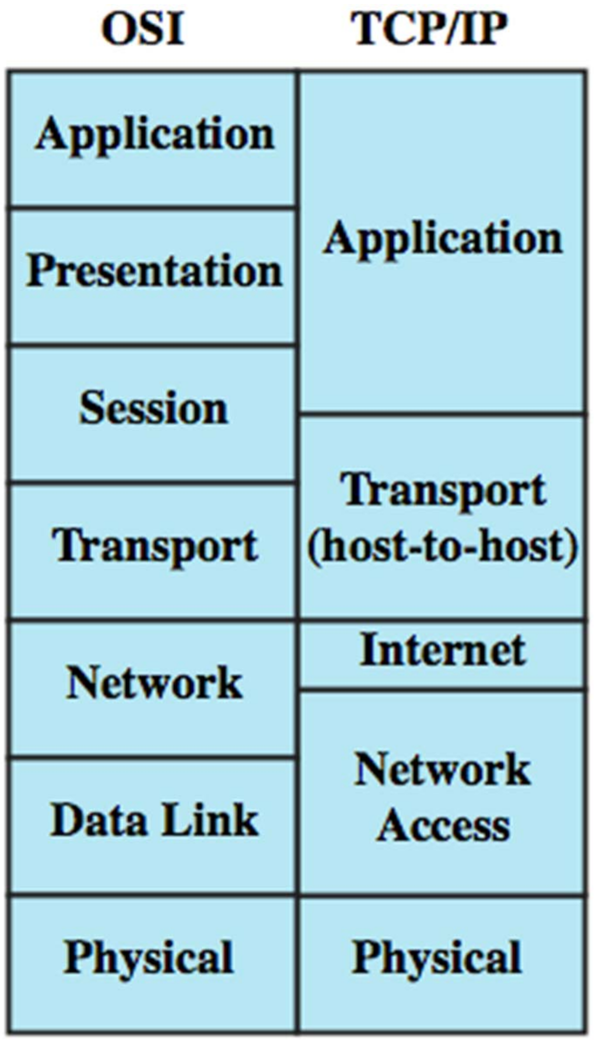
Protocol Architecture and Networks



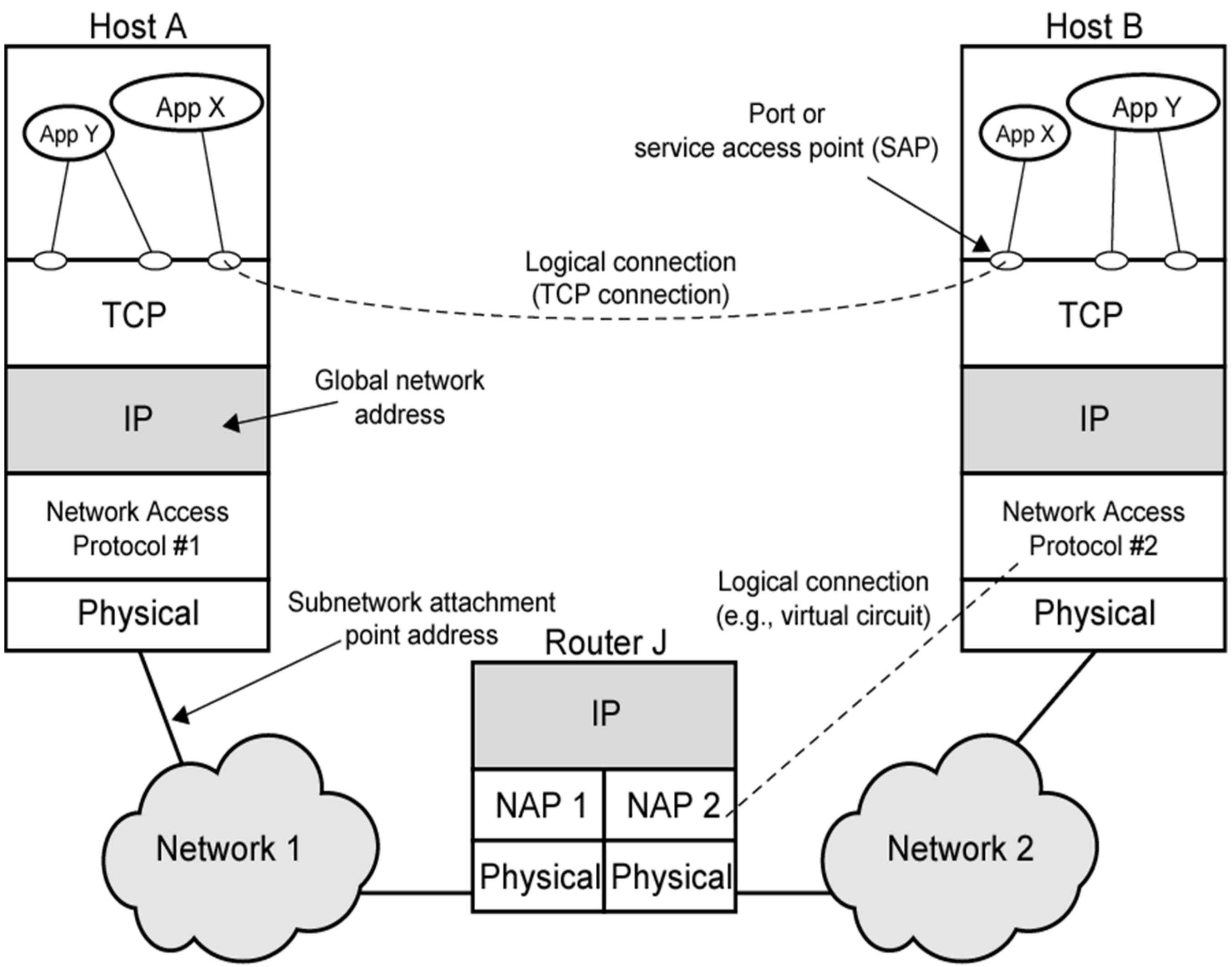
Protocols in a Simplified Architecture



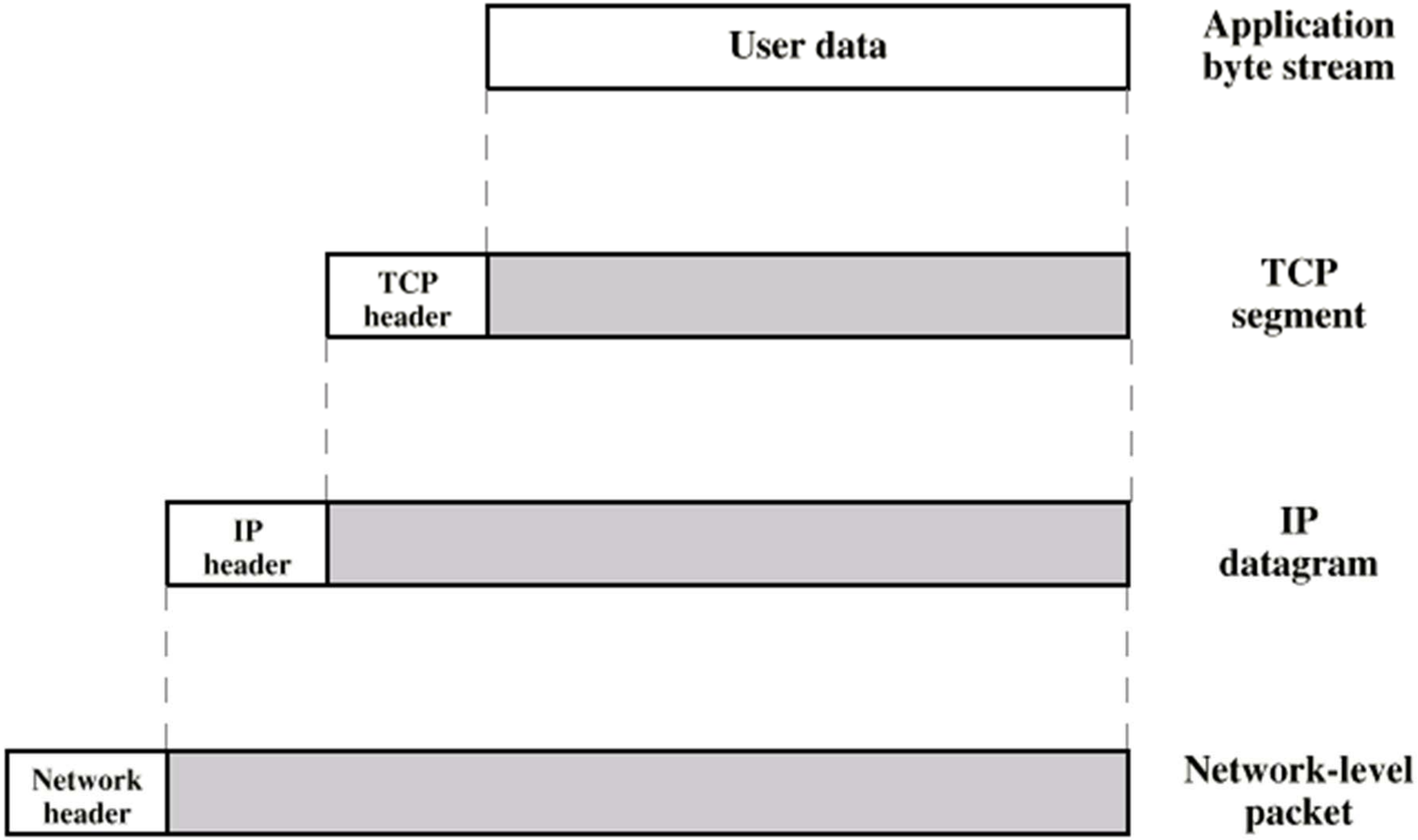
OSI v TCP/IP


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

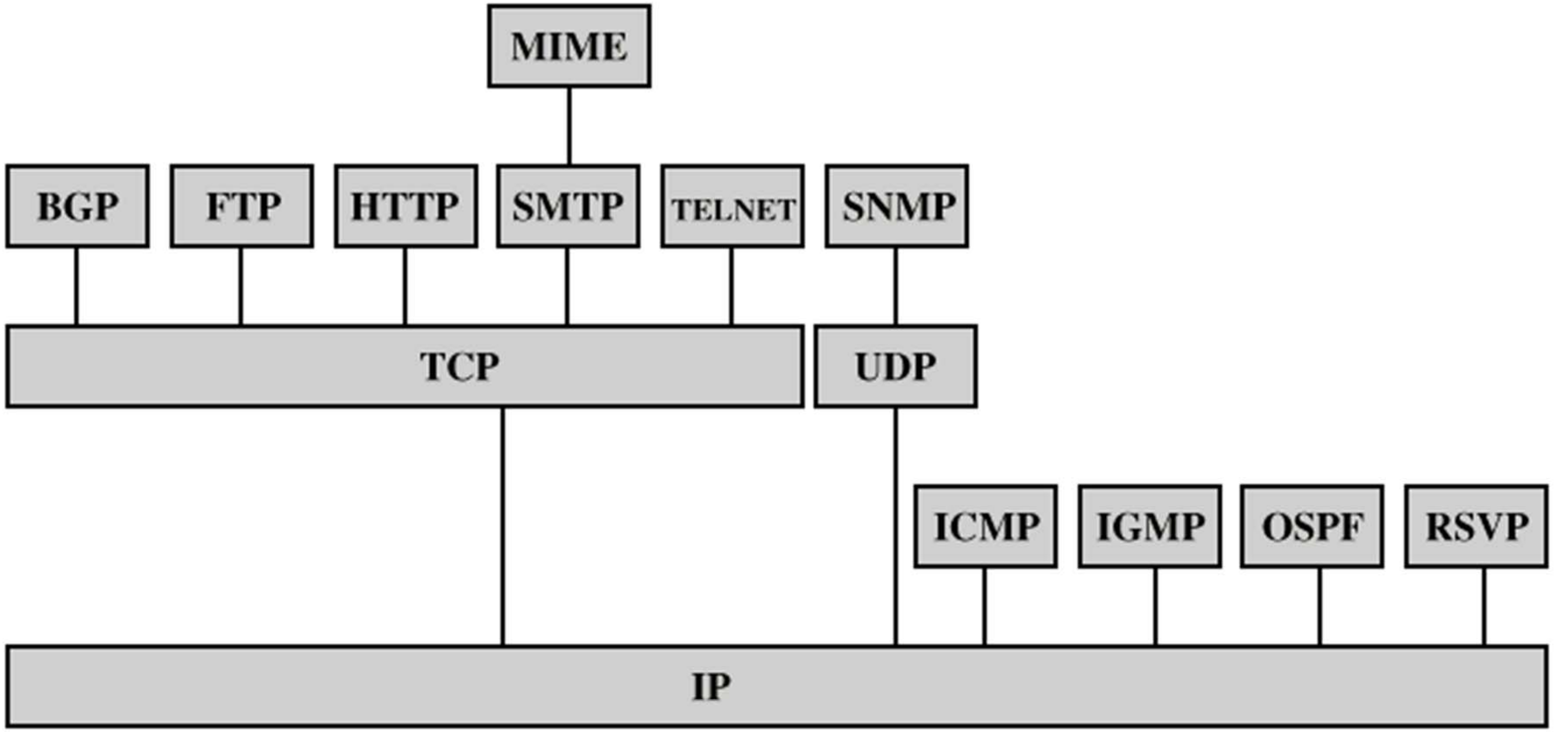
Operation of TCP/IP



Operation of TCP/IP



TCP/IP Protocols



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

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2.2 Protocols control d'enllaç

a la unitat de dades de nivel 2 li diem trama, i a la de nivell 3 paquet

Data Link Control Protocols

- when sending data, to achieve control, a layer of logic is added above the Physical layer
  - data link control or a data link control protocol
- to manage exchange of data over a link:
  - frame synchronization
  - flow control
  - error control
  - addressing @ a nivell 2.
  - control and data es diferència entre control(per gestionar l'enllaç) i dades
  - link management

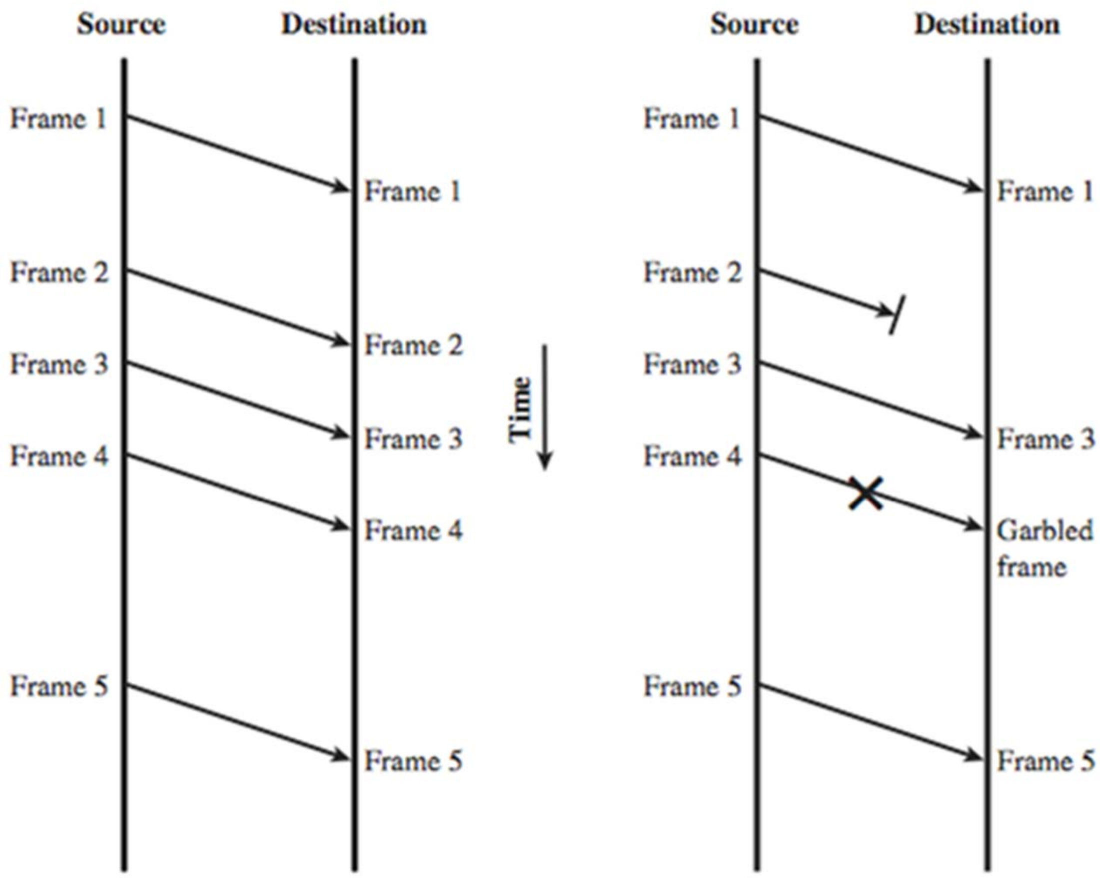
* iconvenient d'ethernet:
a grans distàncies no funcionen
(+ de 100 metres), per problemes
amb CSMA/CD ...

Flow Control

la màxima velocitat a la que es pot propagar una senyal en un medi és la velocitat de la llum en el buit, per cables... baixa una mica

- ensure sending entity does not overwhelm receiving entity
  - prevent buffer overflow (overflow --> pèrdua de dades)
- influenced by: SEMPRE BITS, MAI BYTES
  - transmission time $Tt = 1 / Vt$
    - *time taken to emit all bits into medium*
  - propagation time $Tp = 1 / Vp$ velocitat de propagació Vp = bits / s
    - *time for a bit to traverse the link*
- assumption is all frames are successfully received with no frames lost or arriving with errors

Model of Frame Transmission



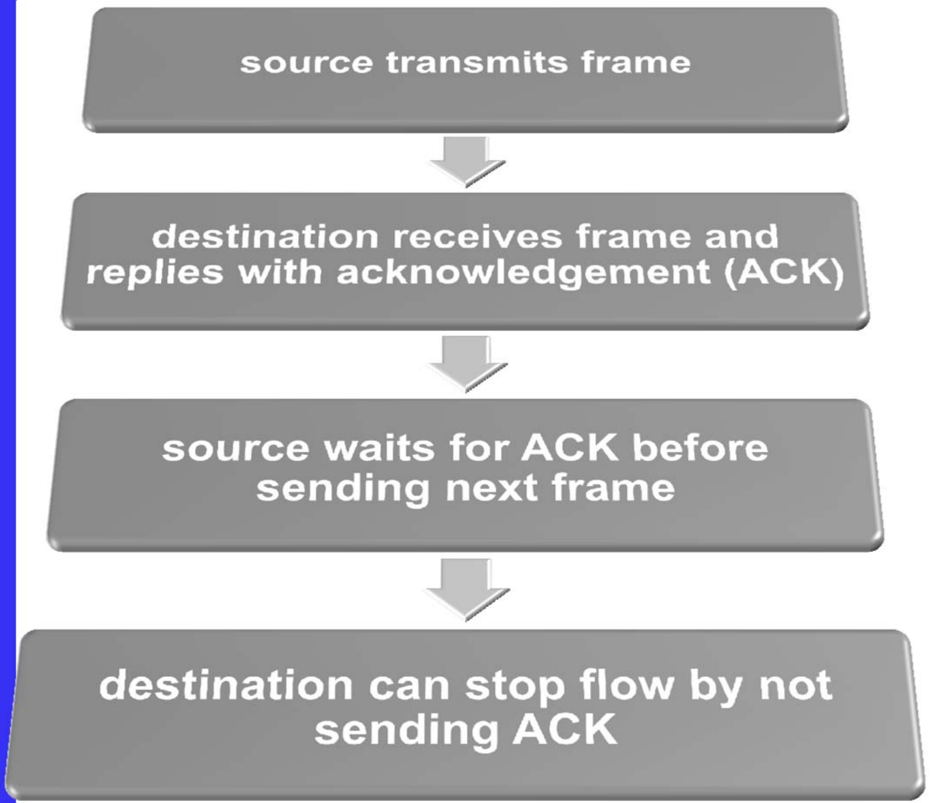
(a) Error-free transmission

(b) Transmission with losses and errors

Stop and Wait

timeout : temps de reacció davant problemes de no resposta
rl timeout minim és tt+tp*2

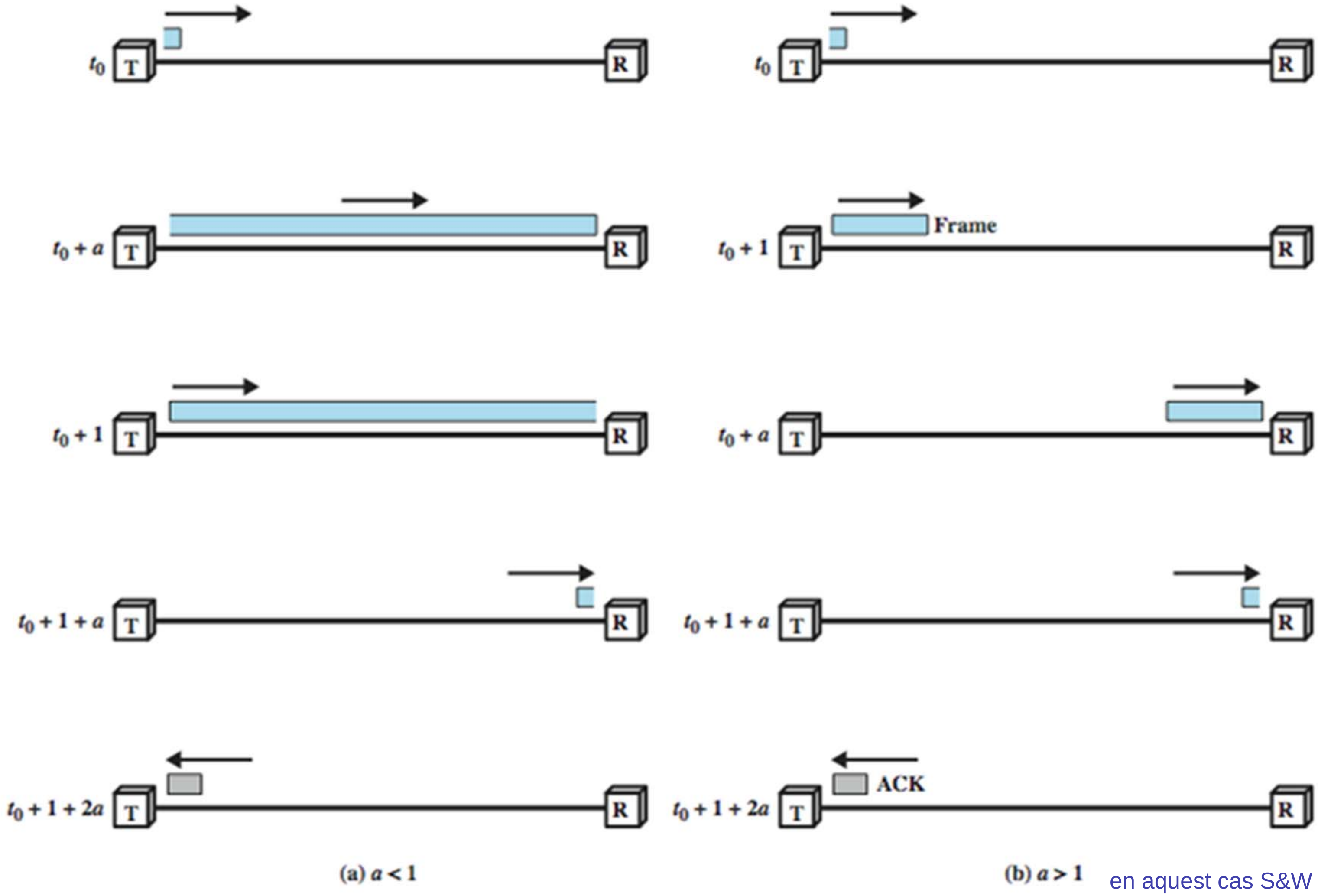
- simplest form of flow control



- 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

S&W és ineficient peruqè està molta estona la xarxa sense fer res

Stop and Wait Link Utilization



en aquest cas S&W
no és una bona opció

Tot el que no estigui en la numeració de trama d'una finestr no es pot transmetre o rebre.

Les trames es numeren, un nombre de sequencia identifica una trama, quan una trama s'envías' "ocupa" una posició de la finestra.

finestra: Transmissió --> indica els numeros de sequencia que es poden transmetre
Recepció --> indica els nmbres de sequencia que es poden rebre

el fet de numerar les trames ens permet augmentar el rendiment del sistema

Sliding Windows Flow Control

- allows multiple numbered frames to be in transit
  - receiver has buffer W long
  - transmitter sends up to W frames without ACK
  - ACK includes number of next frame expected
  - sequence number is bounded by size of field (k)
    - *frames are numbered modulo 2^k*
    - *giving max window size of up to $2^k - 1$*--> sino podriem tenir 2 trames amb el mateix numero pendents de ack
  - receiver can ACK frames without permitting further transmission (Receive Not Ready)
  - must send a normal acknowledge to resume
- if have full-duplex link, can piggyback ACKs

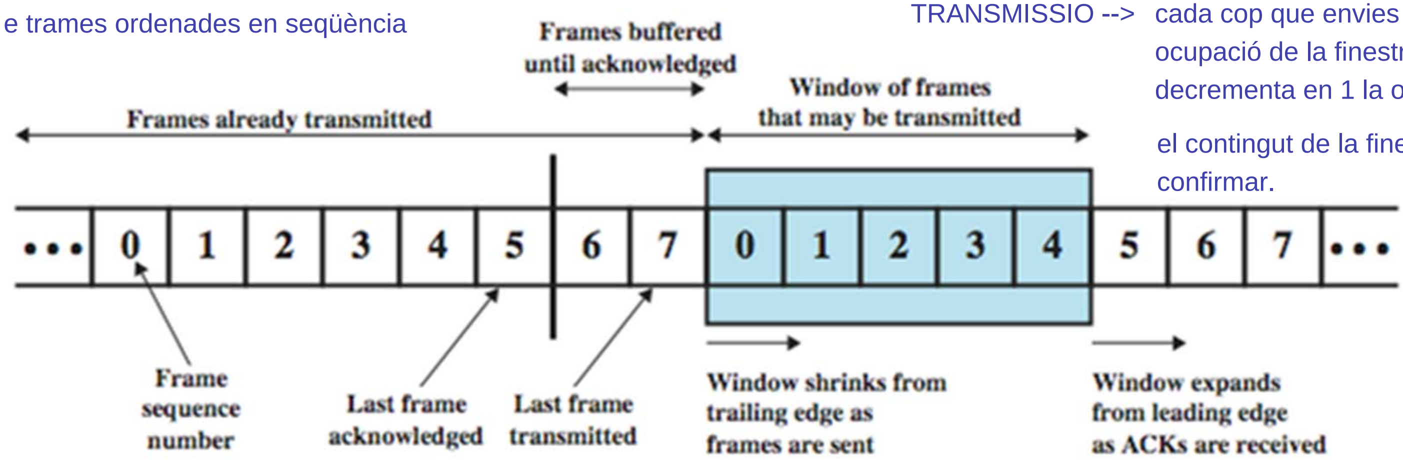
Sliding Window Diagram

el mecanisme de finestra és un mecanisme de control de FLUX

tot es basa e trames ordenades en seqüència

TRANSMISSIO --> cada cop que envies una trama, s'incrementa ne 1 la ocupació de la finestra, i quan es rep un ack es decrementa en 1 la ocupació,

el contingut de la finestra, són les trames pendents de confirmar.



com les tramens estan ordenades, es desplaça progresivament.

(a) Sender's perspective

finestra optima: la que permet que s'enviin el nombre maxim de trames fins que t arriba un ACK

Wopt = Tout / Tt

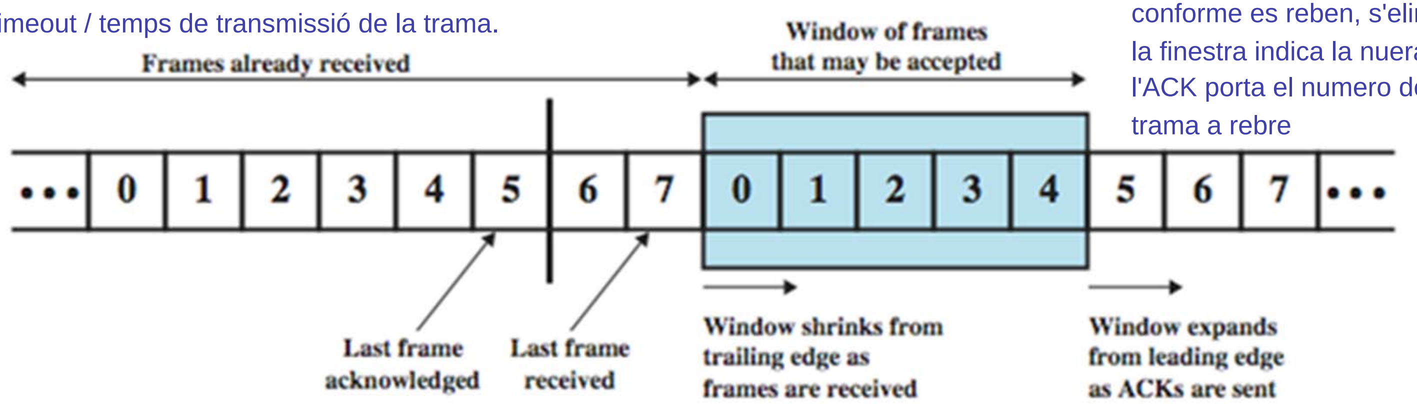
Wmaxopt = timeout / temps de transmissió de la trama.

RECEPCIÓ -->

conforme es reben, s'eliminen de la finestra

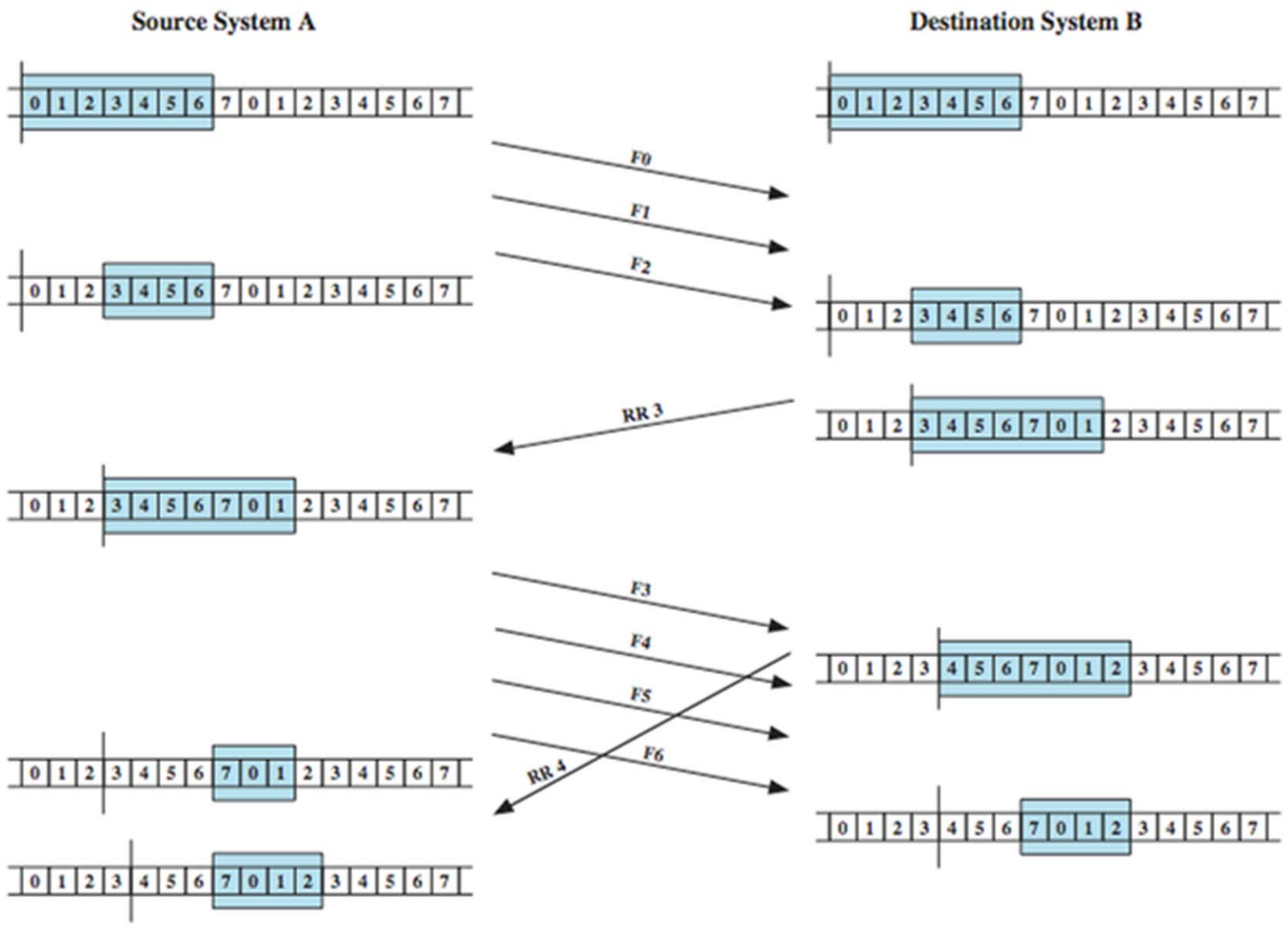
la finestra indica la nueració de les trames a rebre.

l'ACK porta el numero de la següent trama a rebre



(b) Receiver's perspective

Sliding Window Example



és un mecanisme de control d'errors, el cotrol d'errors és molt important a nivell2

Automatic Repeat Request (ARQ)

- collective name for error control mechanisms
- effect of ARQ is to turn an unreliable data link into a reliable one
- versions of ARQ are:
  - stop-and-wait es pot fer servir en distàncies molt curtes i velocitats de transmissió baixes (però es fa servir molt poc)
  - go-back-N és el mètode que es fa servir més. es fa servir fins a un nombre de sequència, i tot fins a un nombre està confirmat
  - selective-reject es fa servir en distàncies llargues (ex: satèl·lits). però és molt complexe ja que les trames no van necessariament ordenades

Stop and Wait ARQ

- source transmits single frame
- waits for ACK
  - *no other data can be sent until destination's reply arrives*
- if frame received is damaged, discard it
  - transmitter has timeout
  - if no ACK within timeout, retransmit
- if ACK is damaged, transmitter will not recognize
  - transmitter will retransmit
  - receiver gets two copies of frame
  - use alternate numbering and ACK0 / ACK1

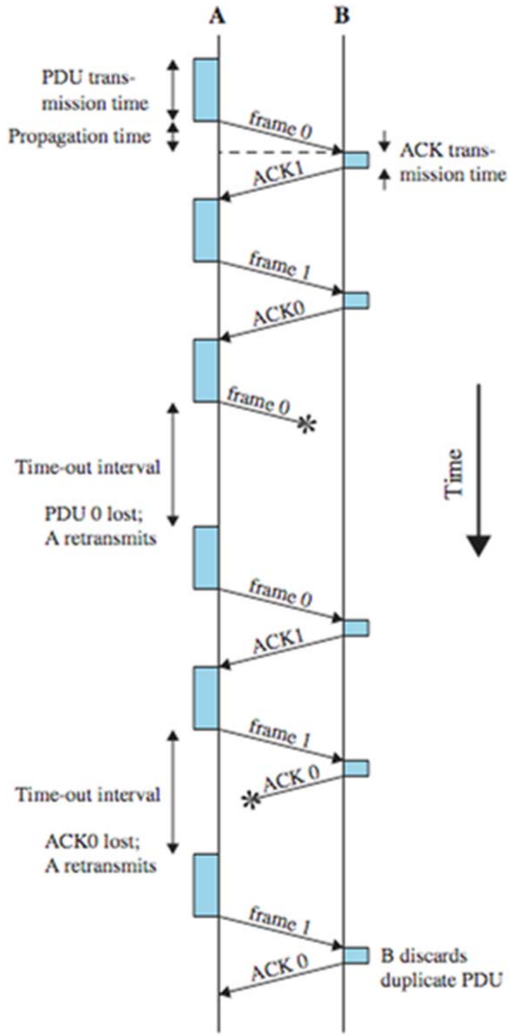
Stop and Wait ARQ

pros

- simplistic

cons

- inefficient



Go-Back-N ARQ

- most commonly used error control
- based on sliding-window
- use window size to control number of outstanding frames
- if no error, ACK as usual
- if error, reply with rejection
  - destination will discard that frame and all future frames until frame in error is received correctly
  - transmitter must go back and retransmit that frame and all subsequent frames

Selective-Reject (ARQ)

cada trama té el seu pròpi acceptament i rebuig. Sembla més eficient que goBackN però és molt més complicat

- also called selective retransmission
- only rejected frames are retransmitted
- subsequent frames are accepted by the receiver and buffered
- minimizes retransmission
- receiver must maintain large enough buffer
- more complex logic in transmitter
  - less widely used
- useful for satellite links with long propagation delays

High Level Data Link Control (HDLC)

és el protocol més important de transmissió de dades de nivell 2, està implementat a tot arreu

sistema de funcionament master/slave

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

  les esatacions primaries són les master (pot haver-ne 1)

- Secondary - under control of primary station

  són les slave, (1 o mes)

- Combined - issues commands and responses

  simultaniament són primaria i secundaria només hi ha 2 esatcions Es el que més s'implementa avui en dia

link configurations

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

modes de consiguració:
només es fan servir els 2 primers

HDLC Transfer Modes

Normal Response Mode (NRM)

- used with an unbalanced configuration
- primary initiates transfer

per no-balancejades (primari - secundaris)

Asynchronous Balanced Mode (ABM)

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

per balançejades

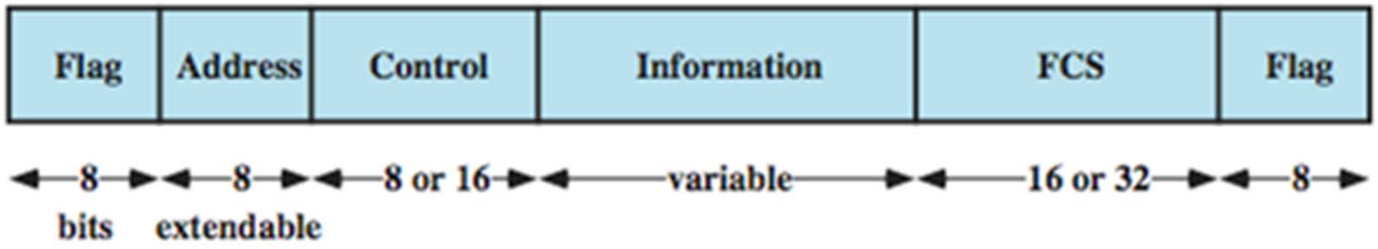
Asynchronous Response Mode (ARM)

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

moltes vegades a nivell 2 no farem control d'errors: en el cas que esperèm que el faci el nivell 4, o en el cas que no hi hàgi errors.

HDLC Frame Structure

la trama té header (capçelera) i després de la informació un tailer ("capçelera" al final)



(a) Frame format

- uses synchronous transmission la sincronització la fa emb els flags
- transmissions are in the form of frames
- single frame format used

Flag Fields and Bit Stuffing

- delimit frame at both ends with 01111110 aquests 8 bits són un flag
- 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

cada 5 1s seguits fora del flag, el transmissor cola un 0 per evitar que hi hagi els 6 seguits que marquen els flags.I el receptor elimina els 0 que hi a després de cada 5 1s. com que ha estat insertat, no afecta al contingut del missage.
· inonvenients:
s'han d'enviar més dades
es perden els octets

Original Pattern:

111111111111011111101111110

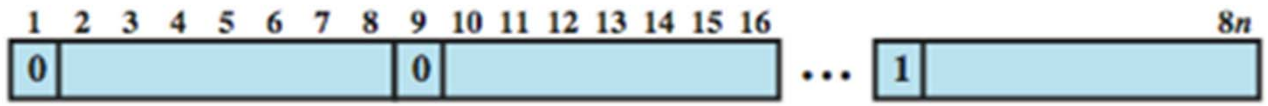
After bit-stuffing

1111101111101101111101011111010

no hi ha un camp per @origen i un per destí, només n'hi ha una:
* en el cas de les primàries/combinades s'envien comandes (envien @destí)
* en el cas de les secundaries/combinades s'envien respostes (envien @origen)
* les combinades envien la seva@ o la@ de l'altre (només n'i ha 2) depenent de si envien comandes o respostes

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



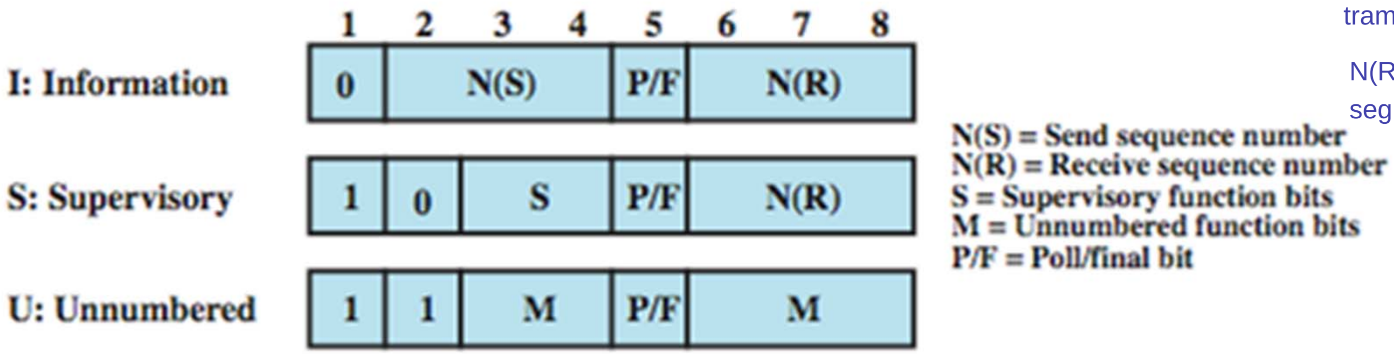
(b) Extended Address Field

Control Field

el fa servir per fer el control de flux i el control d' errors

N(S) nombre de seqüència de la trama

N(R) nombre de seq. de la seguent trama uqe s'espera rebre



(c) 8-bit control field format

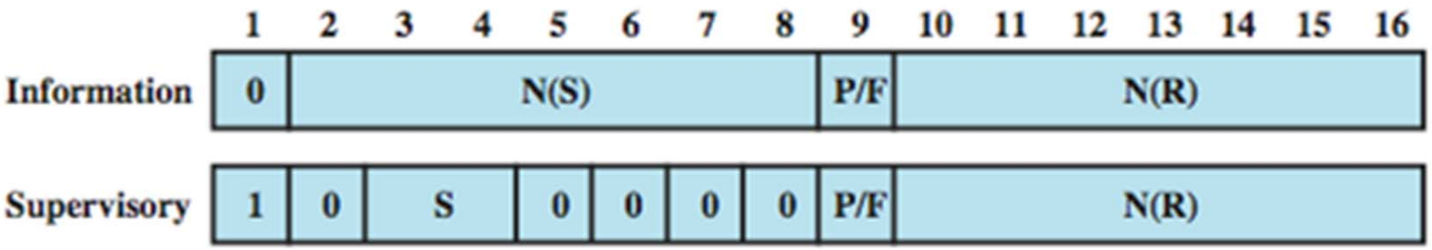
- different frame types
  - Information - data transmitted to user (next layer up)
    - *flow and error control piggybacked on information frames*
  - Supervisory - ARQ when piggyback is not used
  - Unnumbered - supplementary link control functions
- first 1-2 bits of control field identify frame type

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

així és la trama per al format de 128bits

i les trames unnumbered no cavien de format perque ja de per si no porten nuero



(d) 16-bit control field format

Information and Frame Check Sequence (FCS) Fields

es treballa amb octets però no hi ha cap problema amb el bit stuffing,

Information Field

soldra ser un paquet IP

- **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

- either side may request by issuing one of the six set-mode commands

s'inicialitzen les variables: numeració i finestres

Data Transfer

- with flow and error control
- using both I and S-frames (RR, RNR, REJ, SREJ)

Disconnect

- when fault noted or at request of higher-layer user
- sends a disconnect (DISC) frame

només les estacions primàries o combinades poden fer una descnnexió

Commands and Responses (1)

Name	Command/ Response	Description
Information (I)	C/R	Exchange user data
Supervisory (S)		
Receive ready (RR) ACK normal	C/R	Positive acknowledgment; ready to receive I-frame
Receive not ready (RNR) confirma però diu que no envii més. (control de flux)	C/R	Positive acknowledgment; not ready to receive
Reject (REJ) indica que el que ha rebut a partir de la trama indicada no és vàlid	C/R	Negative acknowledgment; go back N
Selective reject (SREJ)	C/R	Negative acknowledgment; selective reject

(només es fa servir per ARQ selective)

"intercanvi de trames no numerades --> stop & wait"
Poll/select --> NRM

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) confirmació no numerada	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

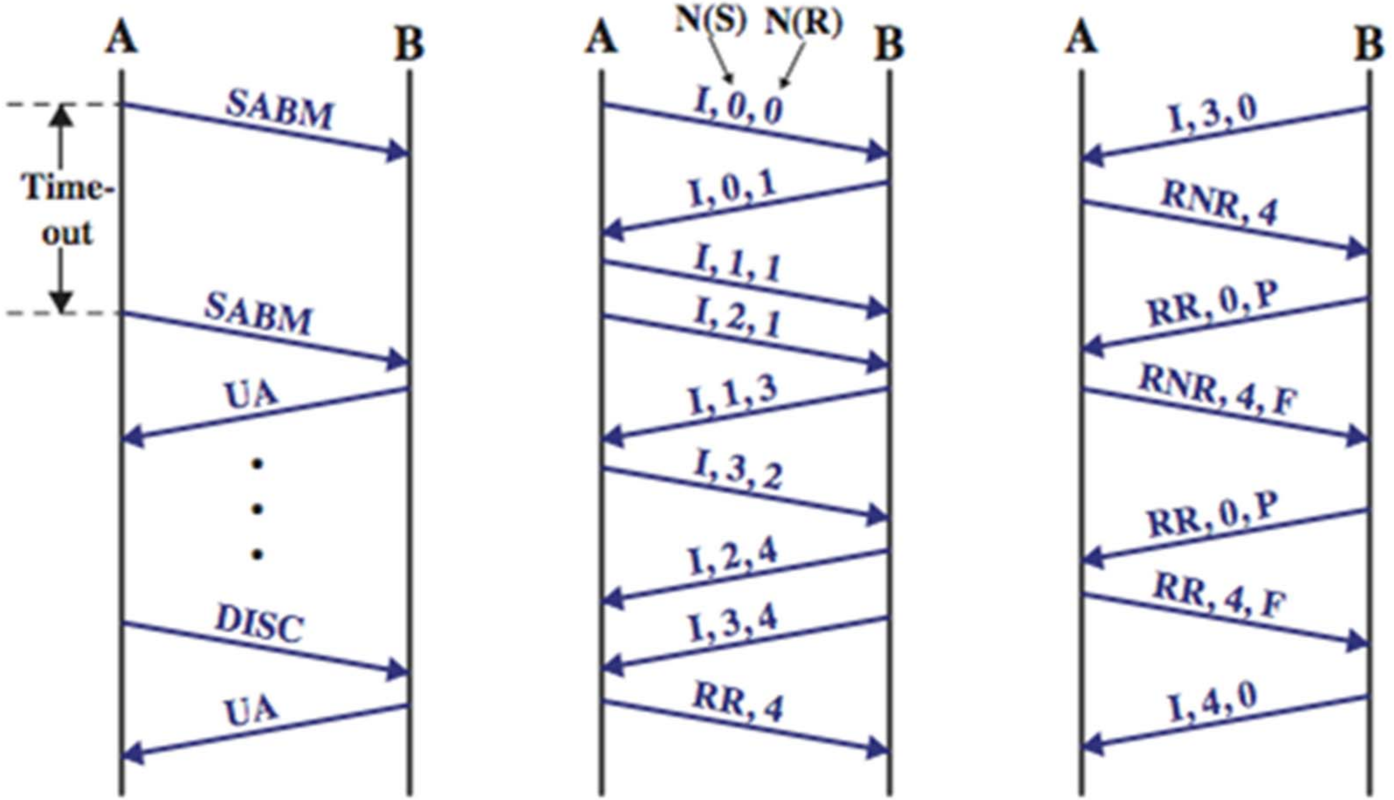
les que porten una E al final, indinquen EXTENDED que es el mode de 128 bits

es fa servir quan hi ha errors raros i es fa un reset desde 0,
EL més habitual és que alguna estació confirmi trames que la altra no ha enviat.

HDLC Operation Example

són estacions combinades

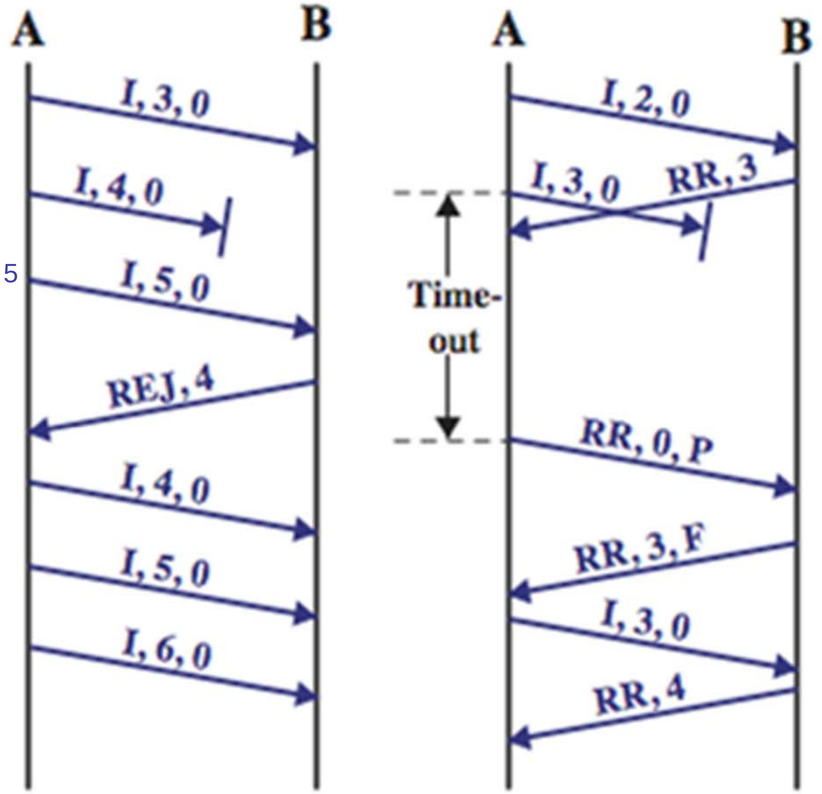
N(s) nombre de la trama que s'està enviant
N(r) nombre de la que s'espera rebre



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

HDLC Operation Example

tot i que ha rebut la 5 diu que li falta la 4, així uqe descarta la 5 i torna a demanar tot a partir de la 4



(d) Reject recovery (e) Timeout recovery

Different types of HDLC

- Nivell 2 X.25
- Senyalització ISDN
- Subnivell LLC LANs
- Frame Relay
  - Control
  - Nucli

Flag	Address	Control	Information	FCS	Flag
8	8n	8 or 16	variable	16 or 32	8

(a) HDLC, LAPB

Flag	Address	Control	Information	FCS	Flag
8	16	16*	variable	16	8

(b) LAPD

MAC control	Dest. MAC address	Source MAC address	DSAP	SSAP	LLC control	Info.	FCS
variable	16 or 48	16 or 48	8	8	16*	variable	32

(c) LLC/MAC

Flag	Address	Control	Information	FCS	Flag
8	16, 24, or 32	16*	variable	16	8

(d) LAPF (control)

Flag	Address	Information	FCS	Flag
8	16, 24, or 32	variable	16	8

(e) LAPF (core)

2.3 Mitjans de transmissió

PDF tema2-fins2.1

Design Factors Determining Data Rate and Distance

bandwidth

- higher bandwidth gives higher data rate

transmission impairments

- impairments, such as attenuation, limit the distance

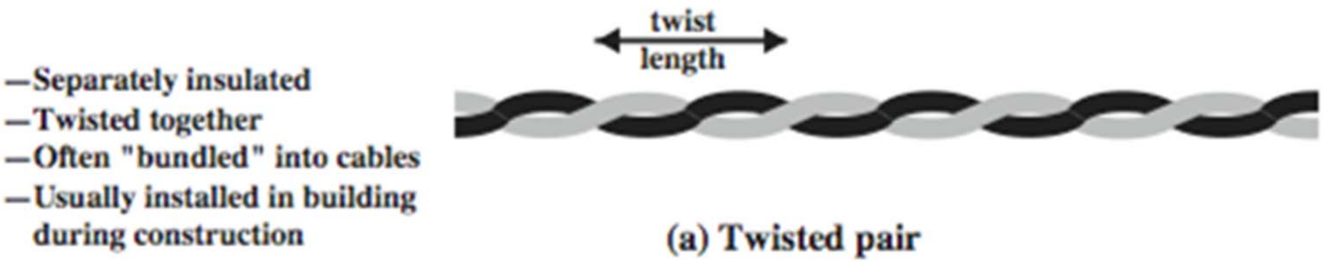
interference

- overlapping frequency bands can distort or wipe out a signal

number of receivers

- more receivers introduces more attenuation

Twisted Pair



(a) Twisted pair

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

Unshielded Twisted Pair (UTP)

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

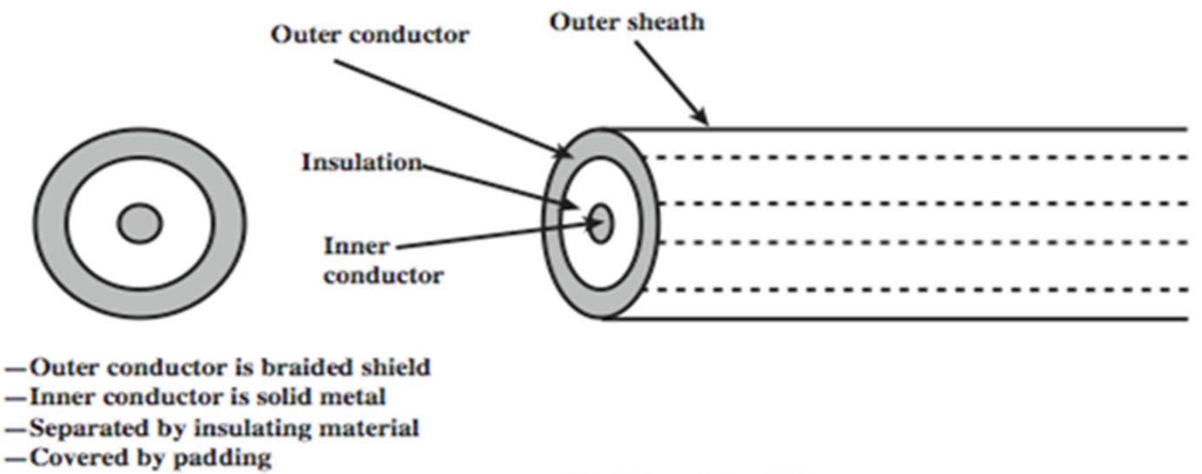
Shielded Twisted Pair (STP)

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

UTP Categories

	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

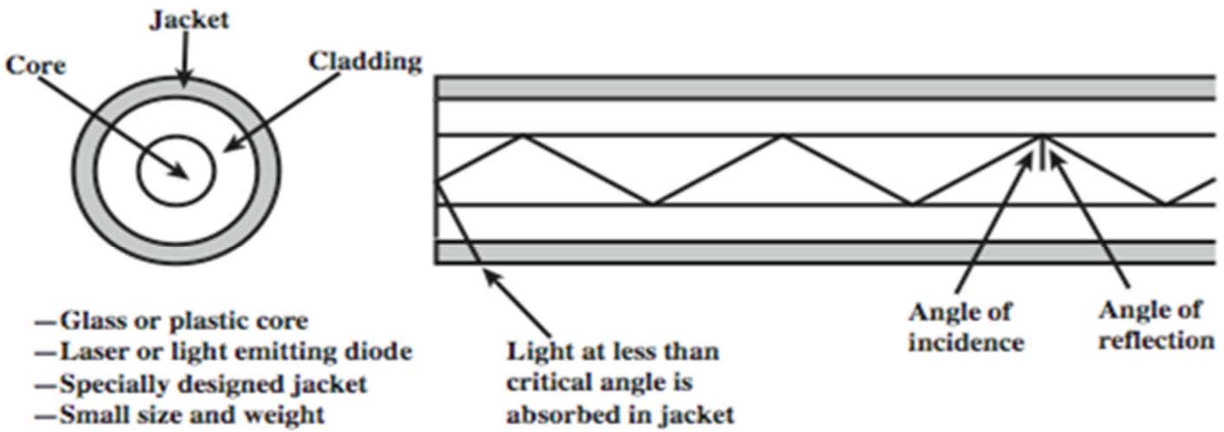


(b) Coaxial cable

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

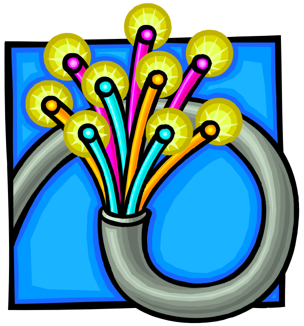


(c) Optical fiber

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

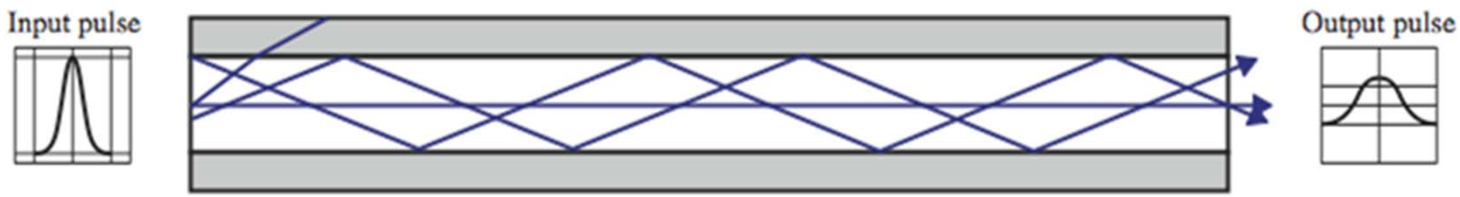
- **various glasses and plastics can be used to make optical fibers**
- **has a cylindrical shape with three sections – core, cladding, jacket**
- **widely used in long distance telecommunications**
- **performance, price and advantages have made it popular to use**

Optical Fiber - Benefits

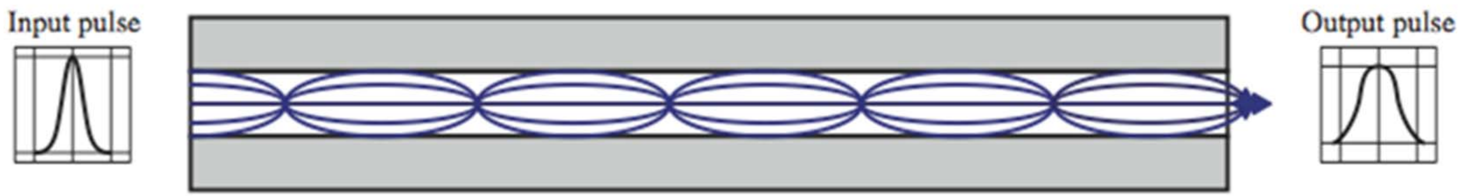


- greater capacity
  - data rates of hundreds of Gbps
- smaller size and lighter weight
  - considerably thinner than coaxial or twisted pair cable
  - reduces structural support requirements
- lower attenuation
- electromagnetic isolation
  - not vulnerable to interference, impulse noise, or crosstalk
  - high degree of security from eavesdropping
- greater repeater spacing
  - lower cost and fewer sources of error

Optical Fiber Transmission Modes



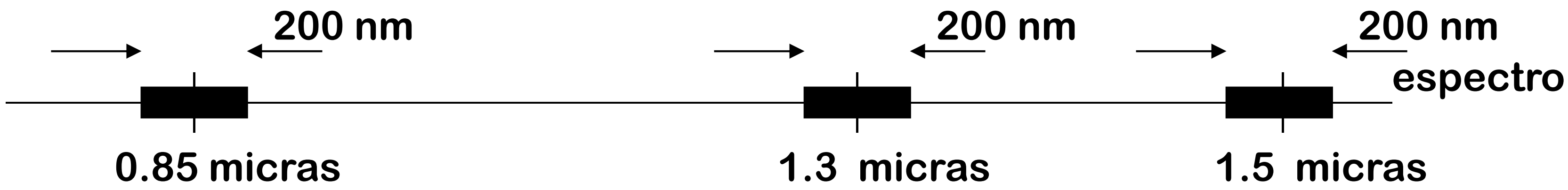
(a) Step-index multimode



(b) Graded-index multimode

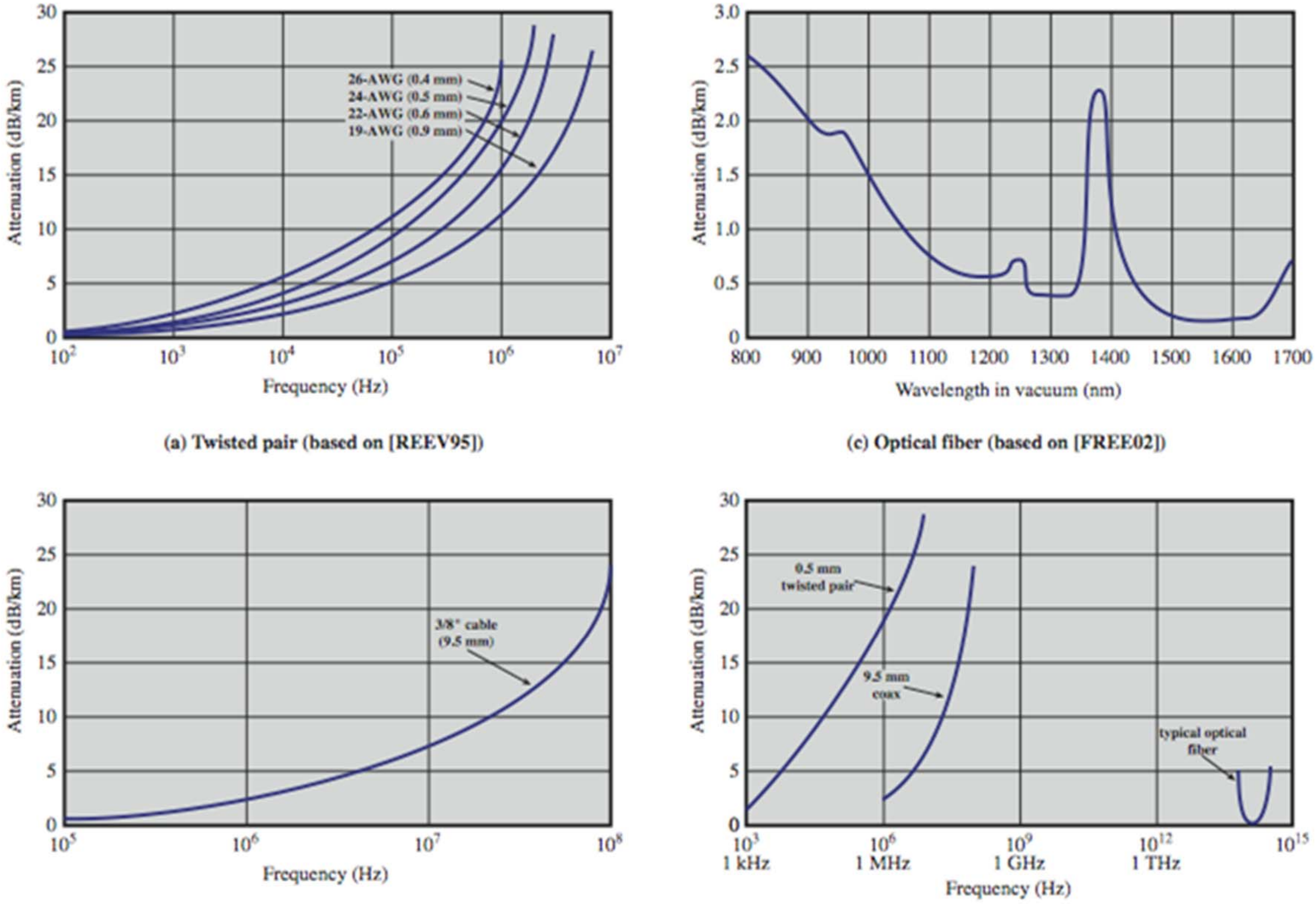
(c) Single mode

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

Attenuation in Guided Media



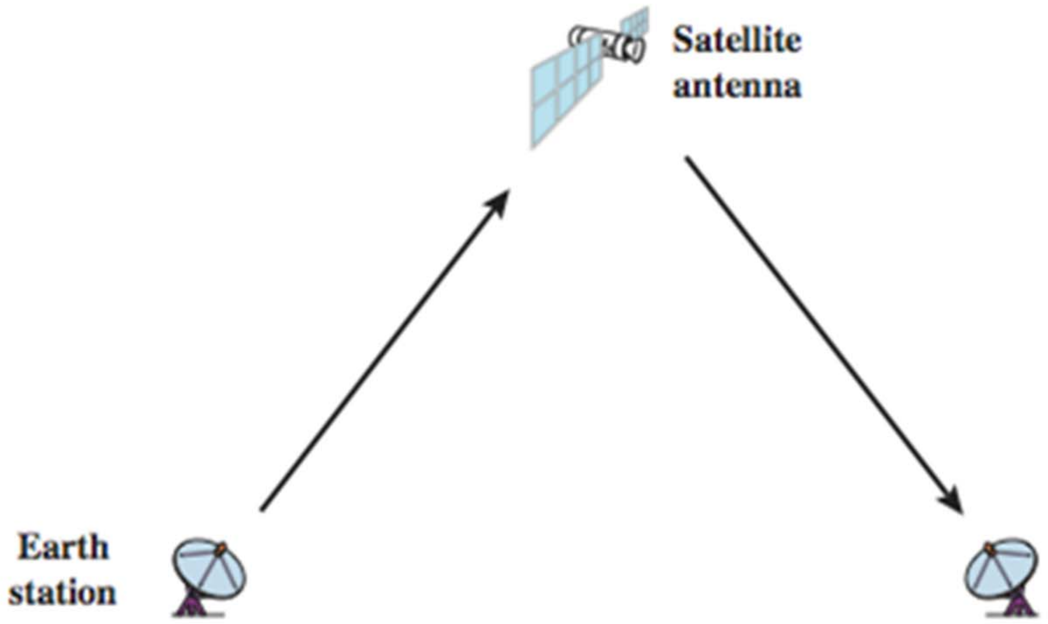
(a) Twisted pair (based on [REEV95])

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

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

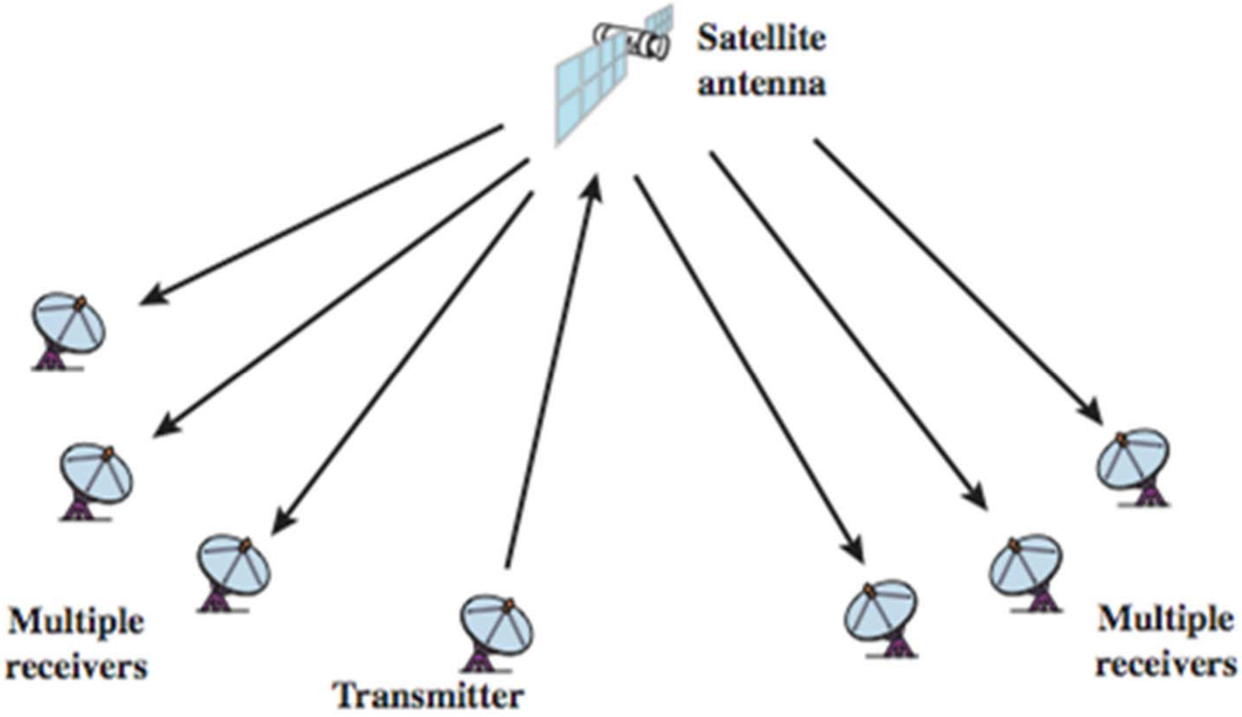
(d) Composite graph

Satellite Point-to-Point Link



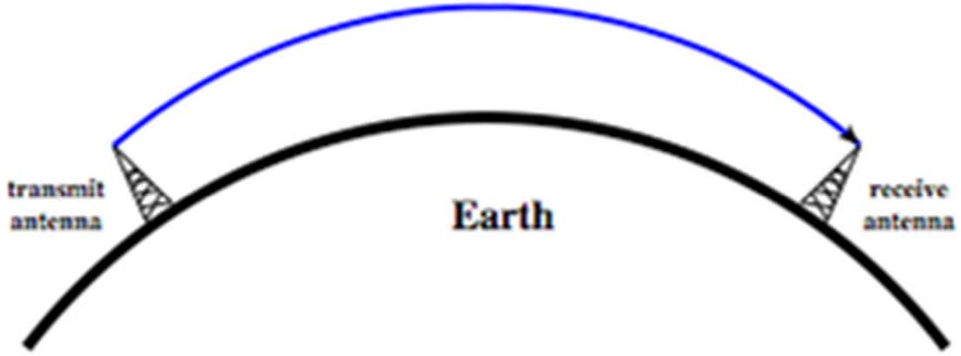
(a) Point-to-point link

Satellite Broadcast Link



(b) Broadcast link

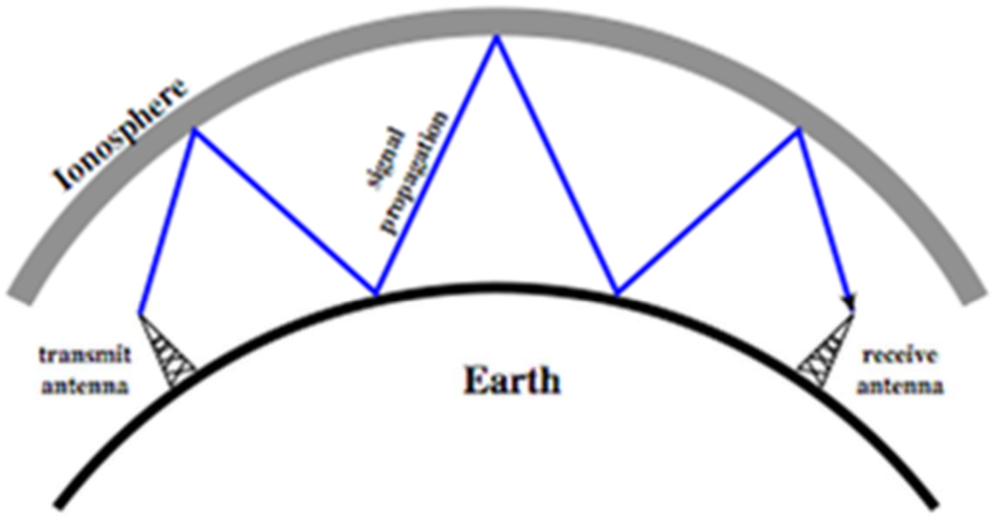
Wireless Propagation Ground Wave



(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

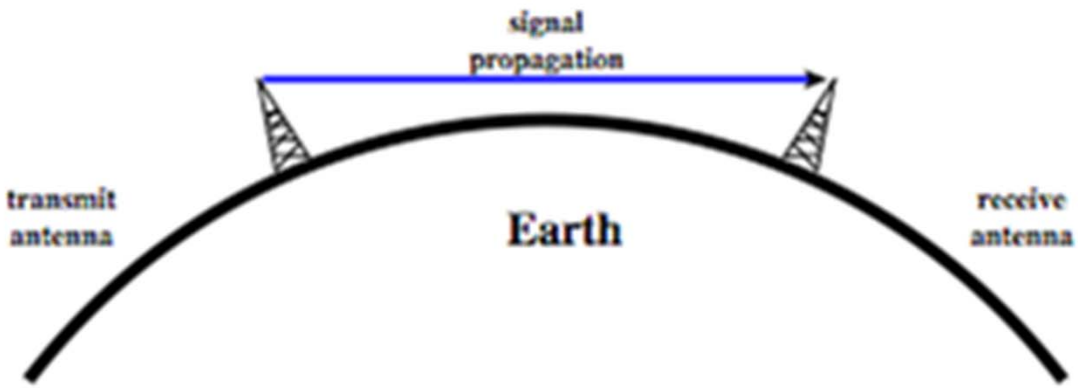
Wireless Propagation
Sky Wave



(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

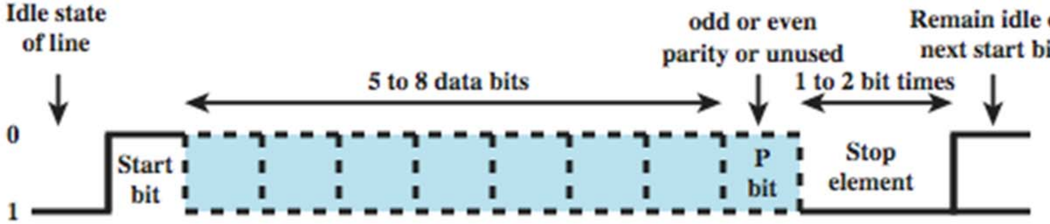


(c) Line-of-sight (LOS) propagation (above 30 MHz)

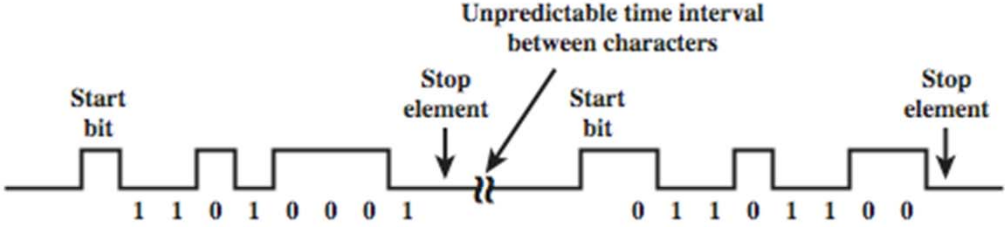
➢ **ground and sky wave propagation modes do not operate above 30 MHz - - communication must be by line of sight**

2.4 Tècniques comunicació de dades

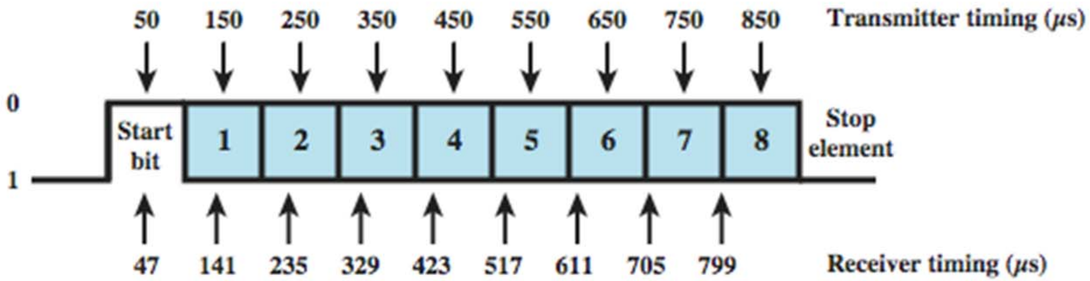
Asynchronous Transmission



(a) Character format



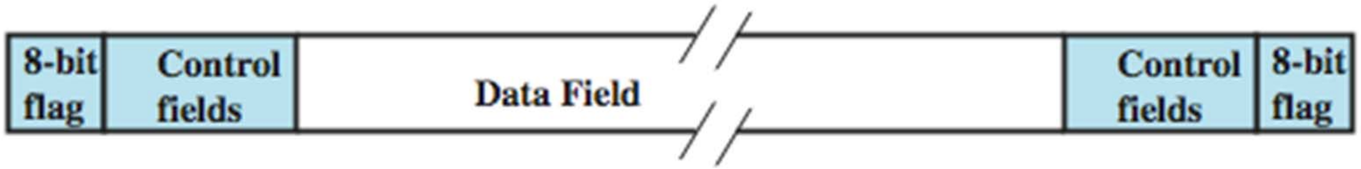
(b) 8-bit asynchronous character stream



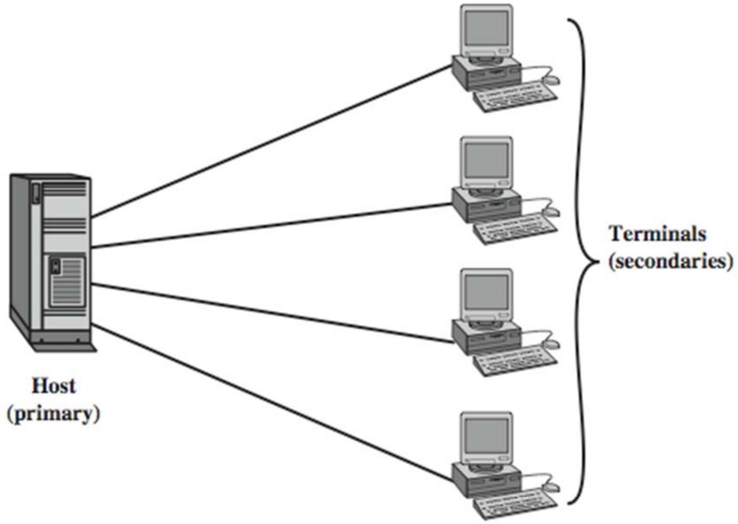
(c) Effect of timing error

Synchronous Transmission

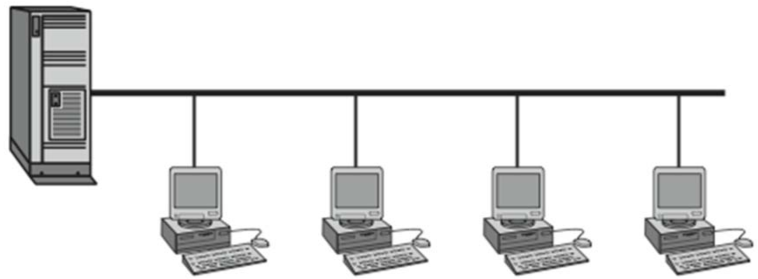
- block of data transmitted sent as a frame
- clocks must be synchronized
  - can use separate clock line
  - or embed clock signal in data
- need to indicate start and end of block
  - use preamble and postamble
- more efficient (lower overhead) than async



Line Configuration - Topology



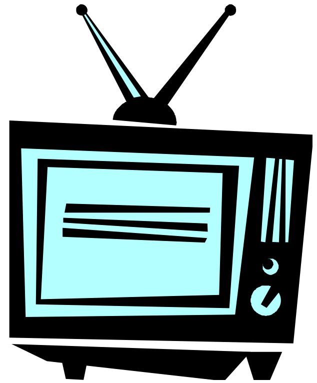
(a) Point-to-point



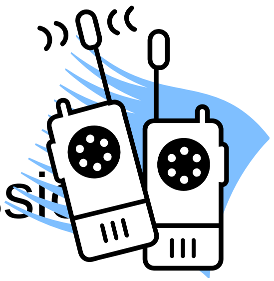
(b) Multipoint

Transmission Terminology

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



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



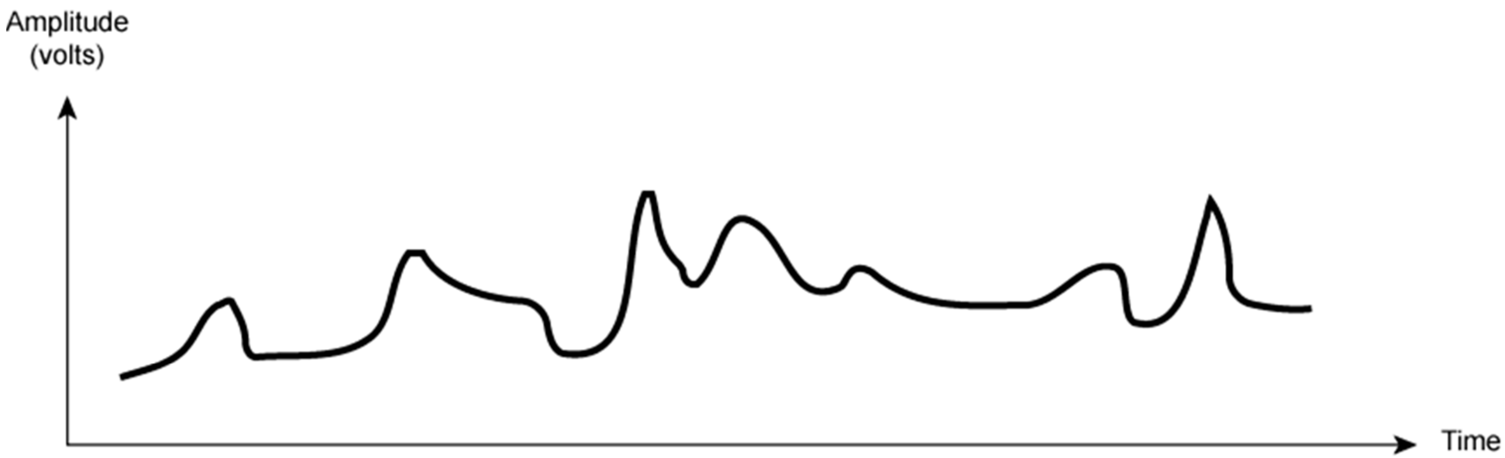
- **Full duplex**
  - simultaneous transmissi
    - *eg. telephone*

Frequency, Spectrum and Bandwidth

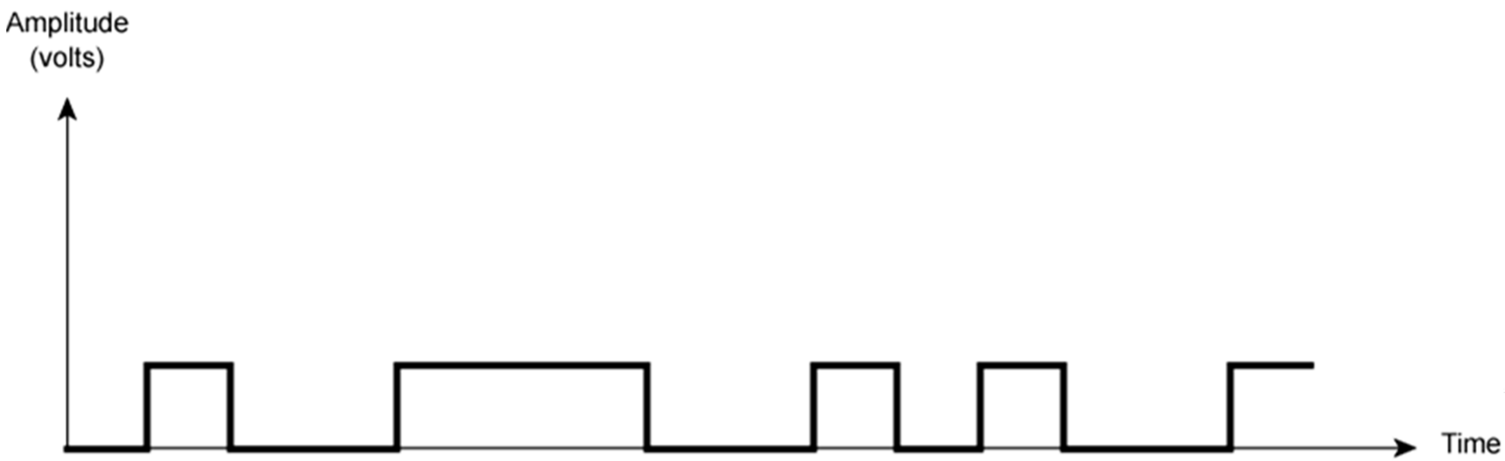
Time Domain Concepts

- **analog signal**
  - *signal intensity varies smoothly with no breaks*
- **digital signal**
  - *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*

Analog and Digital Signals

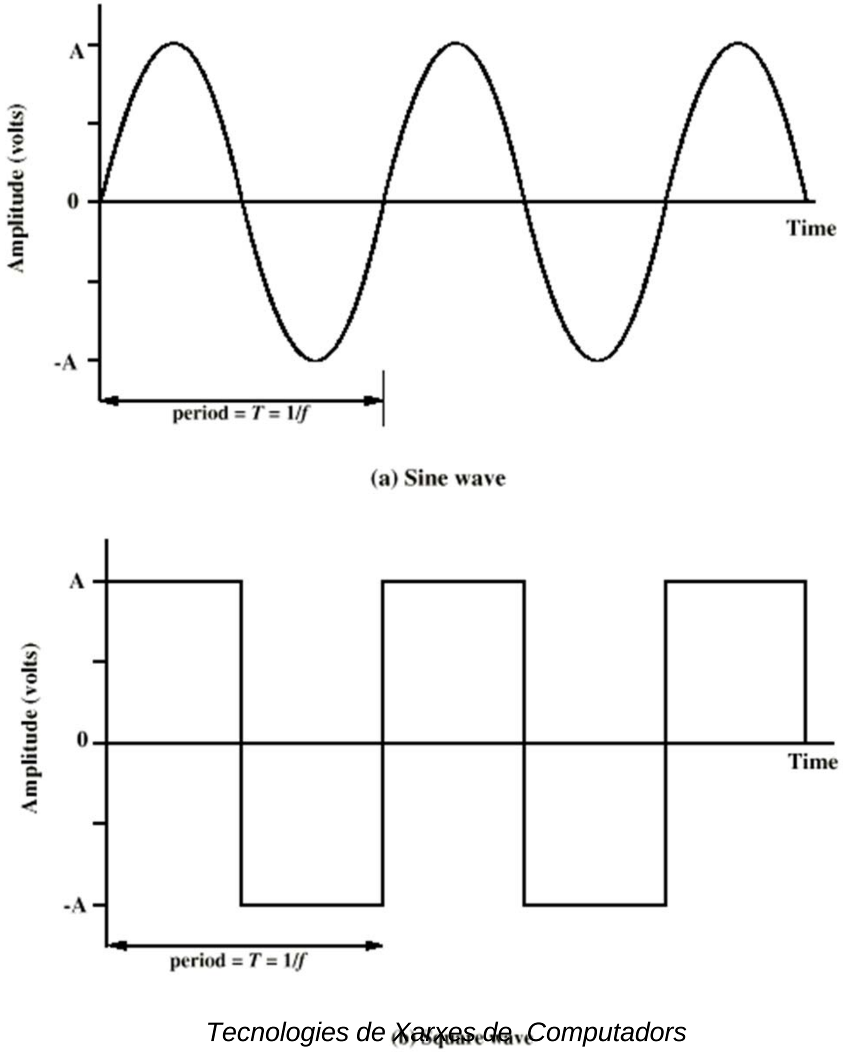


(a) Analog



(b) Digital

Periodic Signals

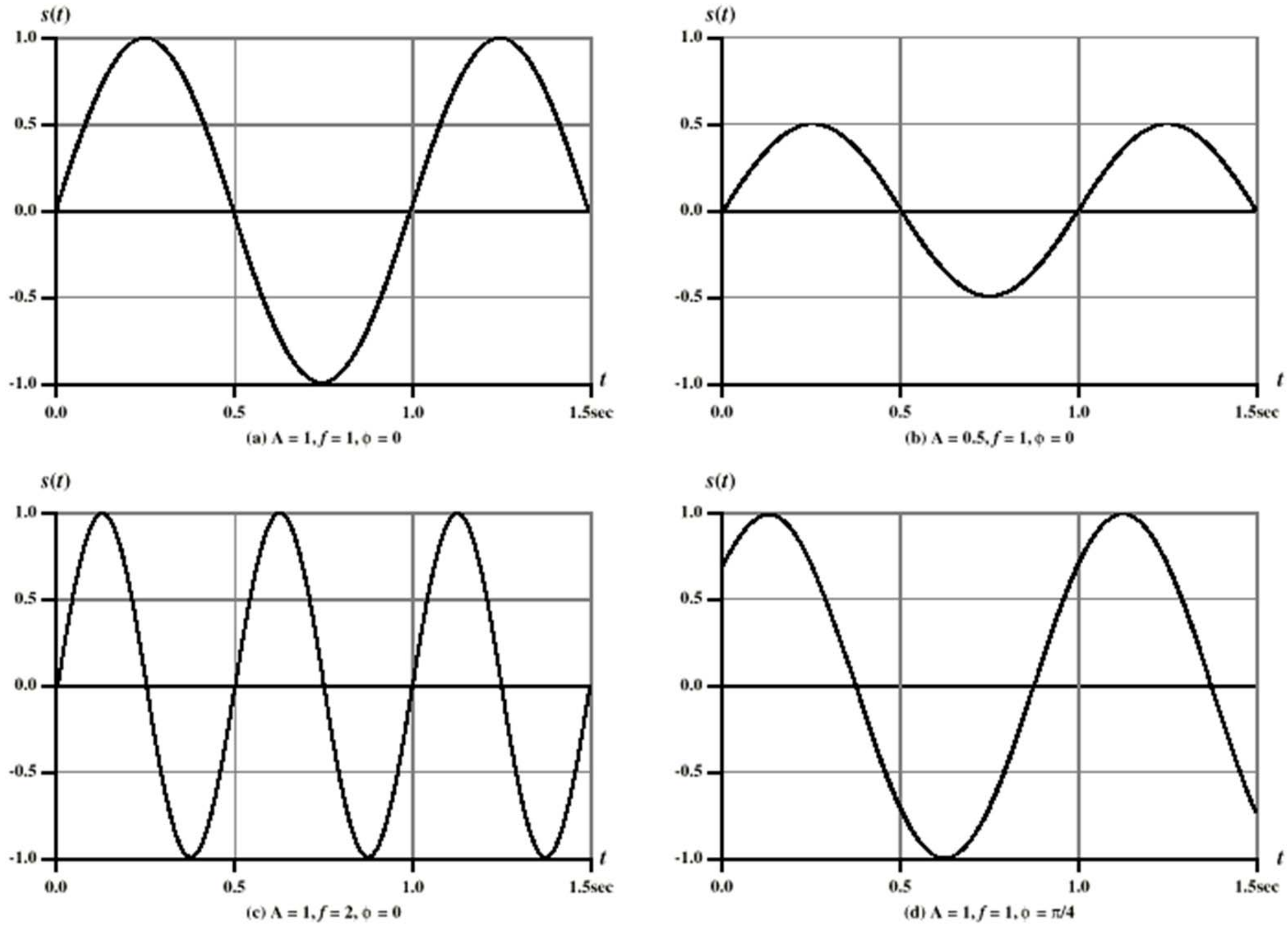


Sine Wave

(periodic continuous signal)

- **peak amplitude (A)**
  - maximum strength of signal
  - typically measured in volts
- **frequency (f)**
  - 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
$s(t) = A \sin(2\pi ft + \Phi)$

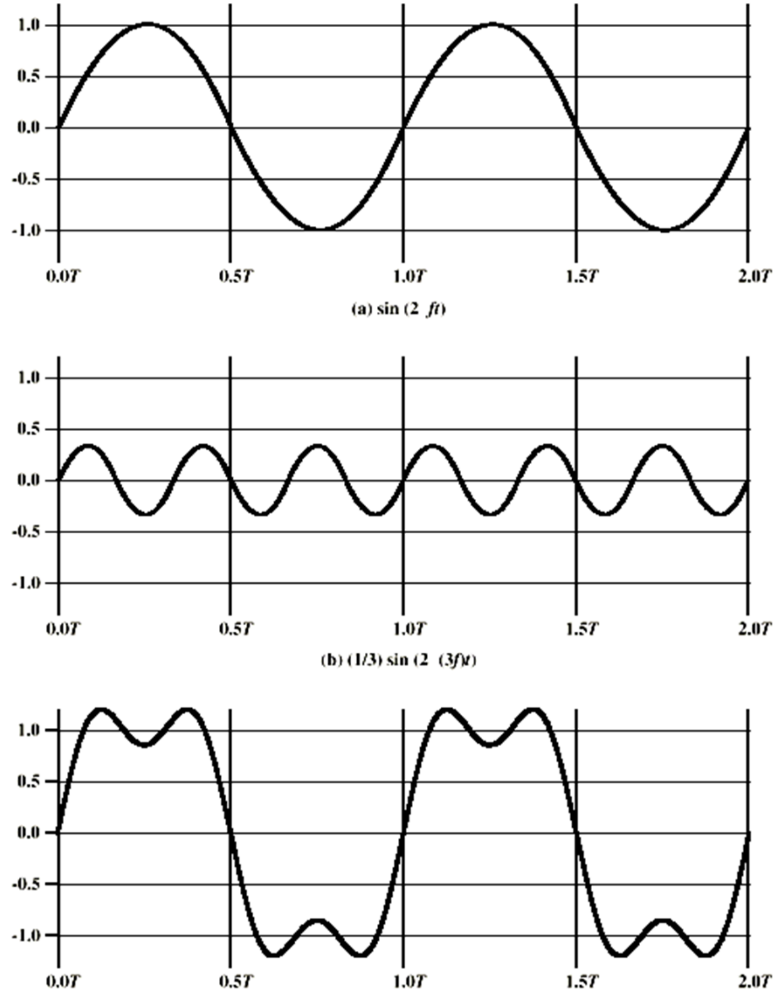


Frequency Domain Concepts

- signals are made up of many frequencies
- components are sine waves
- 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*



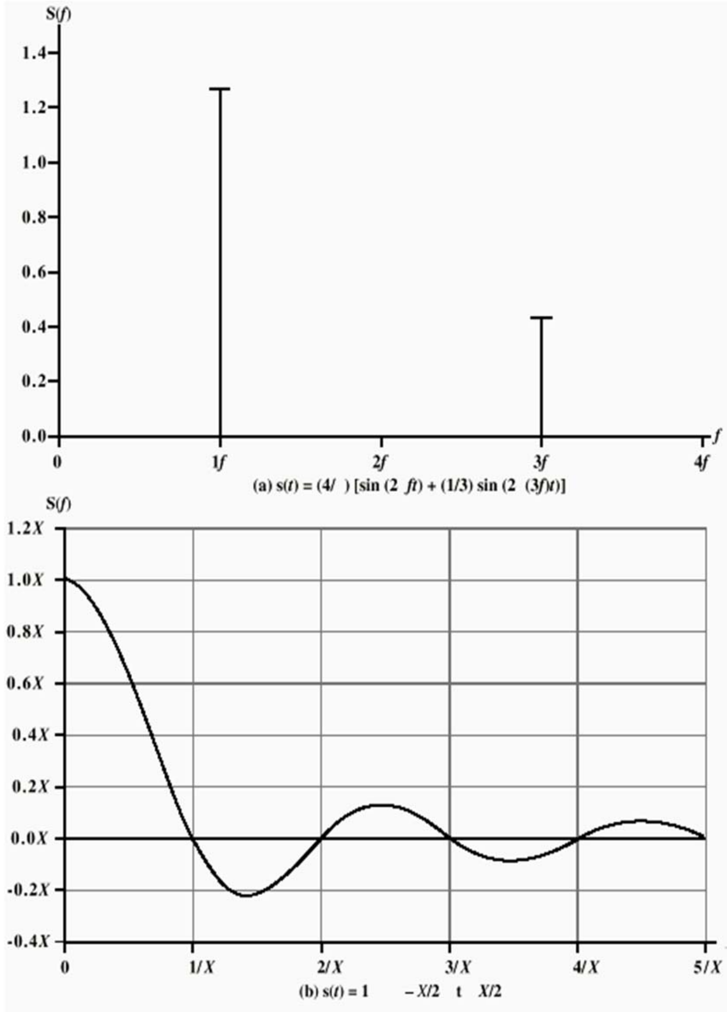
(a) sin (2 *ft*)

(b) (1/3) sin (2 (3*f*)*t*)

(c) (4/) [sin (2 *ft*) + (1/3) sin (2 (3*f*)*t*)]

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

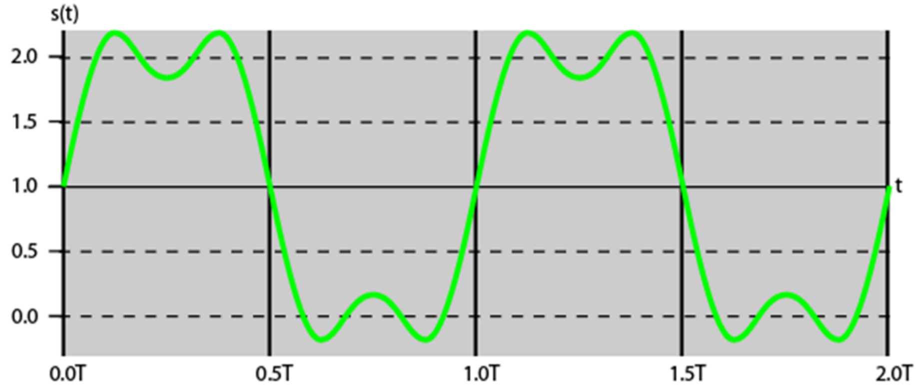
effective bandwidth

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

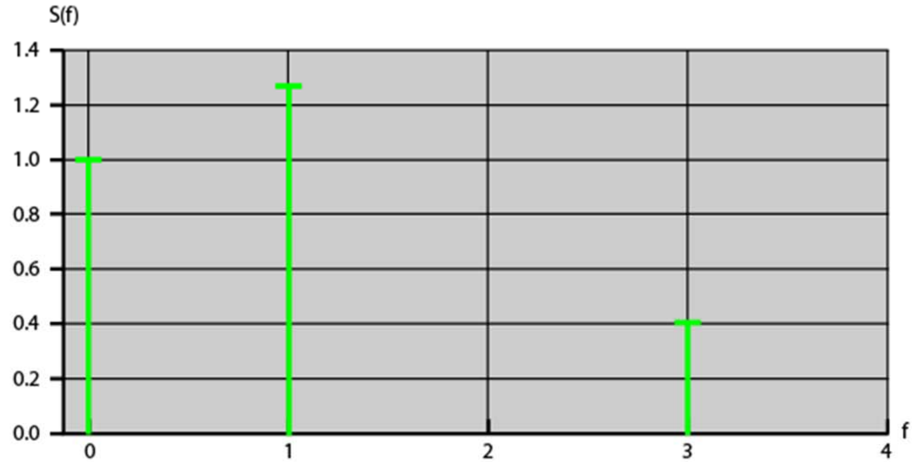
dc component

- 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

any transmission system has a limited band of frequencies

this limits the data rate that can be carried on the transmission medium

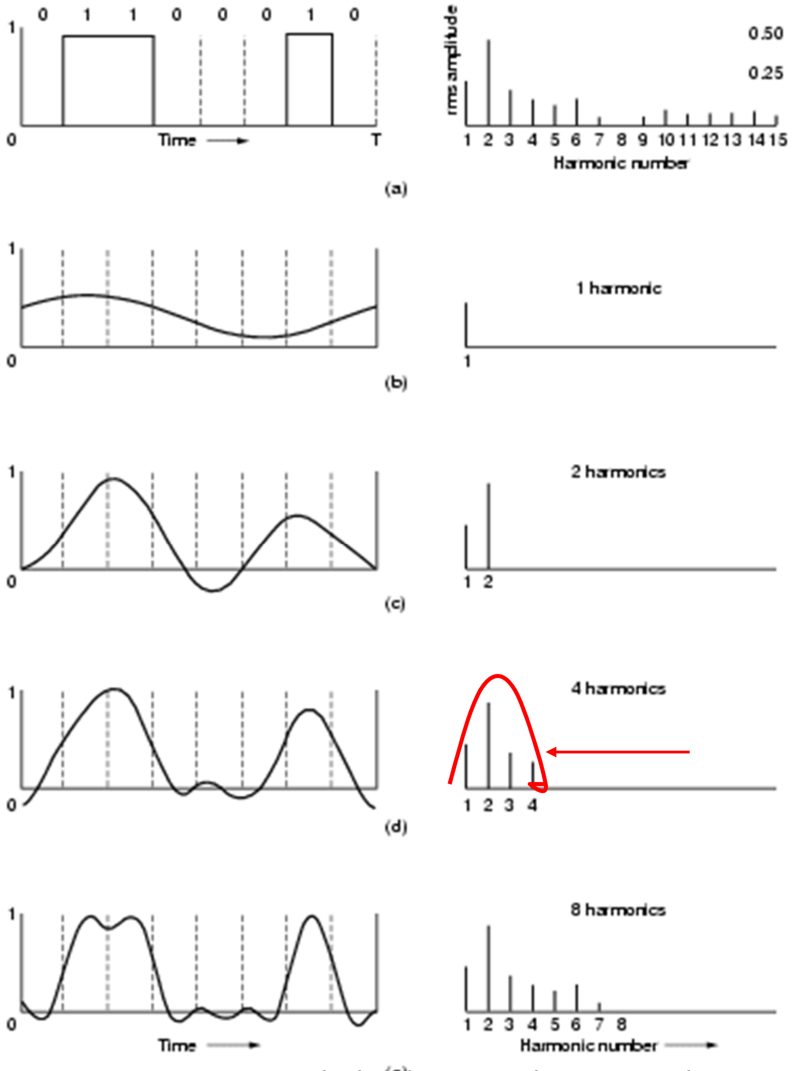
square waves have infinite components and hence an infinite bandwidth

most energy in first few components

limiting bandwidth creates distortions

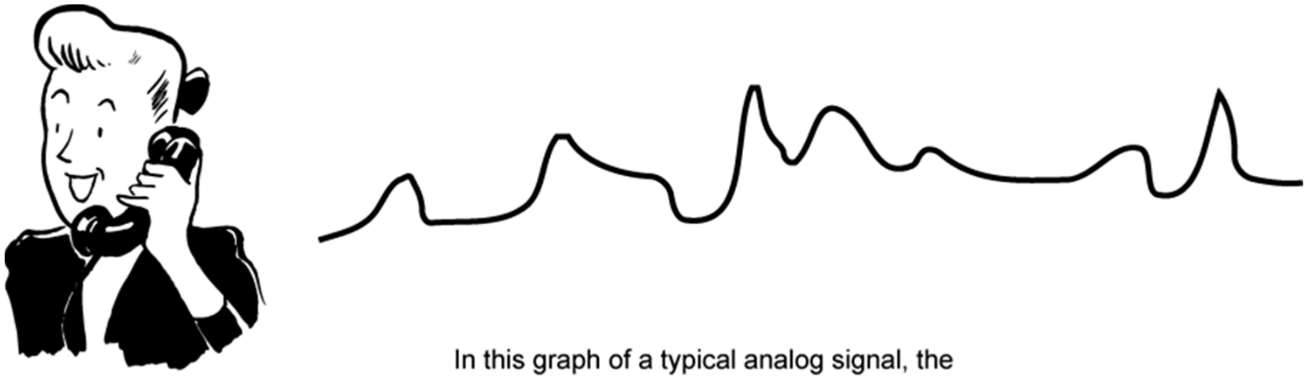
There is a direct relationship between data rate and bandwidth.

Example spectral analysis



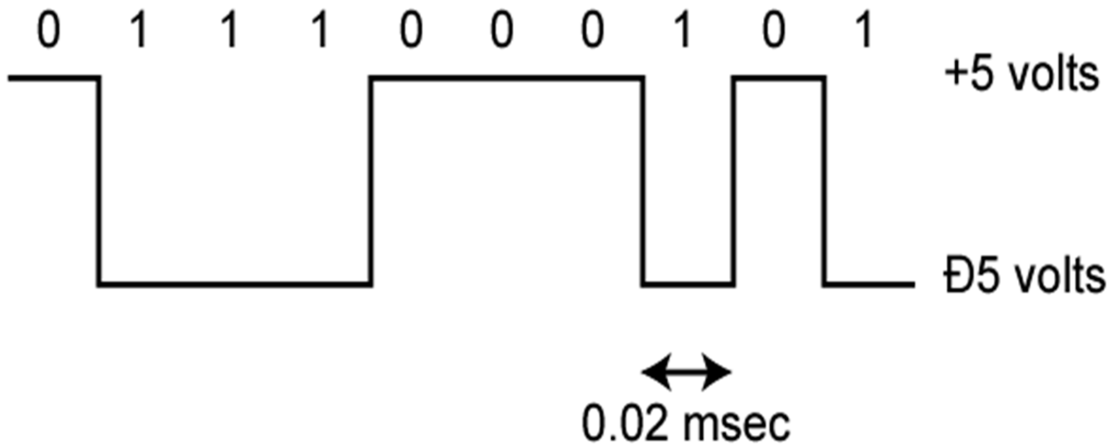
Audio Signals

- 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



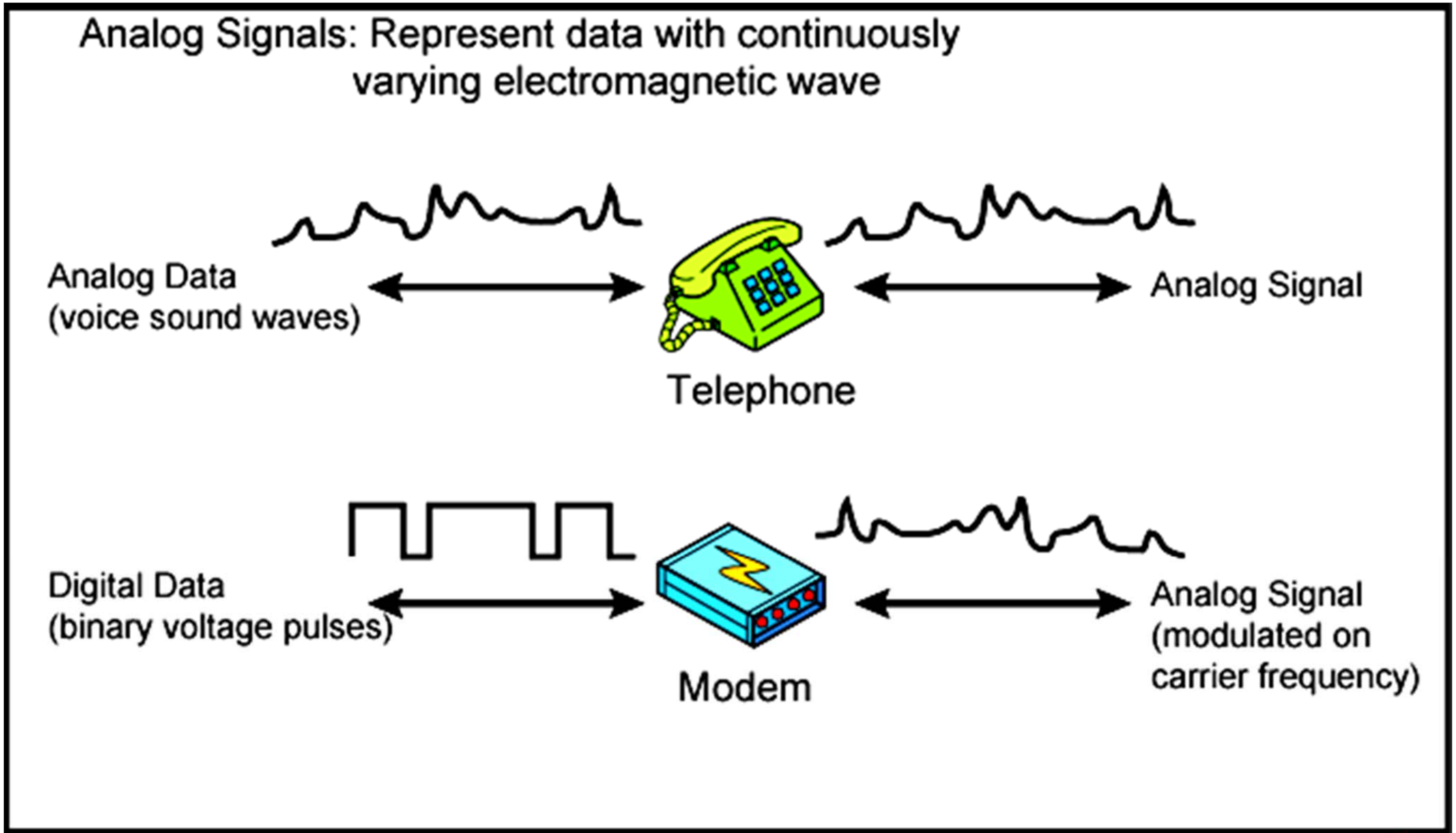
In this graph of a typical analog signal, the variations in amplitude and frequency convey the gradations of loudness and pitch in speech or music. Similar signals are used to transmit television pictures, but at much higher frequencies.

Conversion of PC Input to Digital Signal



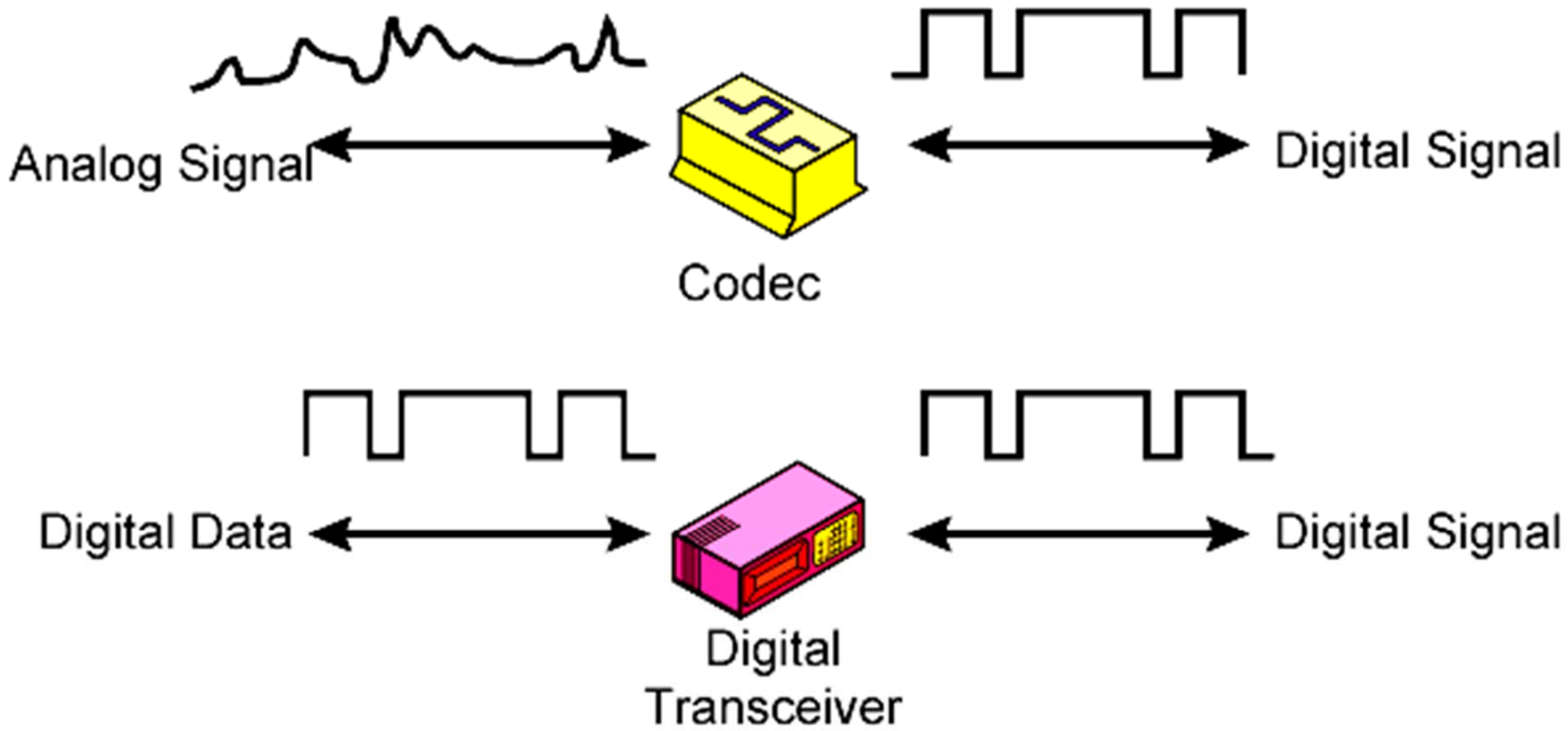
User input at a PC is converted into a stream of binary digits (1s and 0s). In this graph of a typical digital signal, binary one is represented by Ð5 volts and binary zero is represented by +5 volts. The signal for each bit has a duration of 0.02 msec, giving a data rate of 50,000 bits per second (50 kbps).

Analog Signals



Digital Signals

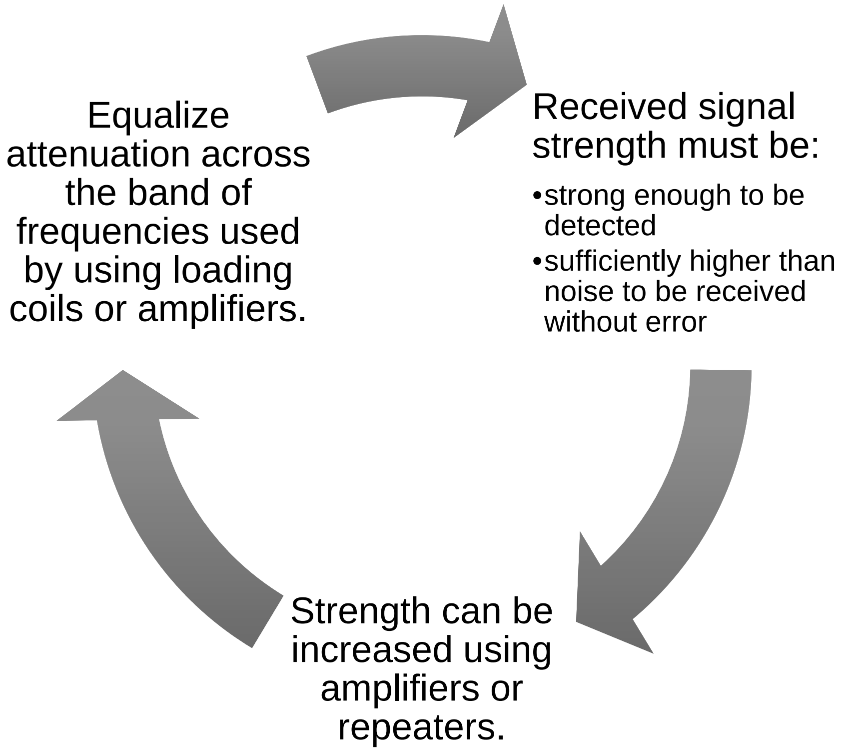
Digital Signals: Represent data with sequence of voltage pulses



Transmission Impairments

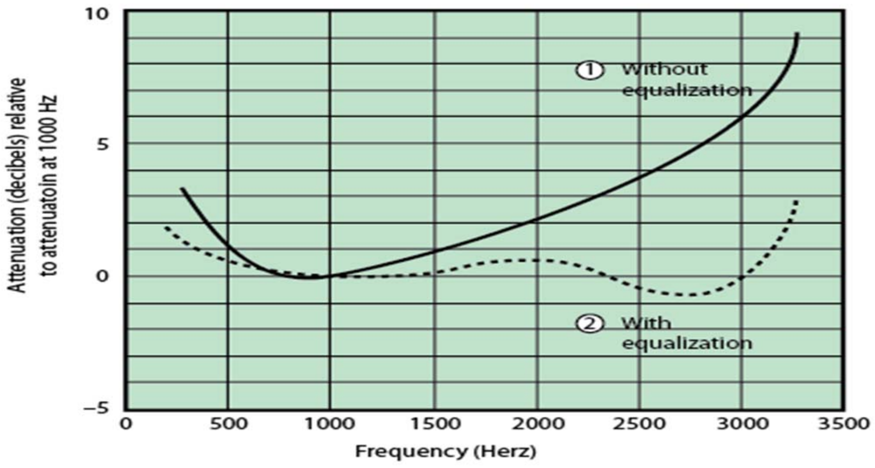
- signal received may differ from signal transmitted causing:
  - analog - degradation of signal quality
  - digital - bit errors
- most significant impairments are
  - attenuation and attenuation distortion
  - delay distortion
  - noise

Attenuation

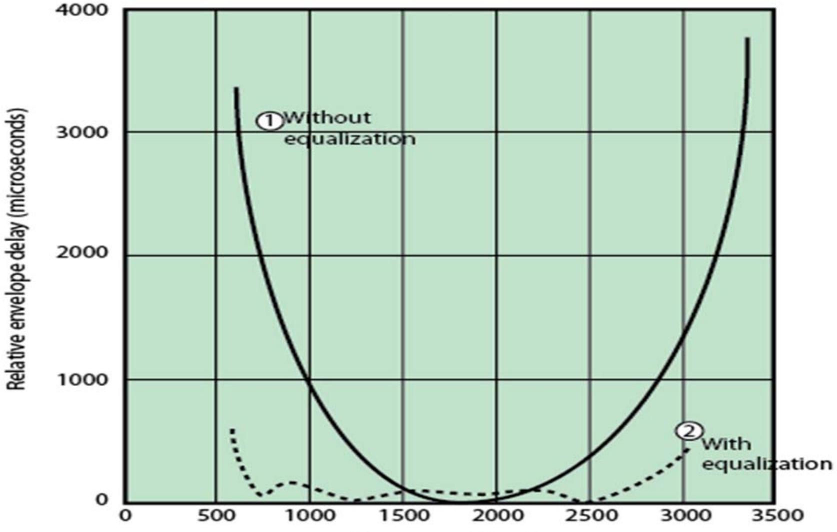


- **signal strength falls off with distance over any transmission medium**
- **varies with frequency**

Attenuation Distortion



(a) Attenuation



(b) Delay 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

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

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*

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

2.5 Codificació de senyals

Signal Encoding Techniques

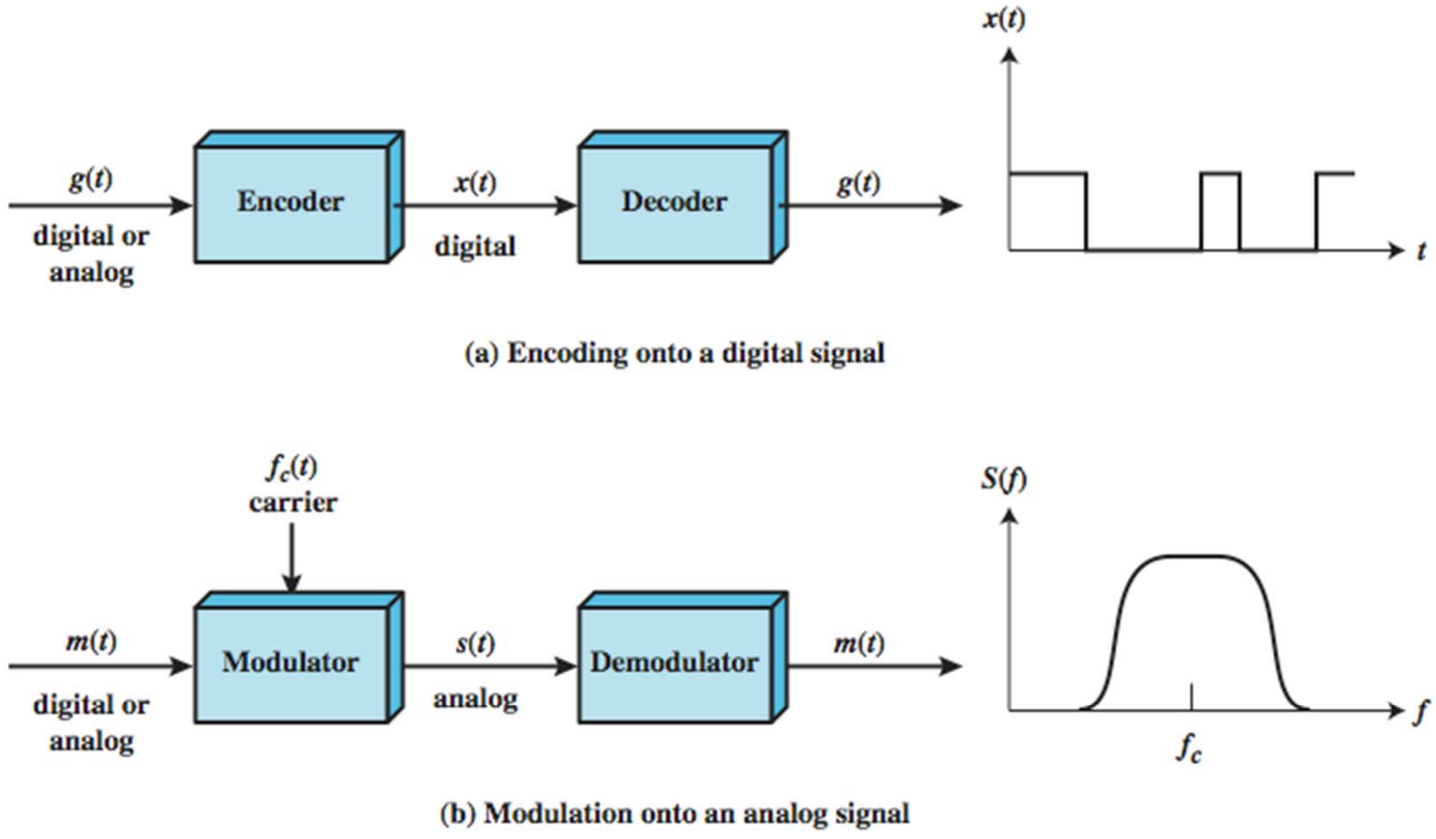


Figure 5.1 Encoding and Modulation Techniques

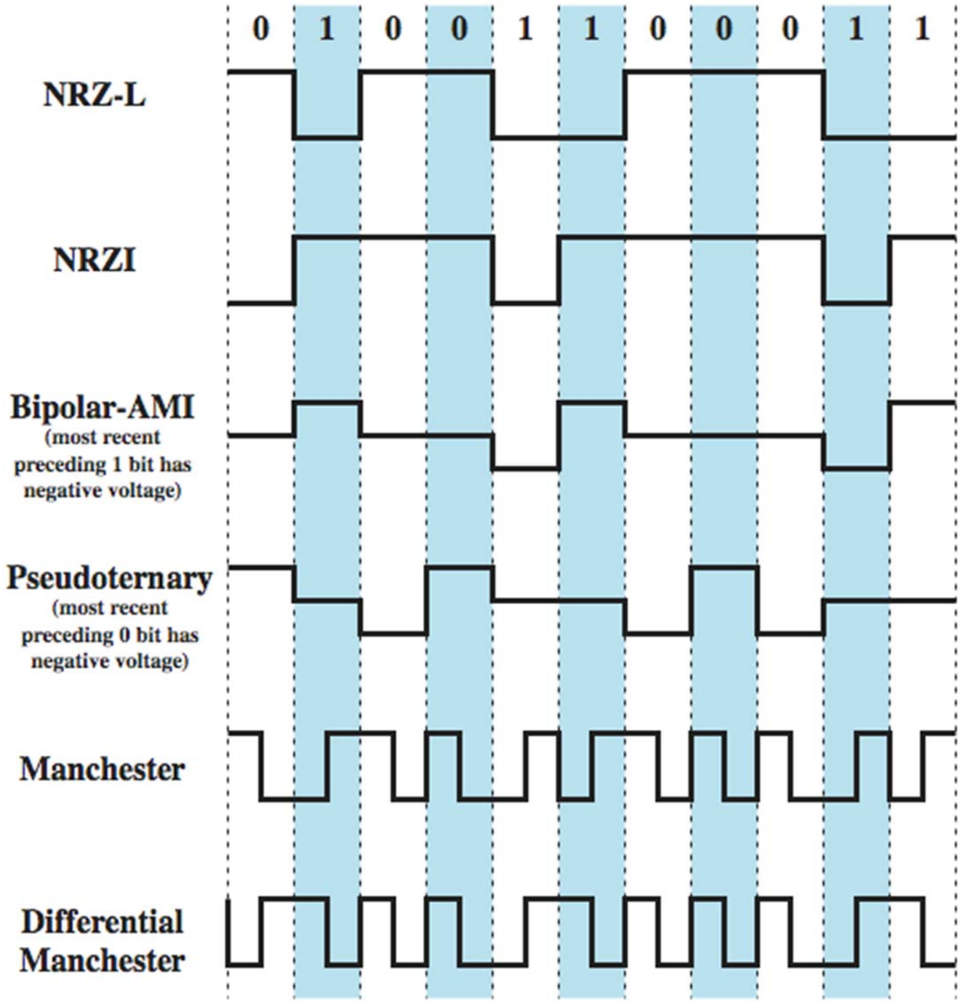
Terminology

- **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
- **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.
- **mark and space** – binary 1 and binary 0

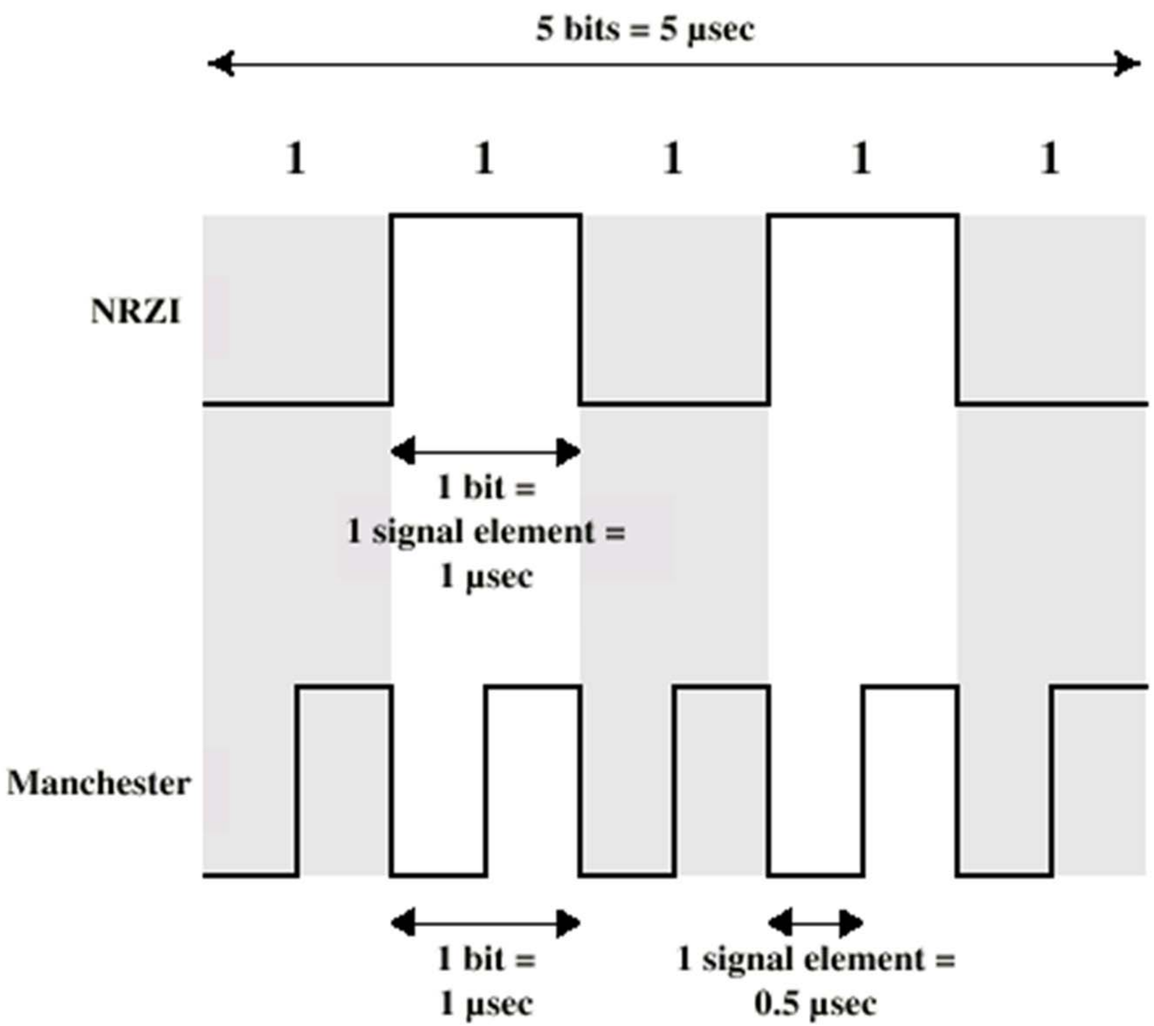
Comparison of Encoding Schemes

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

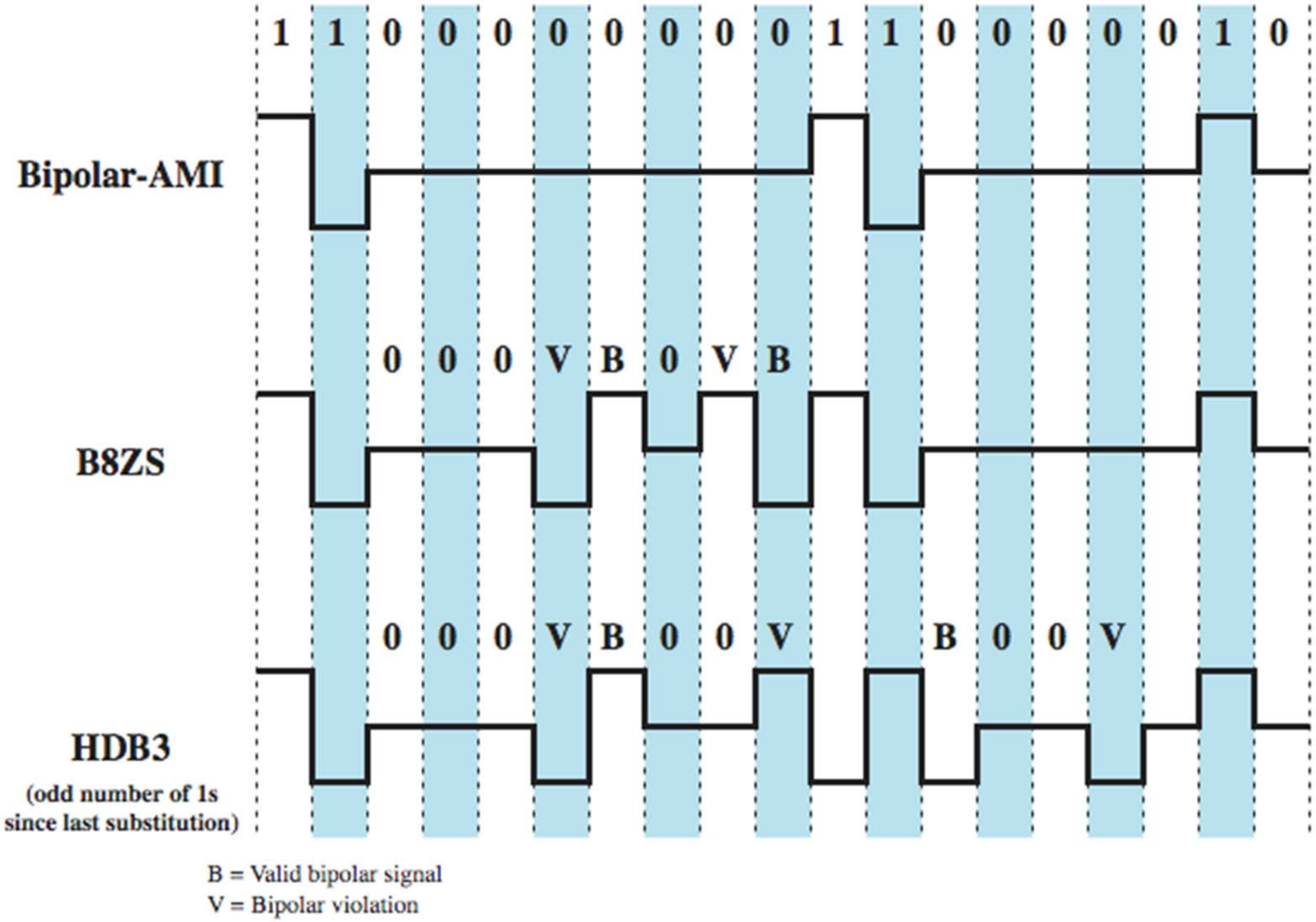
Encoding Schemes



Modulation Rate



B8ZS and HDB3



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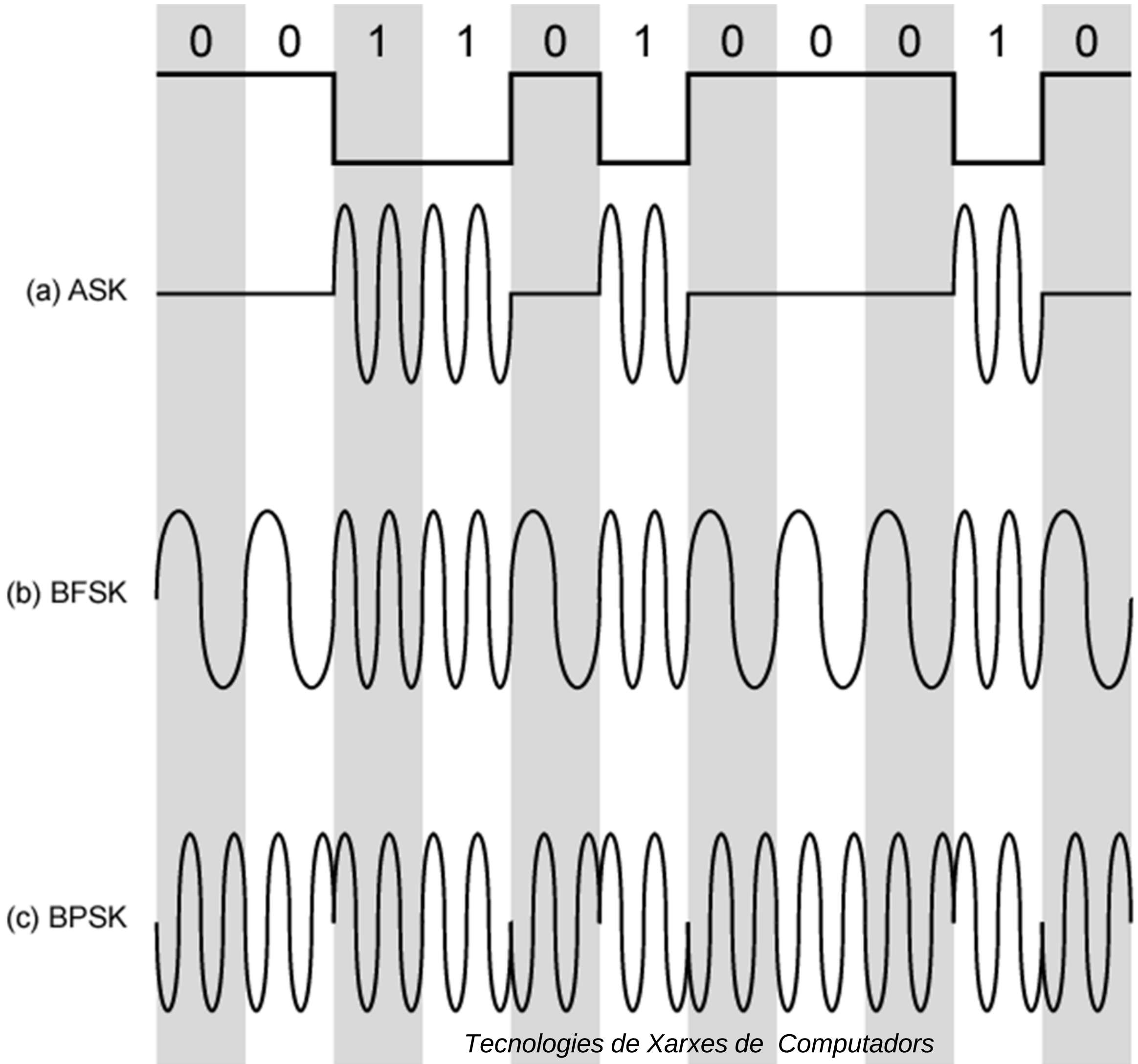
2.6 Modulació

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)

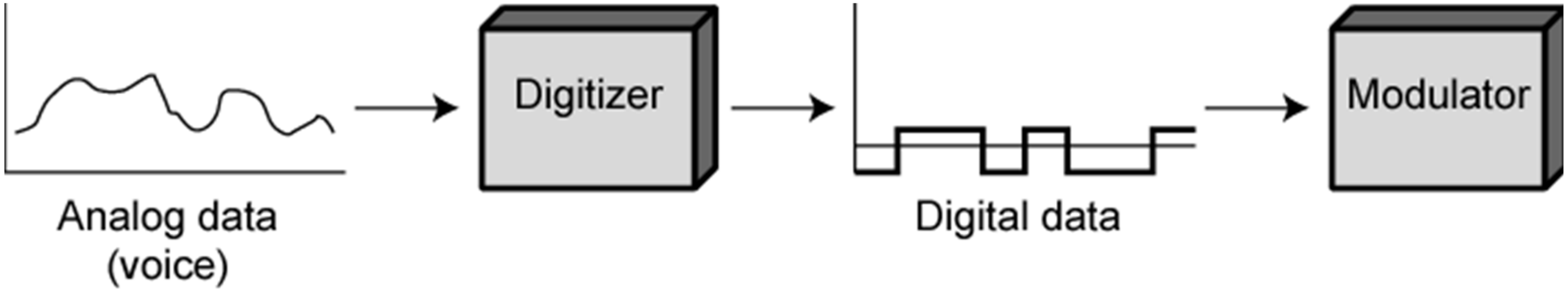
Modulation Techniques

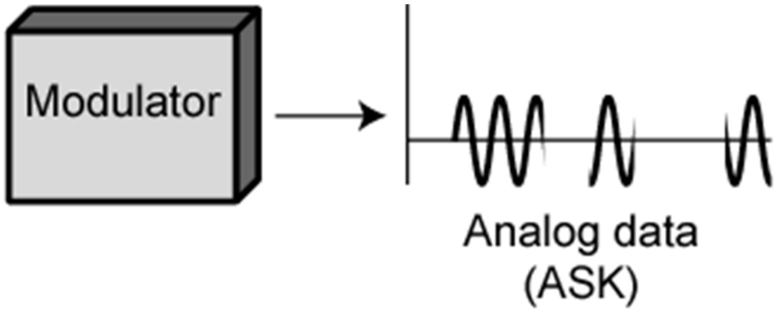


Quadrature Amplitude Modulation

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

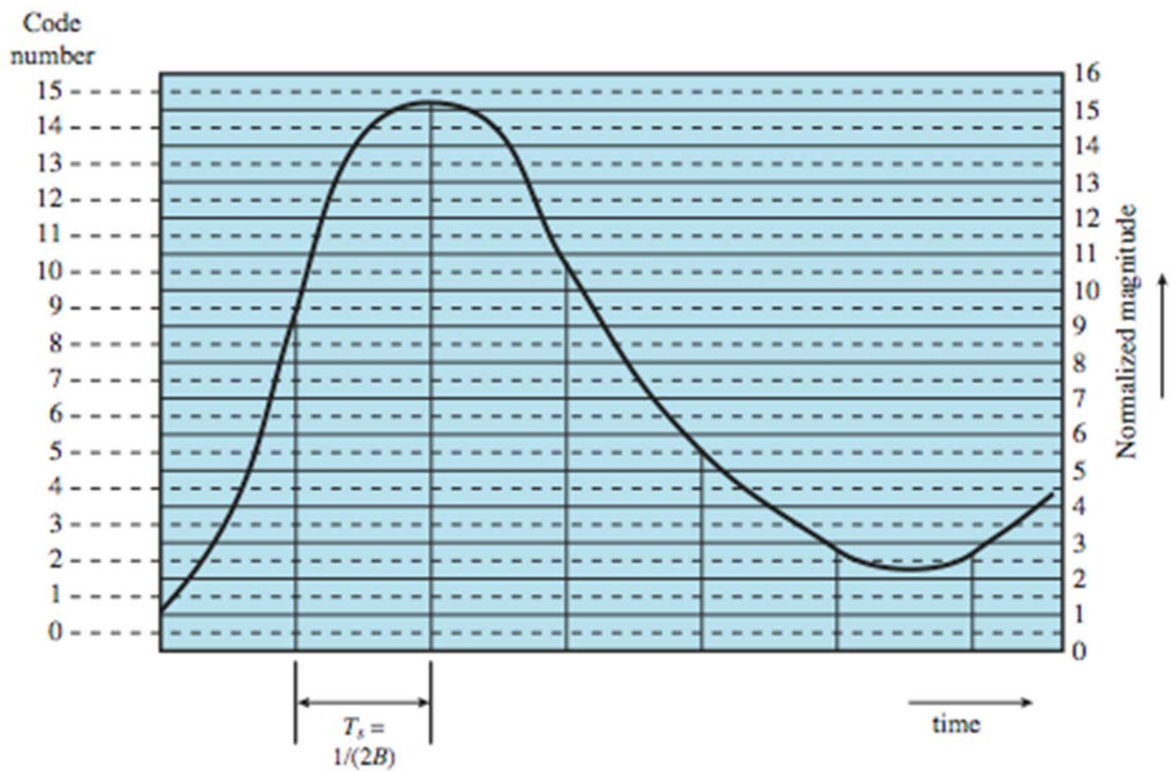




Pulse Code Modulation (PCM)

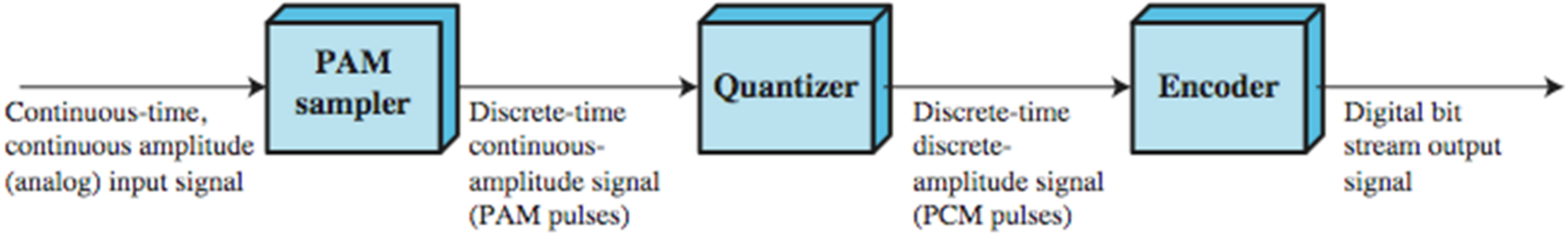
- sampling theorem:
  - "If a signal is sampled at regular intervals at a rate higher than twice the highest signal frequency, the samples contain all information in original signal"
  - eg. 4000Hz voice data, requires 8000 sample per sec
- strictly have analog samples
  - Pulse Amplitude Modulation (PAM)
- so assign each a digital value

PCM Example

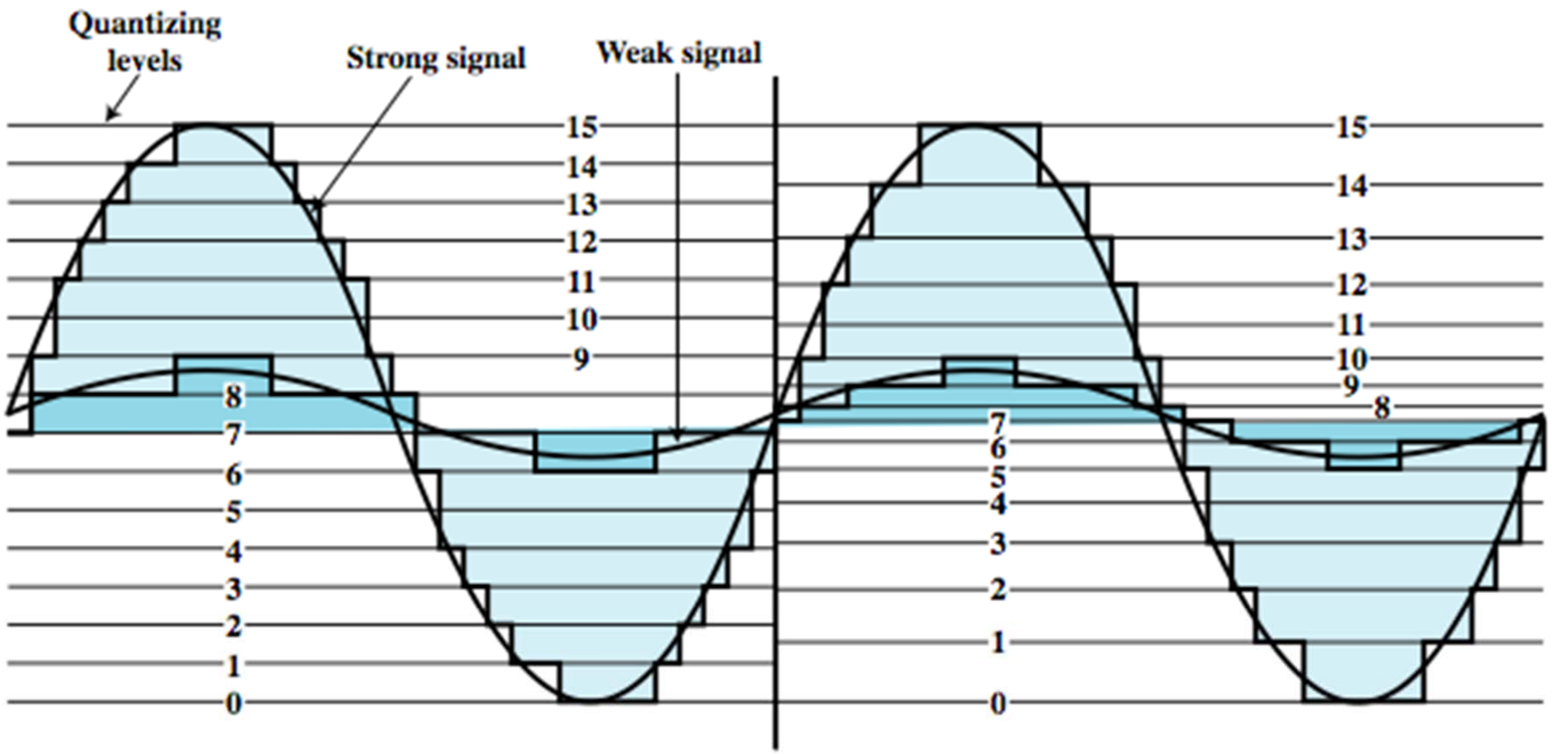


PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

PCM Block Diagram



Non-Linear Coding

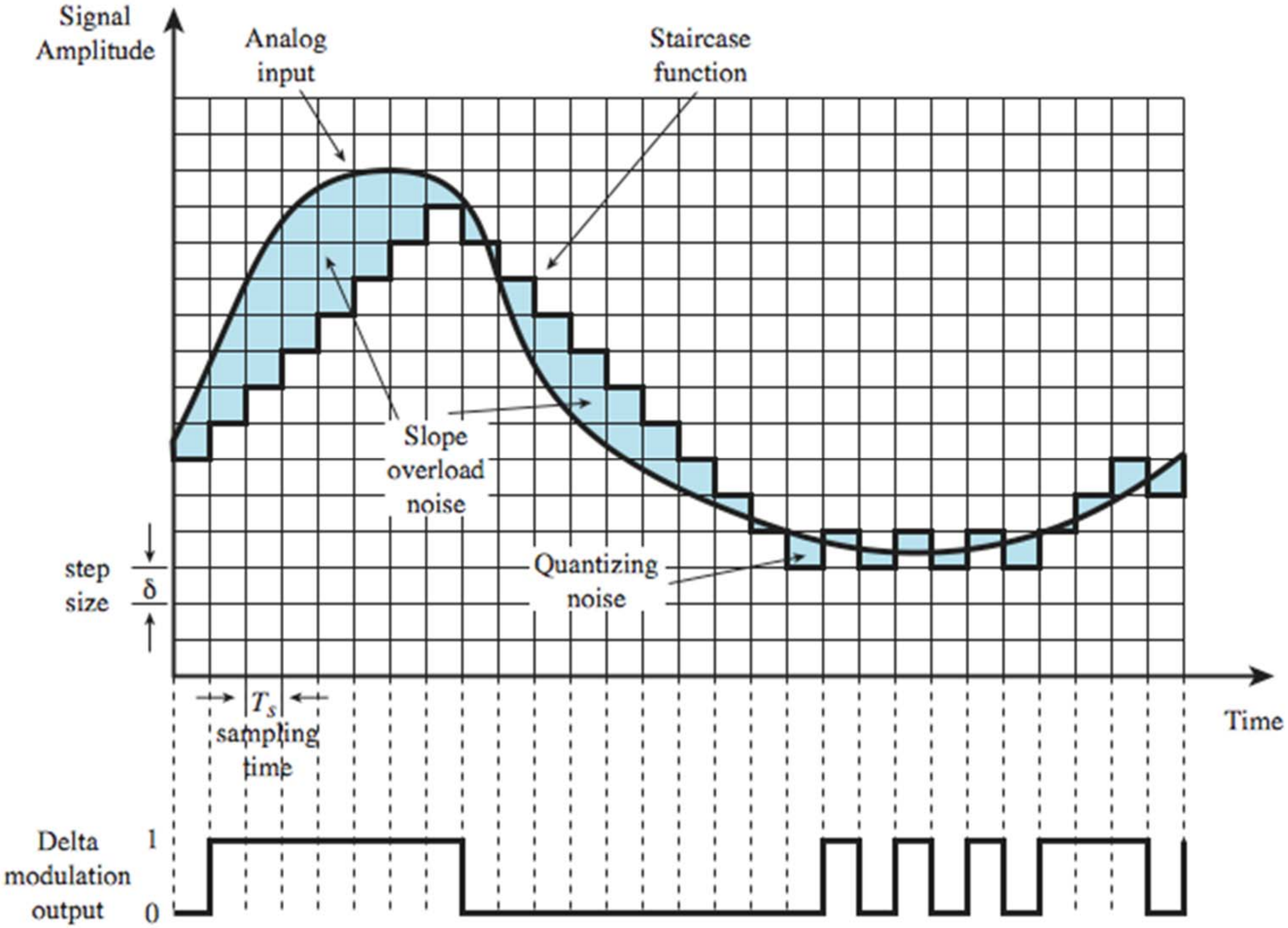


(a) Without nonlinear encoding (b) With nonlinear encoding

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

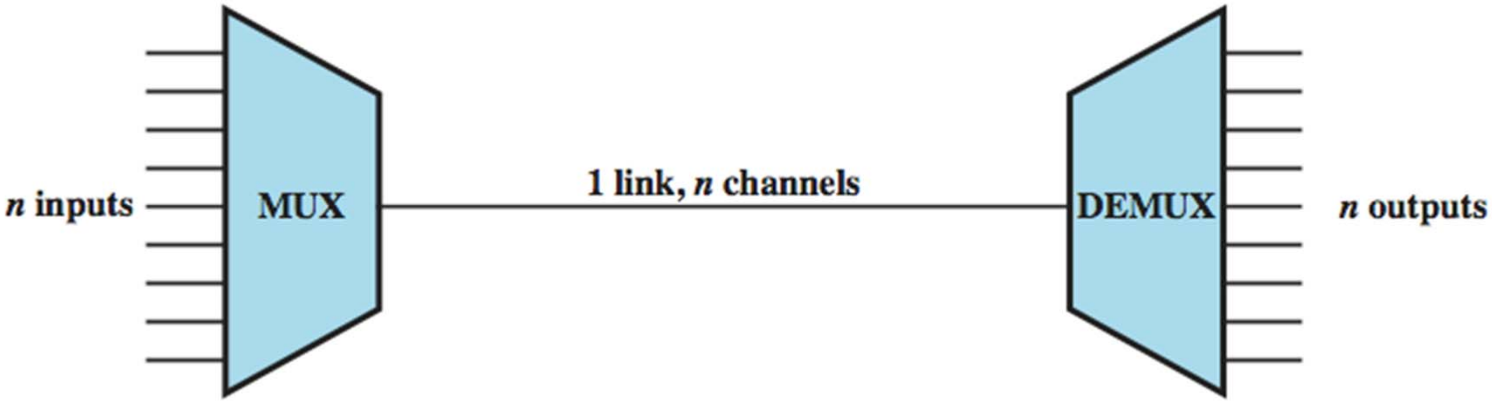
Delta Modulation Example



2.7 Multiplexació

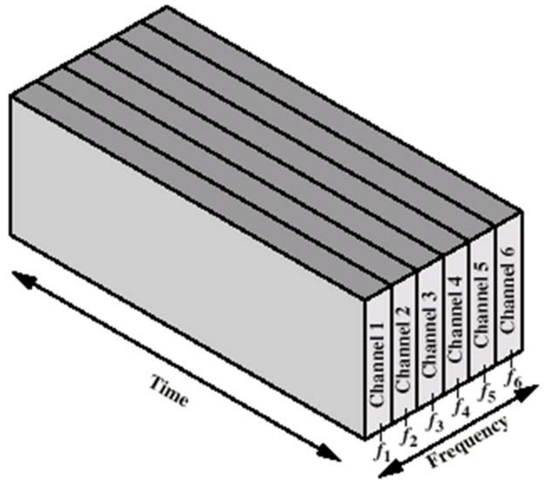
Multiplexing

- 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

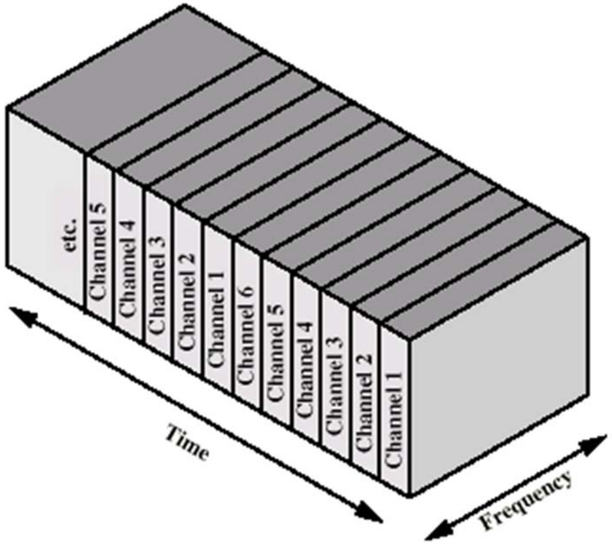


Wavelength Division Multiplexing

- 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

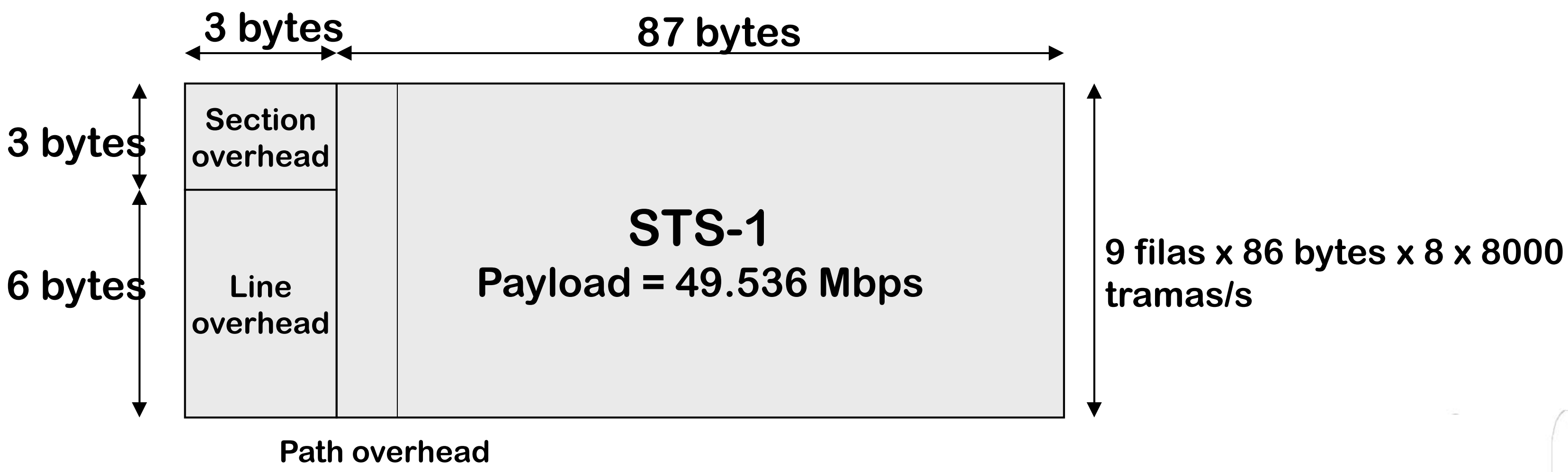
(c) Subframe with multiple sources per frame

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

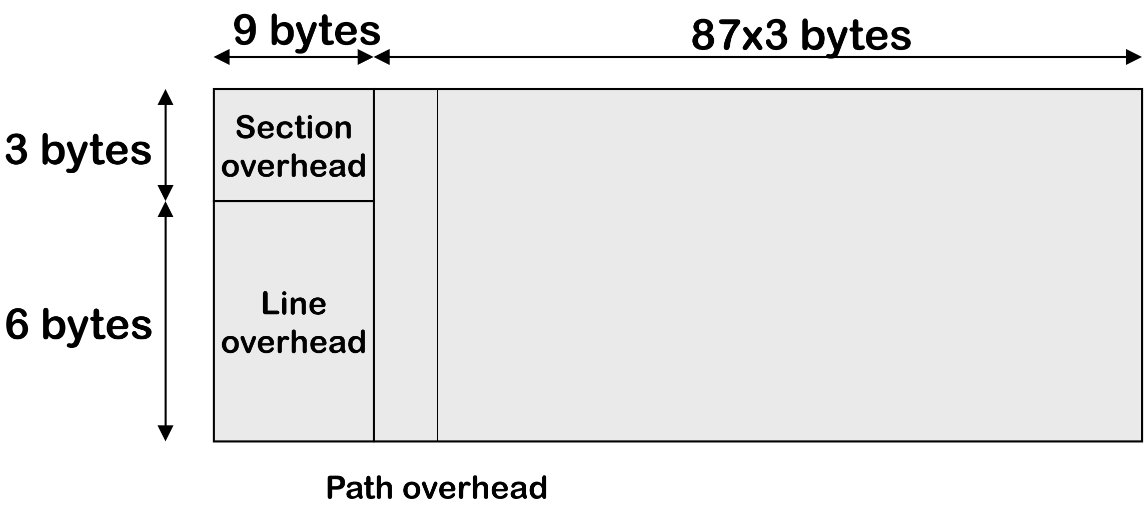
SONET

- 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



Cada 125 μs

SONET Overhead

90 bytes

9 Rows

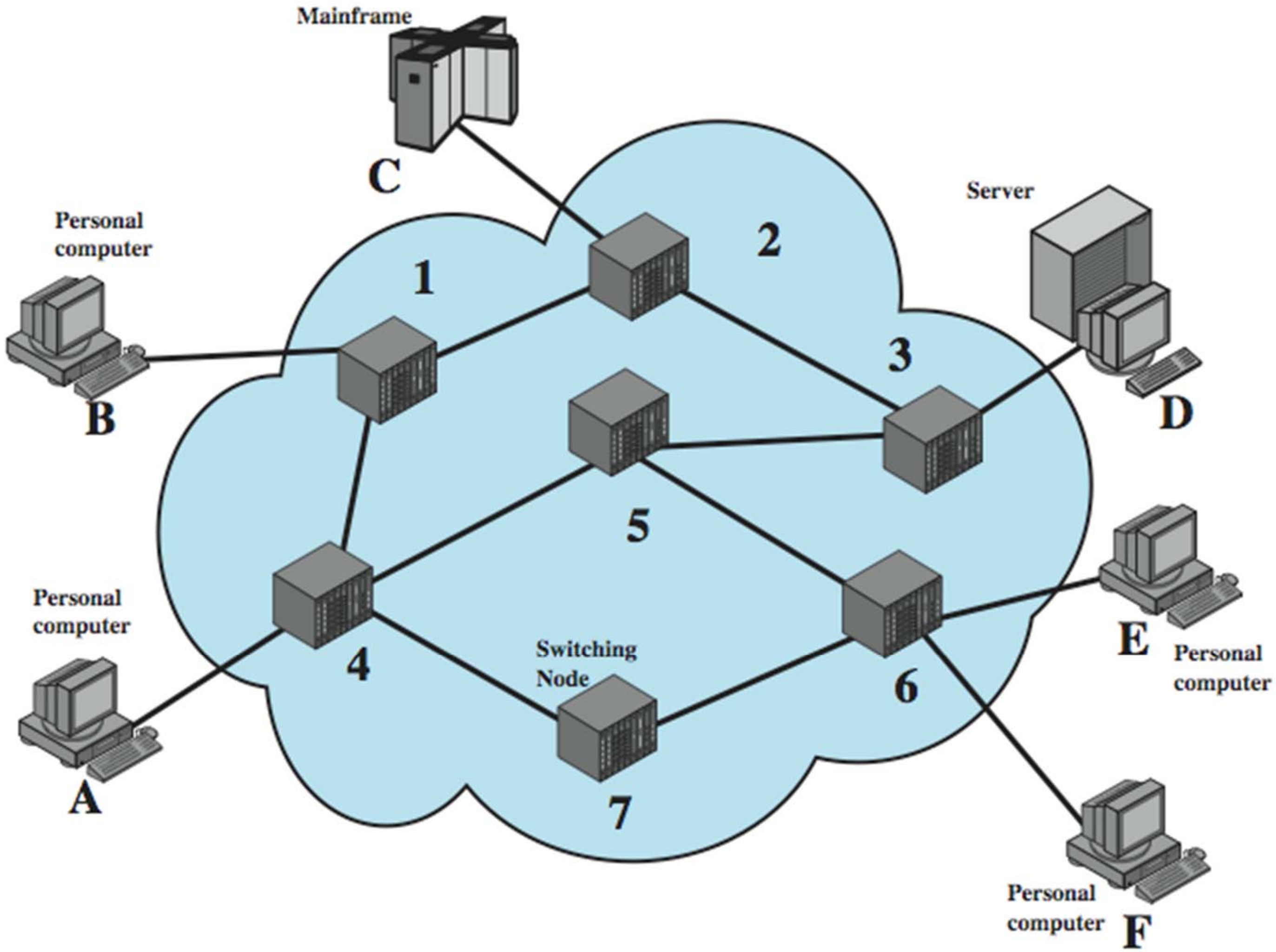
Section Overhead	Framing A1	Framing A2	STS1 ID C1
	BIP-8 B1	Orderwire E1	User F1
	Data Com D1	Data Com D2	Data Com D3
Line Overhead	Pointer H1	Pointer H2	Pointer Action H3
	BIP-8 B2	APS K1	APS K2
	Data Com D4	Data Com D5	Data Com D6
	Data Com D7	Data Com D8	Data Com D9
	Data Com D10	Data Com D11	Data Com D12
	Growth Z1	Growth Z2	Orderwire E2

Path Layer Overhead →

Trace J1
BIP-8 B3
Signal Label C2
Path Status G1
User Channel F2
Multiframe H4
Growth Z3
Growth Z4
Growth Z5

2.8 Commutació

Switched Network



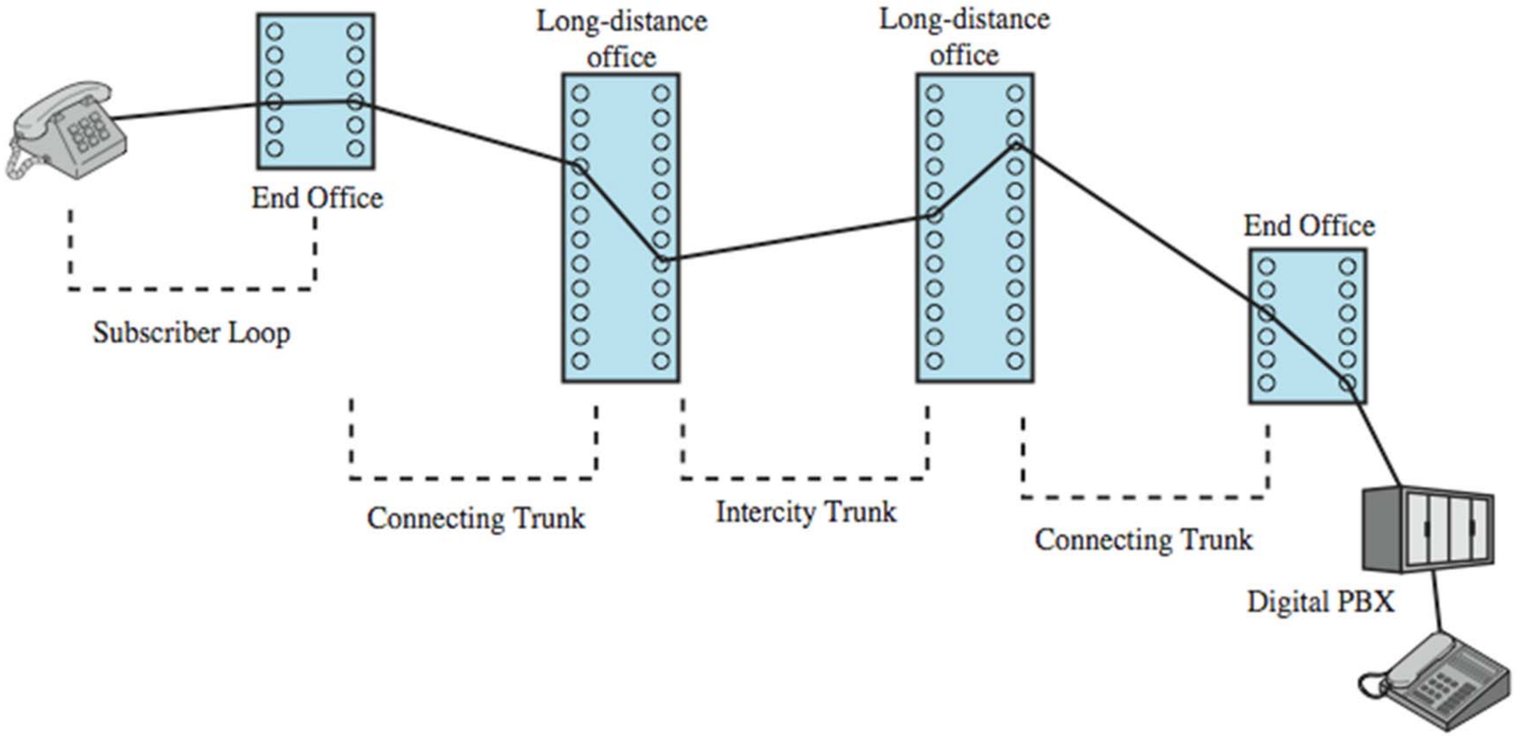
Nodes

- 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

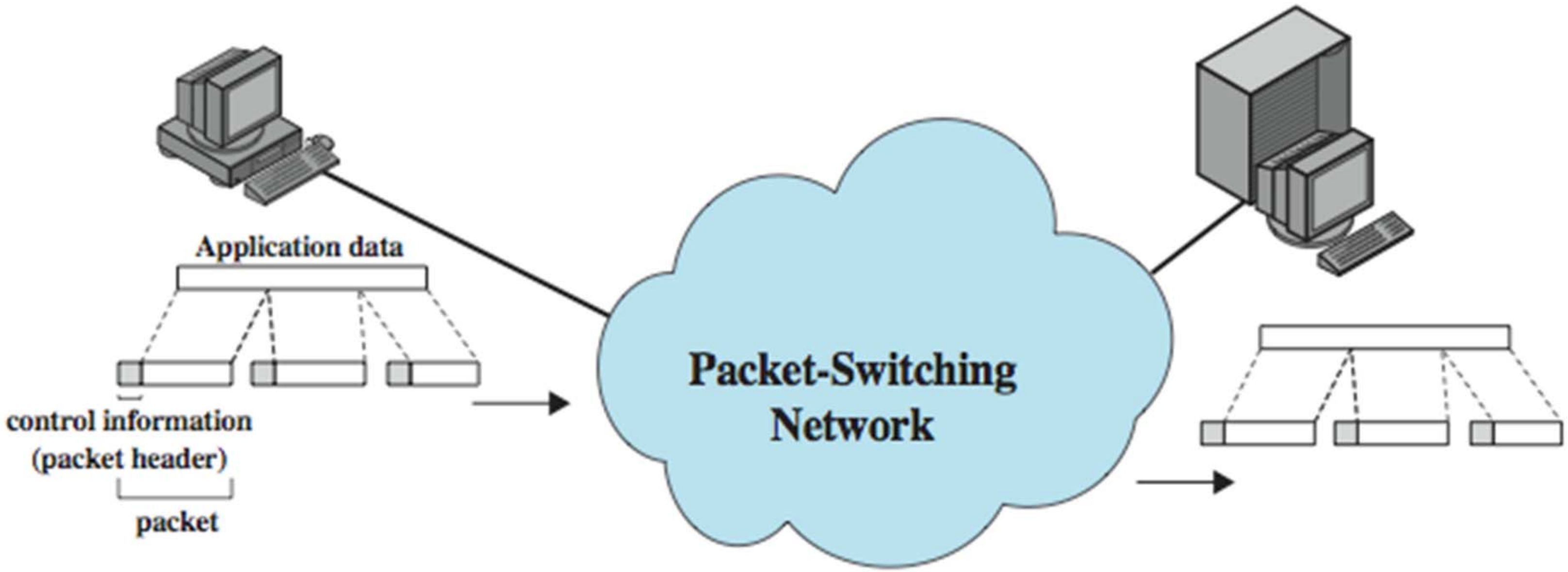
Public Circuit Switched Network



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

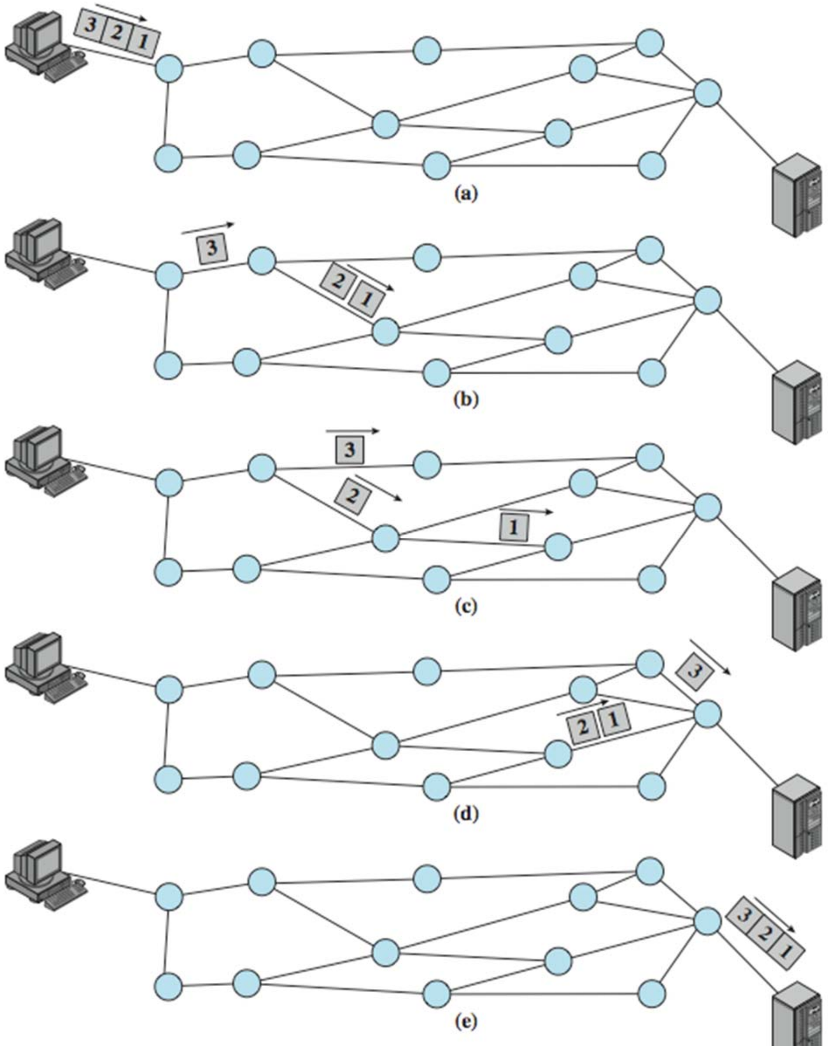


Figure 10.9 Packet Switching: Datagram Approach

Virtual Circuit Diagram

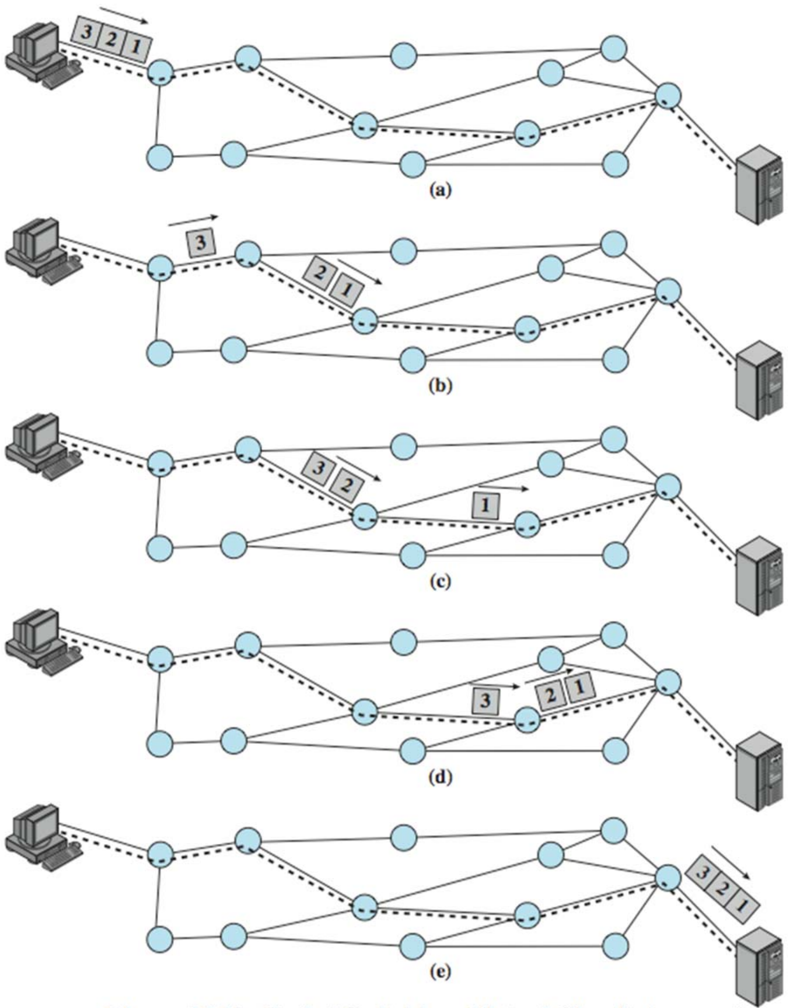
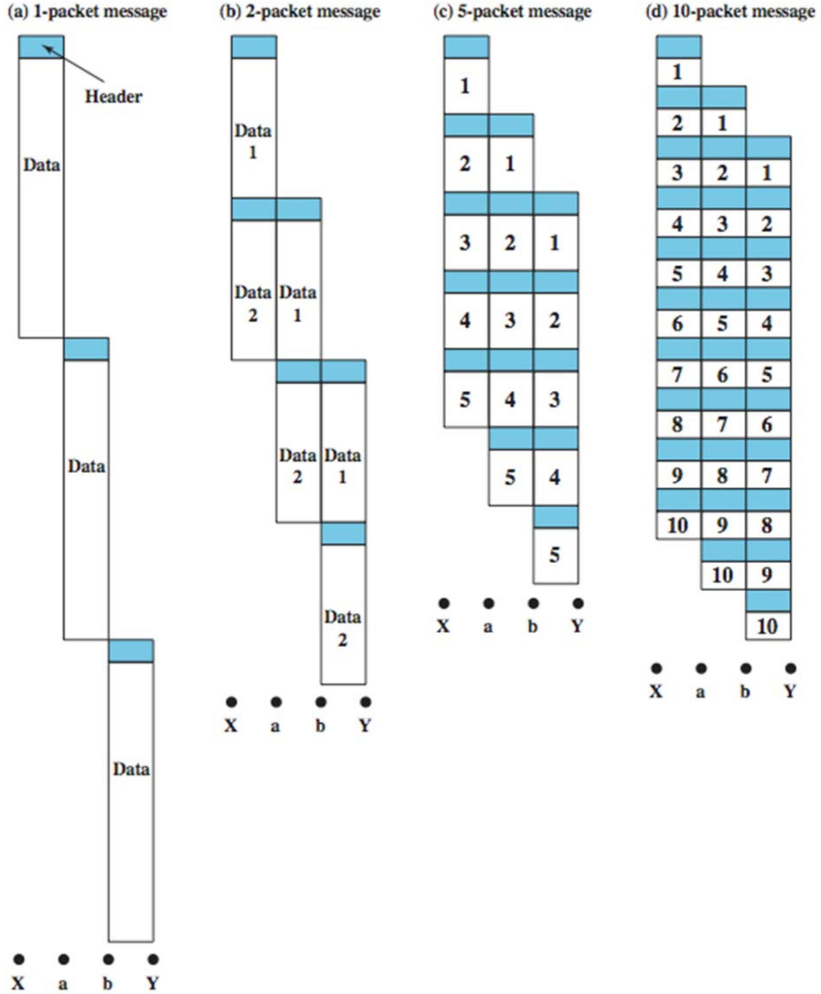


Figure 10.10 Packet Switching: Virtual-Circuit Approach

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