PART 2

Cours/Lecture Series

1987-1988 ACADEMIC TRAINING PROGRAMME

SPEAKER : B. CARPENTER & F. FLÜCKIGER / CERN-DD
TITLE : Computer communications : theory and practice
DATES : 14, 15, 16, 17 and 18 March
TIME : 11.00 hrs to 12.00 hrs
PLACE : Auditorium (except on 15 March : Council Chamber)

PART 2

ABSTRACT

The lectures are intended for people who use or expect to use local or wide area computer networks, and who want a better understanding of their design and implementation.

(Thus instructions for the use of networks will ***not*** *be given, and should be sought in the normal documentation.)*

The nature of networks, the services they can provide, and general notions of their architecture, will be introduced.

The basic technique of transmission, switching, layering, and protocols will be described.

The various protocol layers from hardware up to application services will be discussed, with illustrative examples chosen from both ad hoc and standard protocols in use at CERN (including X-25, Ethernet, TCP/IP, CERNET, X-400, etc.).

Finally, future prospects offered by emerging technology will be presented.

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Computer Networks : Part 2

1 Network Components

2 Communication SubNetworks

- 2.1 Transmission technology
  - 2.1.1 Transmission Media
  - 2.1.2 Transmission Techniques
- 2.2 Network topologies
- 2.3 Switching techniques
  - 2.3.1 Circuit Switching
  - 2.3.2 Packet Switching
- 2.4 PTT offering for WANs

3 OSI Model

- 3.1 Basic principles of layering
- 3.2 Layer Services
- 3.3 The 7 Layers

4 Test Case : the X25 Protocols

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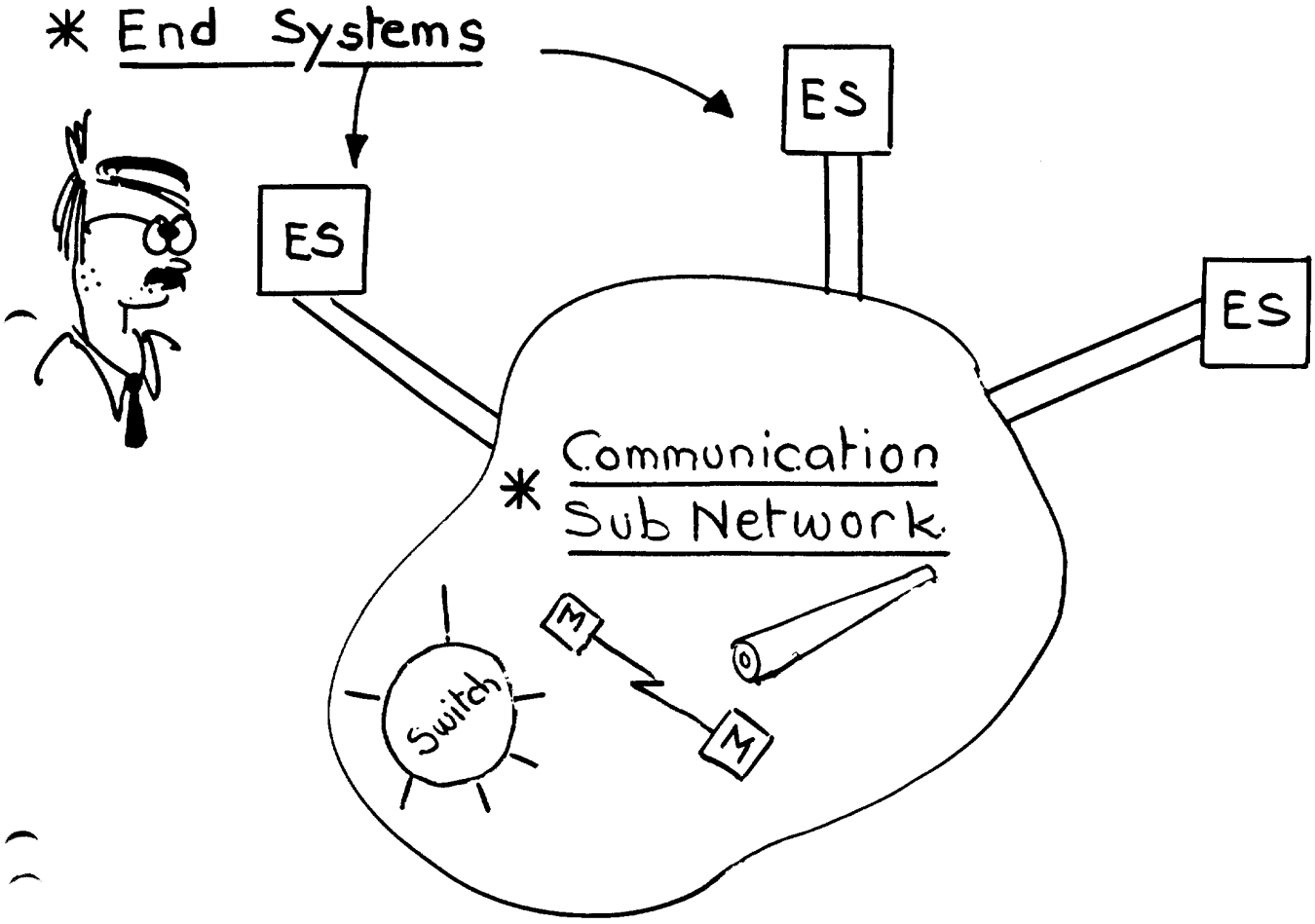
Network Components

Model



End Systems : where the Service is provided

Communication: collection of *transmission Sub Net and *switching equipment

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Communication SubNetwork

Transmission Technology

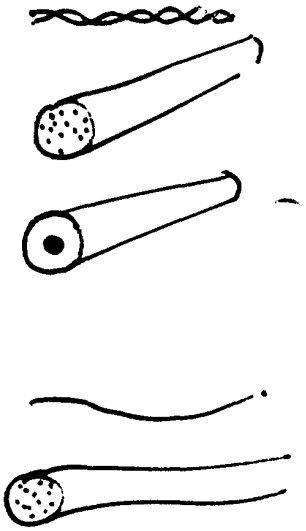
- Transmission media ?
- Transmission techniques ?

Major Transmission Media

All use electric or electro-magnetic transmission

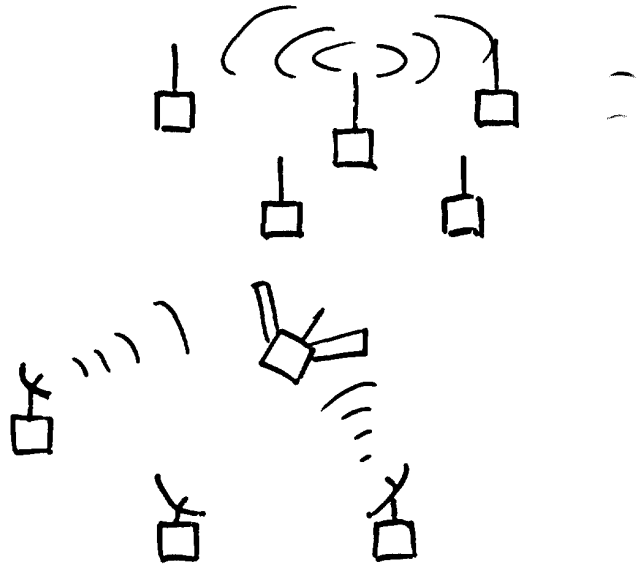
"Physical"

- Cables
  - pairs
  - grouped pairs
  - coaxial
- Fibres
  - optic fibres



"Aerial"

- Radio
- Satellite



Major Transmission Media

Basic Features

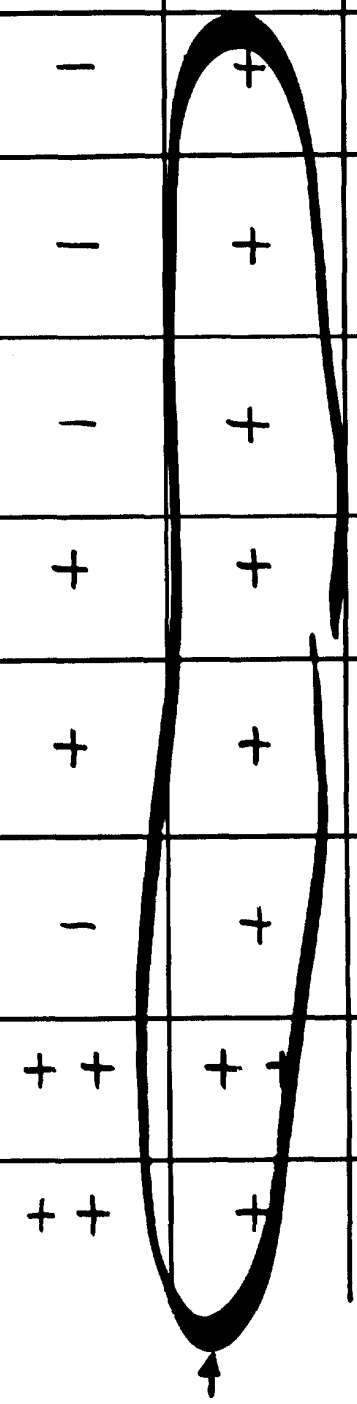
	Pairs	Coax	Fibre	Radio	Satellite.
1 Transmission Speed	−	+	++	+	+
2 Transmission errors	−	+	++	−	−−
3 Multiplexing capabilities	−	+	++	+	+
4 Distances	+	+	+	−	++
5 Transmission delay	+	+	+	+	− −
*Broadcasting Facilities	−	+	−	++	+ +
7 Lifetime	+ +	+ +	+	+	−
8 Economics	+ +	+	+	++	−

OK for modest performances

Major Transmission Media

Basic Features

	Pairs	Coax	Fibre	Radio	Satellite.
1 Transmission Speed	−	+	++	+	+
2 Transmission errors	−	+	++	−	−−
3 Multiplexing capabilities	−	+	++	+	+
4 Distances	+	+	+	−	++
5 Transmission delay	+	+	+	+	− −
6* Broadcasting Facilities	−	+	−	++	+ +
7 Lifetime	+ +	+ +	+	+	−
8 Economics	+ +	+	+	++	−



PerFormant

OK for LANs

Major Transmission Media

Basic Features

	Pairs	Coax	Fibre	Radio	Satellite.
1 Transmission Speed	−	+	++	+	+
2 Transmission errors	−	+	++	−	−−
3 Multiplexing capabilities	−	+	++	+	+
4 Distances	+	+	+	−	++
5 Transmission delay	+	+	+	+	− −
6 Broadcasting Facilities	−	+	−	++	++
7 Lifetime	++	++	+	+	−
8 Economics	++	+	+	++	−

4

- Highly performant
- The media of the 80's (90's ?)

Major Transmission Media

Basic Features

	Pairs	Coax	Fibre	Radio	Satellite.
1 Transmission Speed	−	+	++	+	+
2 Transmission errors	−	+	++	−	−−
3 Multiplexing capabilities	−	+	++	+	+
4 Distances	+	+	+	−	++
5 Transmission delay	+	+	+	+	− −
6*Broadcasting Facilities	−	+	−	++	+ +
7 Lifetime	+ +	+ +	+	+	−
8 Economics	+ +	+	+	++	−

- Performance Problems
- Only for short distance and/or broadcast

Major Transmission Media

Basic Features

	Pairs	Coax	Fibre	Radio	Satellite.
1 Transmission Speed	−	+	++	+	+
2 Transmission errors	−	+	++	−	−−
3 Multiplexing capabilities	−	+	++	+	+
4 Distances	+	+	+	−	++
5 Transmission delay	+	+	+	+	−−
6 Broadcasting Facilities	−	+	−	++	++
7 Lifetime	++	++	+	+	−
8 Economics	++	+	+	++	−

- The most controversial
- Seems to be superseded by Fibres

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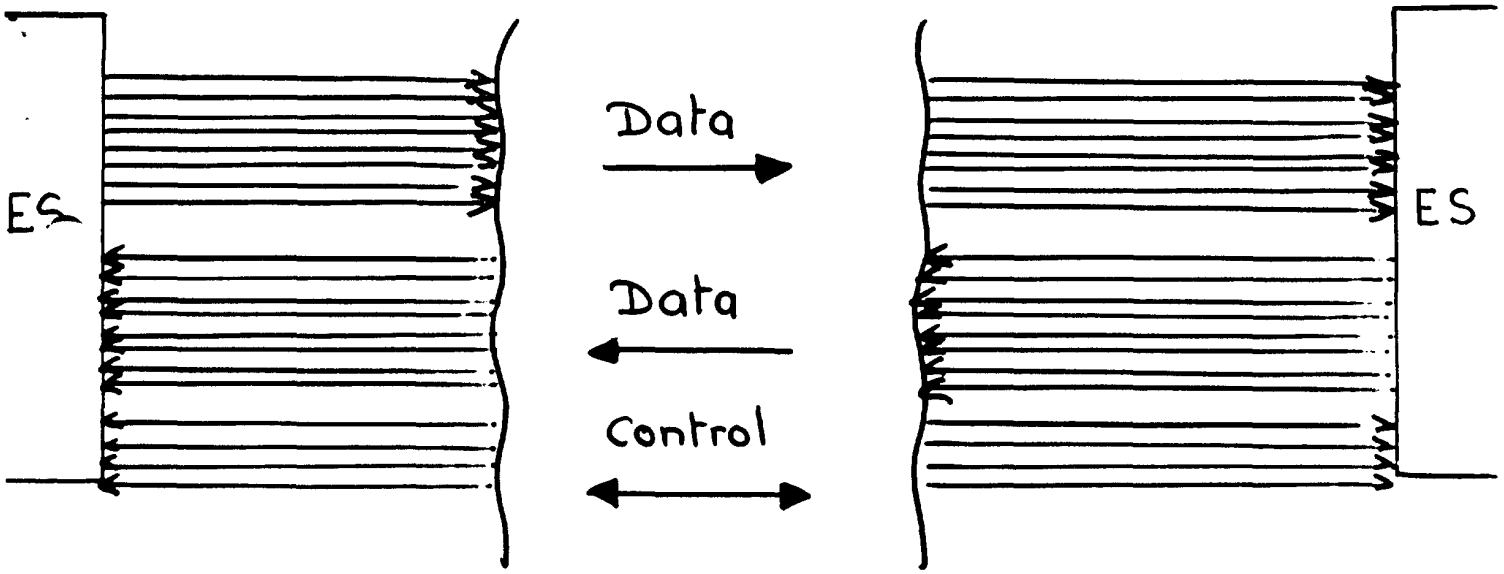
Communication Sub Network

Transmission Techniques

Simplest : * Parallel transmission



Example : . Buses
. Flat Cables

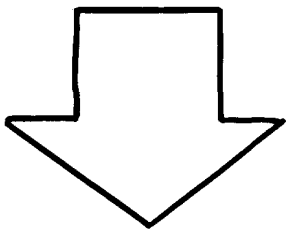
Problems : • Unafordable

• Attenuation , Noise =>
Limited distances

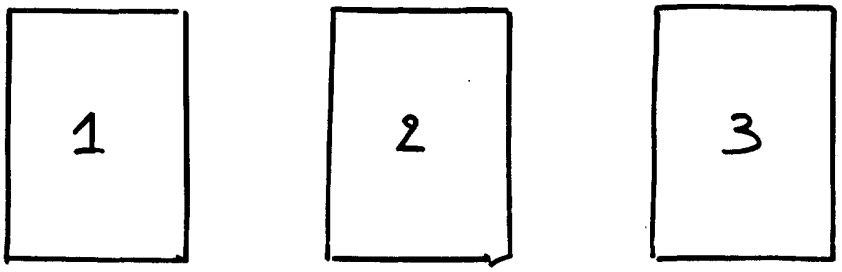
- cheaper media (less wires)

+

- higher distances
  error protections



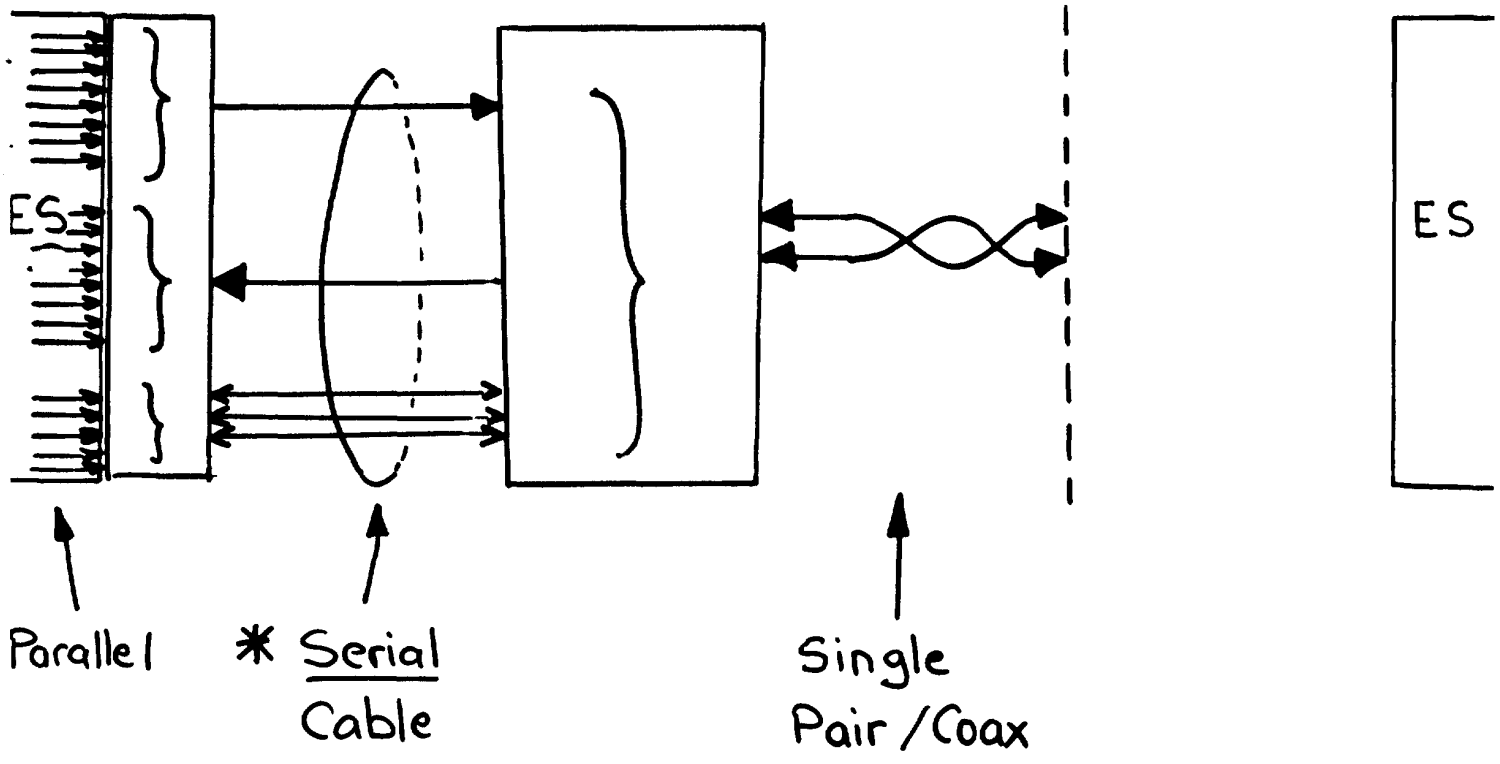
3 types of
"Magic Boxes"



Communication SubNetwork

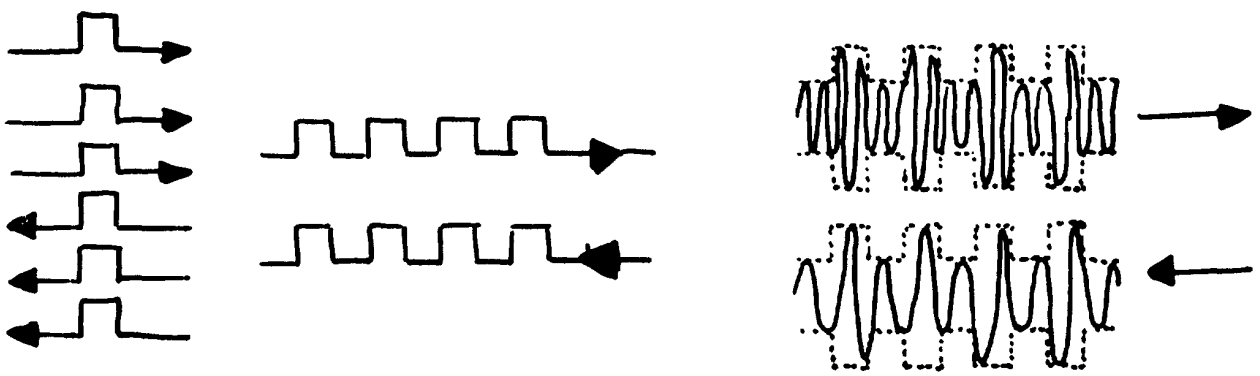
Transmission Techniques

* Communic. Interface
* "Modem"



Example: RS232 / V24

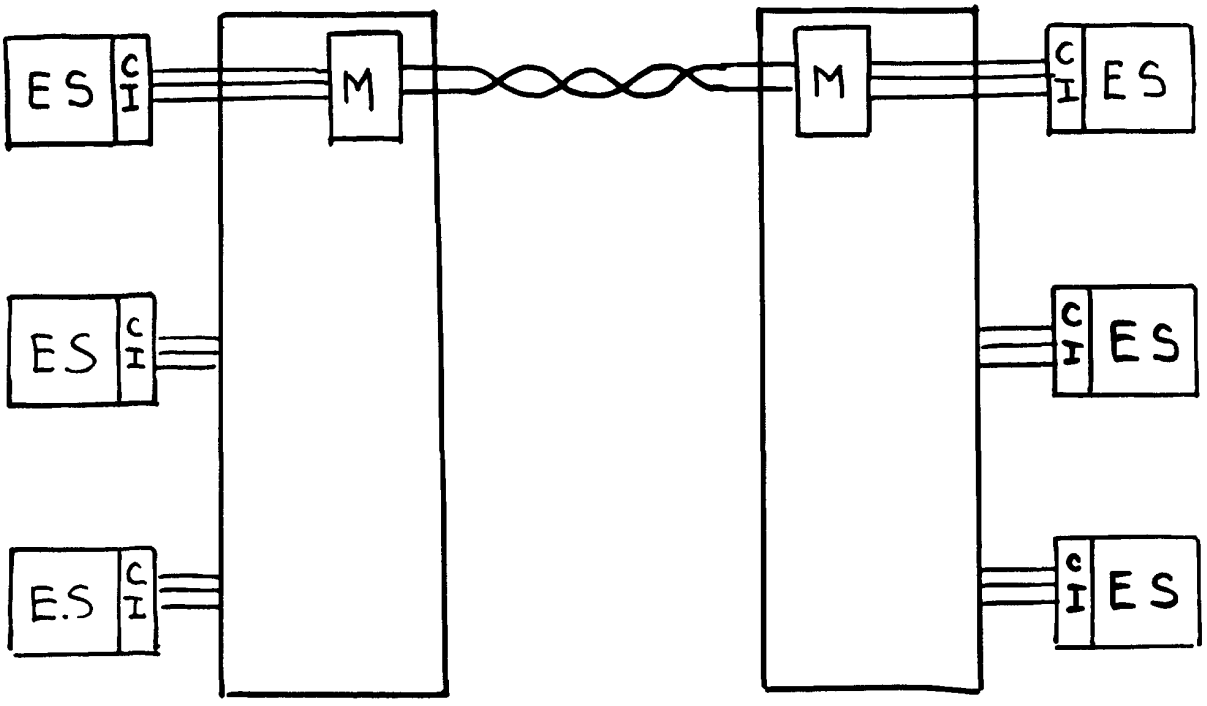
Example: Freq. Mod. Modems



* "Digital"

* "Modulated Analog"

Transmission Techniques



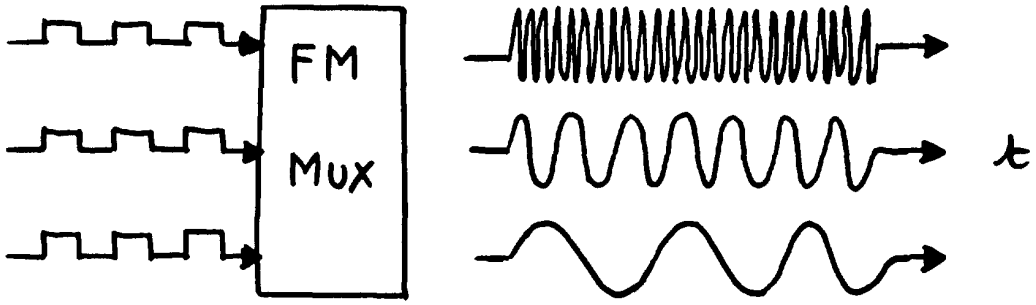
* Multiplexers

Transmission Techniques

Multiplexing

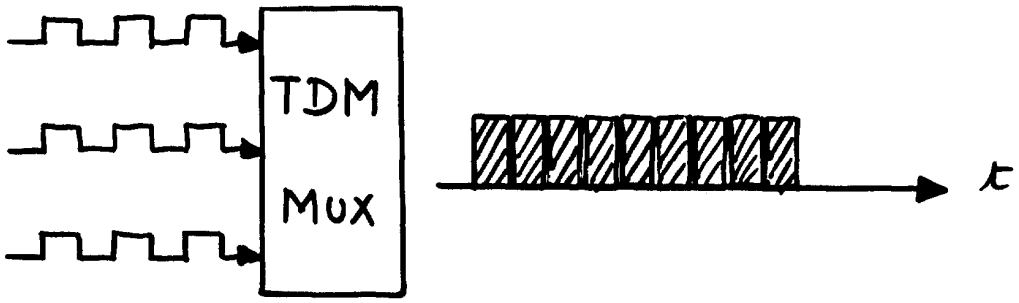
*FDM

Frequency Division Multiplexing



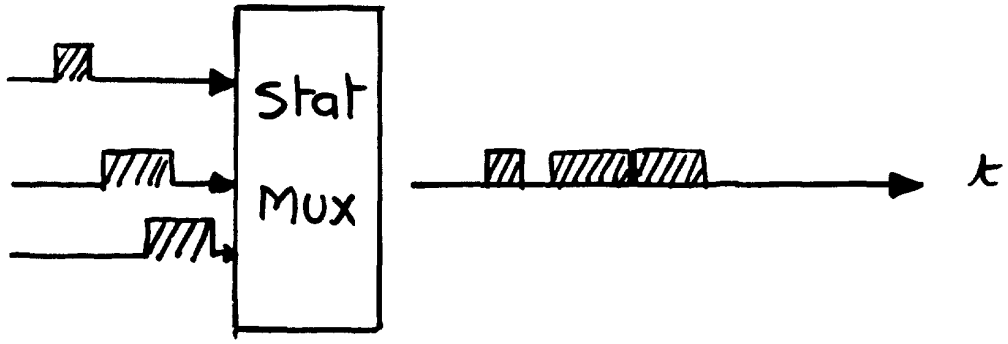
*TDM

Time Division Multiplexing



*SM (ATDM)

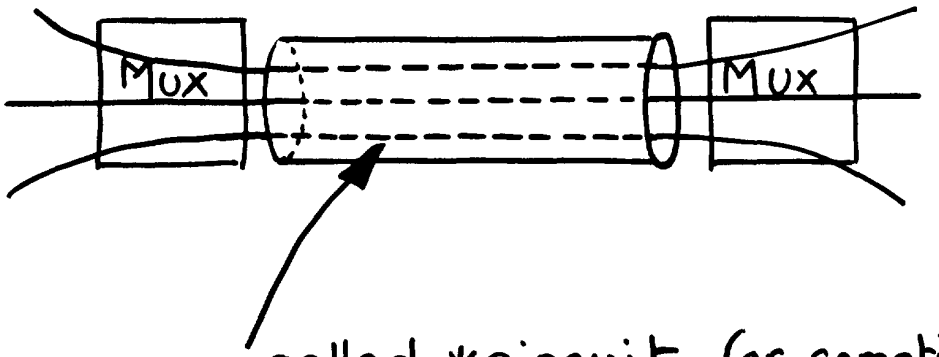
Statistical Multiplexing



When connecting terminals, also called *concentrators

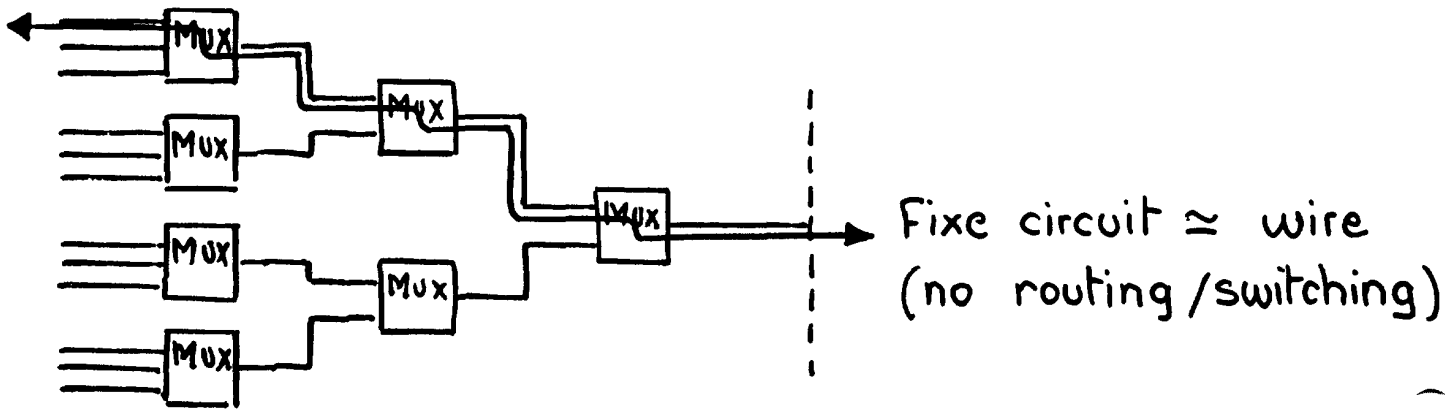
Multiplexing

1.



called *<u>circuit</u> (or sometimes channel)

2.



3. PTTs use mainly TDM and FDM

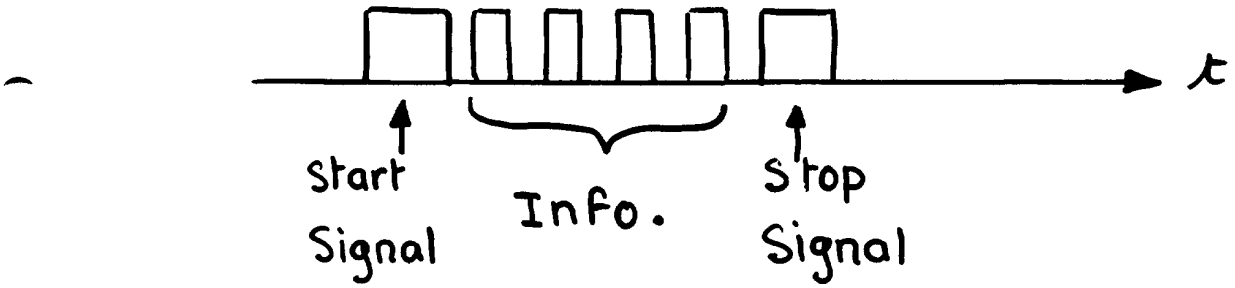
for sharing their media

Transmission Techniques

Asynchronous and Synchronous Transm.

1*Async.

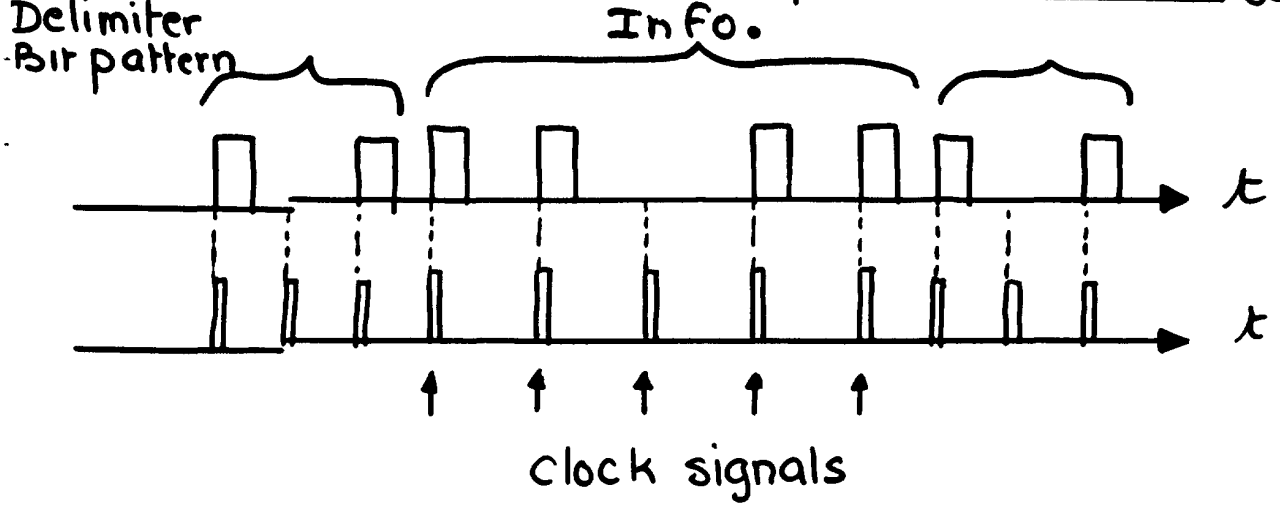
Transmission may start at any time



Used by most of the "ASCII" Terminals

2*Sync.

Transmission must take place on *clock signals



Used by most of the "computer" communications

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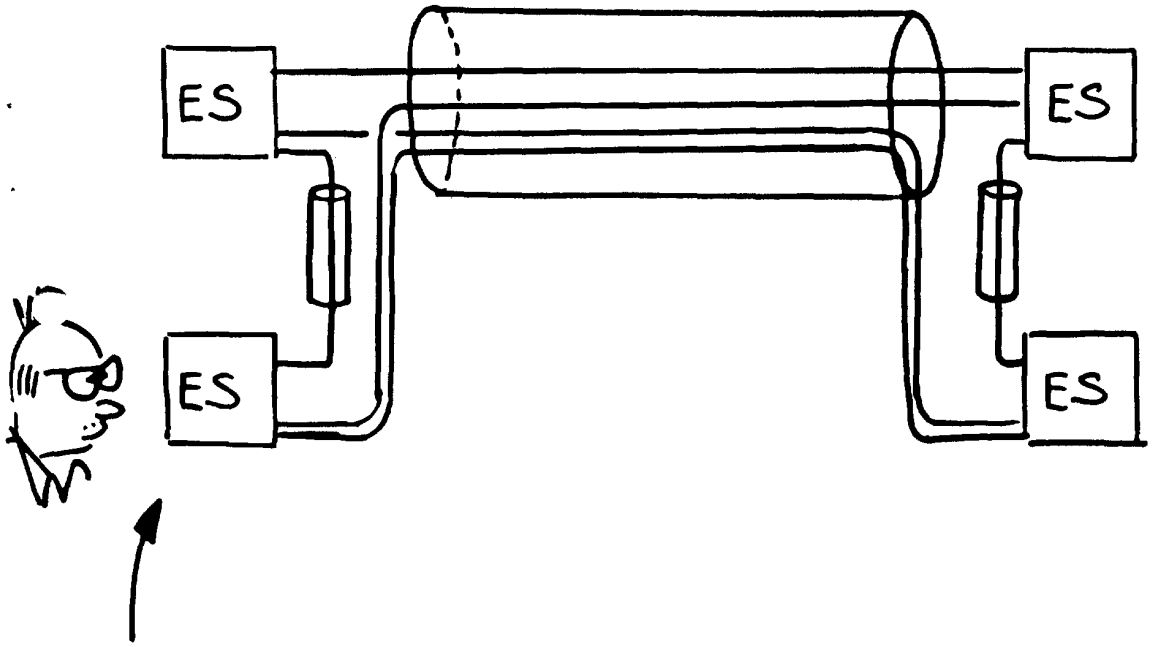
Communication Sub Network

* Topologies



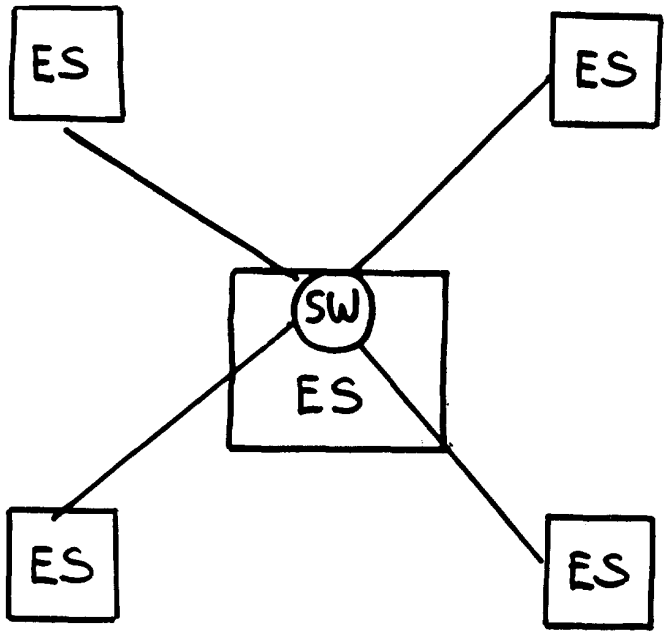
Requires already "addressing"

Simplest solution : Full Interconnection

(e.g. : primitive telephone net.)

Topologies *(Point-to-point)

Star



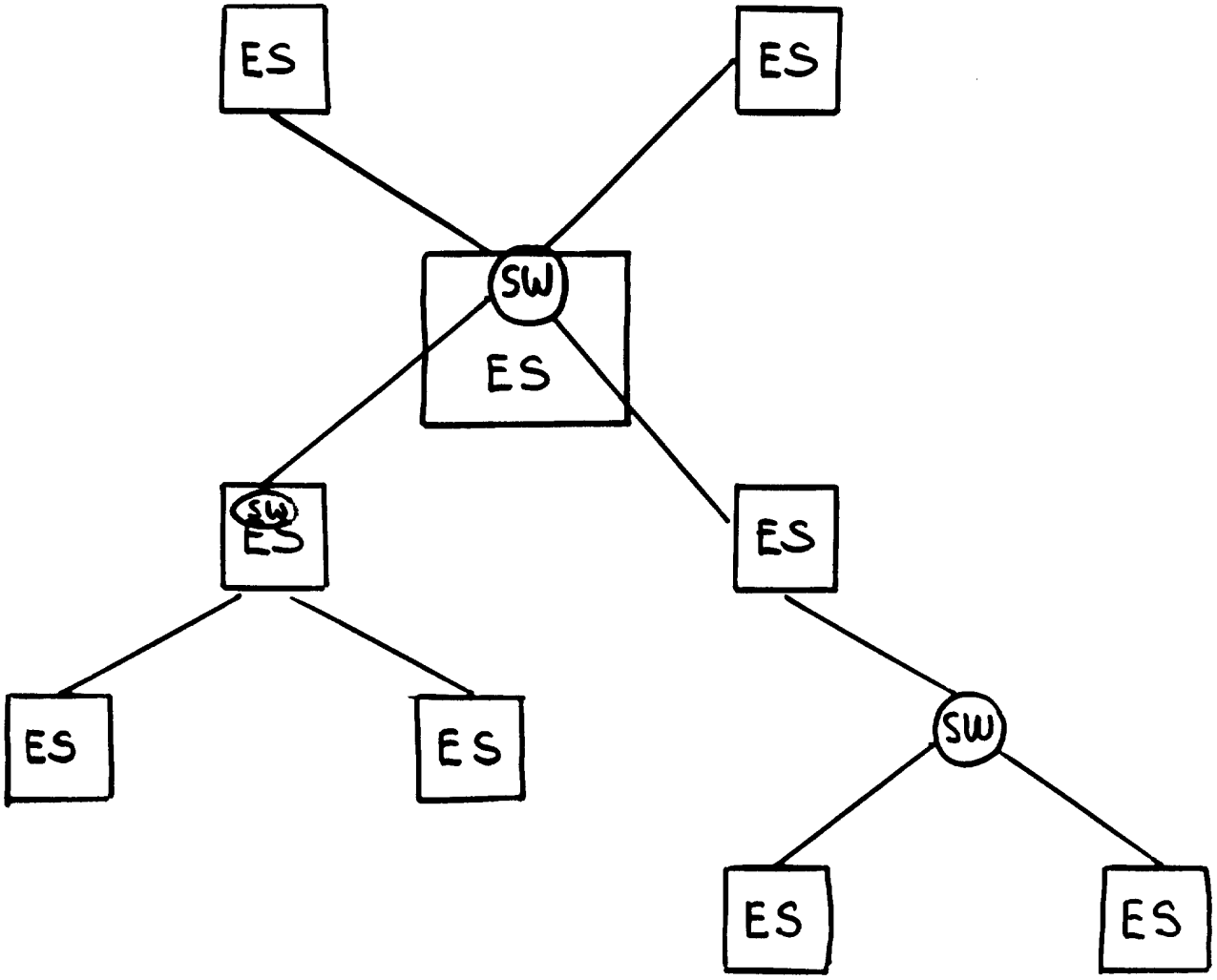
Single Route between 2 ES

Example : CERN former telephone network

Topologies *(Point-to-point)

Star

Tree



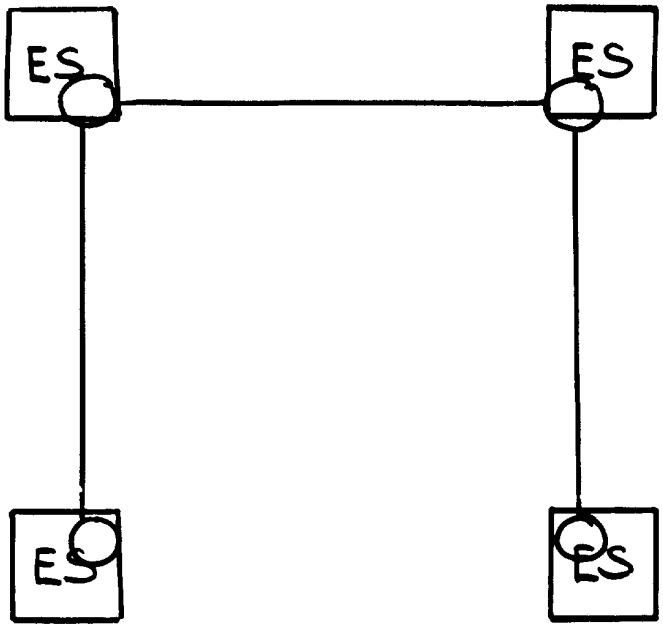
Single Route between 2 ES

INDEX at CERN

Example : CERN former telephone network,
Example : most of the terminal networks"

Topologies

Chain

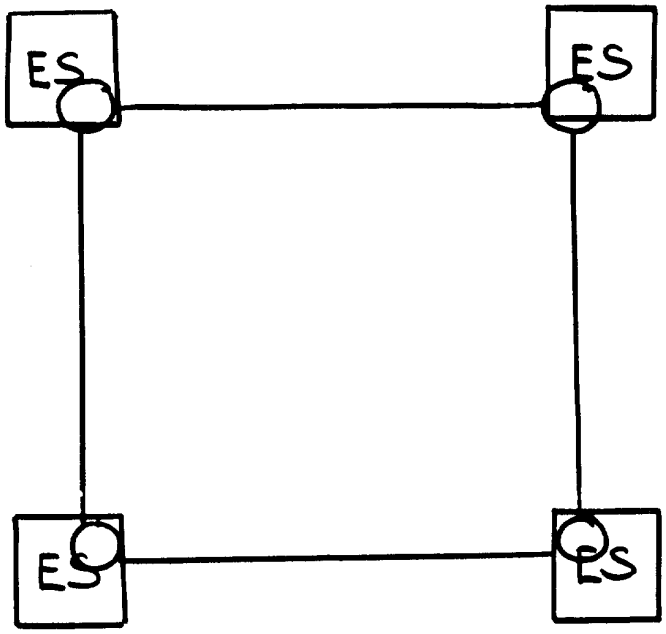


Topologies

Chain

↓

Loop (Ring)



Topologies

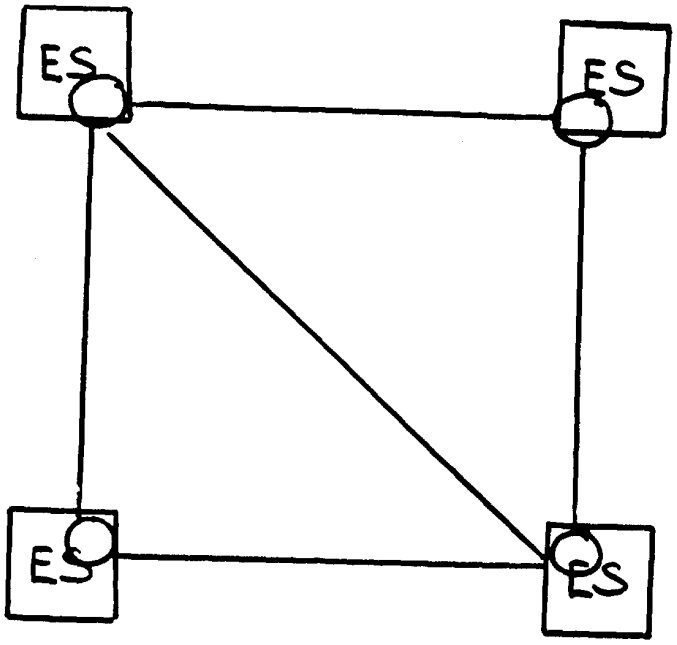
Chain

↓

Loop (Ring)

↓

Mesh



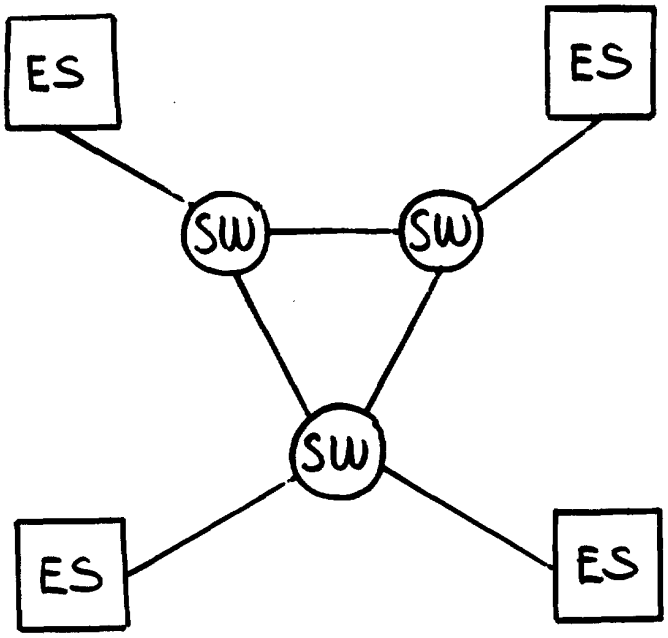
Alternate Routes

Example : DECNETs (some)

Topologies

Mesh

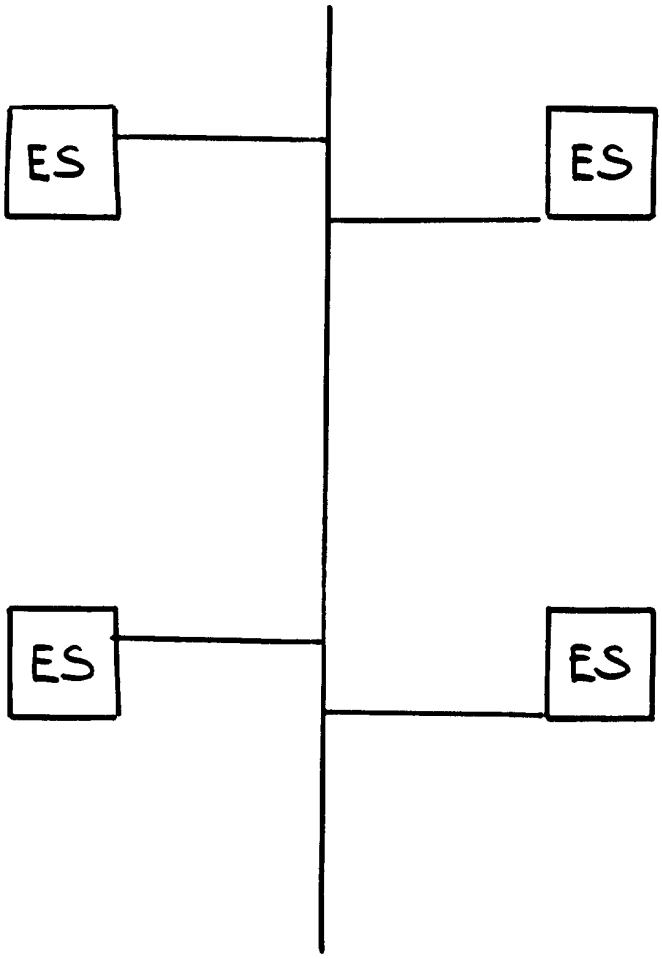
(Dedicated Switches)



Example : CERNET
"X25" Networks

Topologies *(Broadcast)

Multipoint
(Shared cable)



Example : Ethernet

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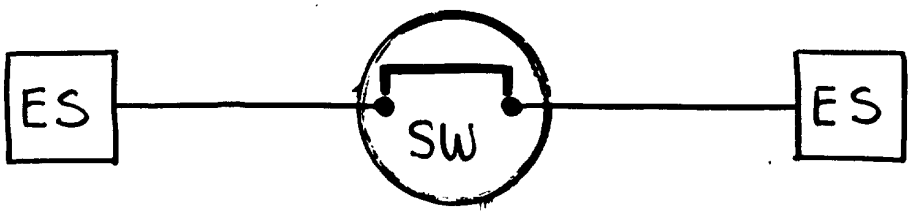
Switching Techniques

Circuit Switching

" A "physical" path (circuit) is established at the begining of the communication (call set up) "



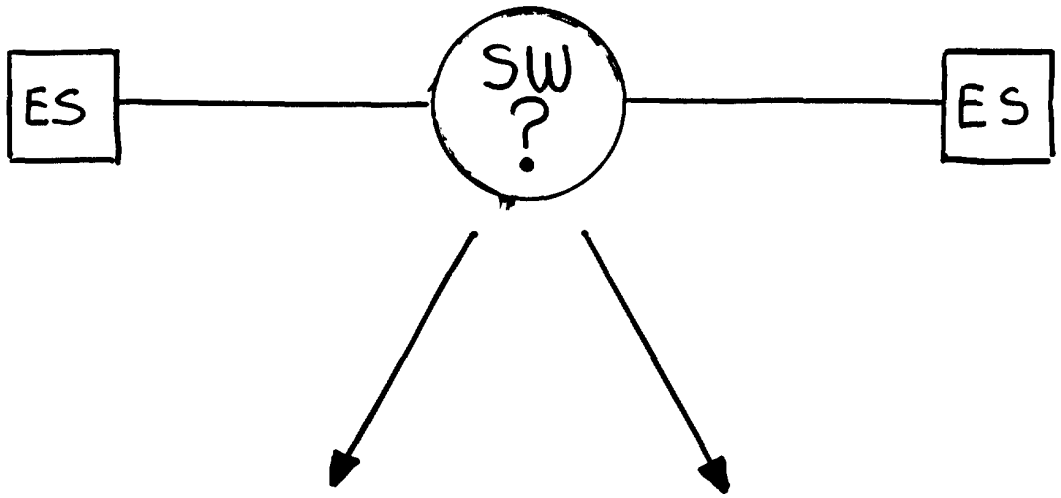
The historical switching technique

Examples:

- TELEPhone networks
- INDEX at CERN
- "X21" Networks
- Future ISDN networks

Communication Sub Network

Switching Techniques



* Circuit Switching

* Packet Switching

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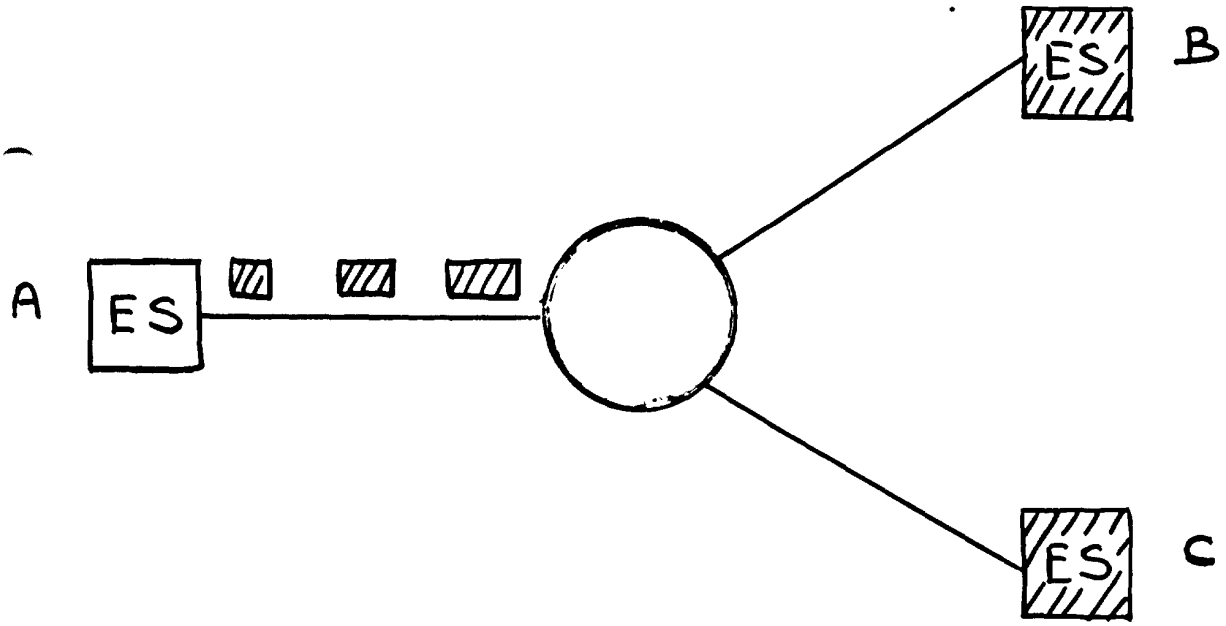
Switching Techniques

Packet Switching

Small bursts (packets) from several communications are multiplexed and routed individually by the switch



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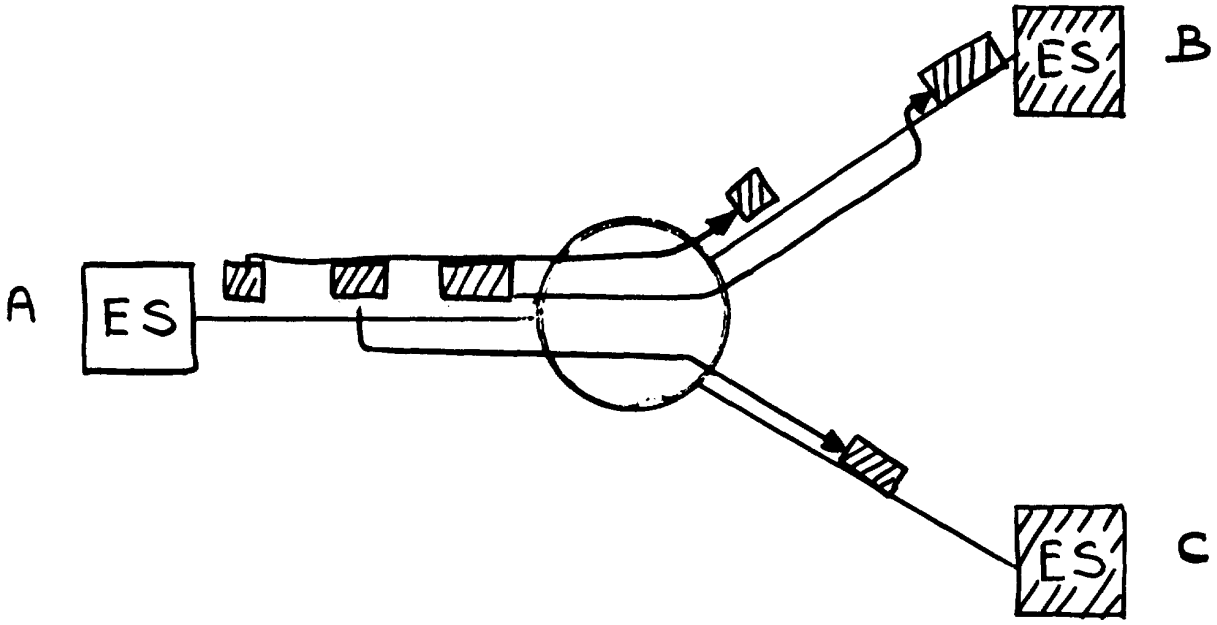


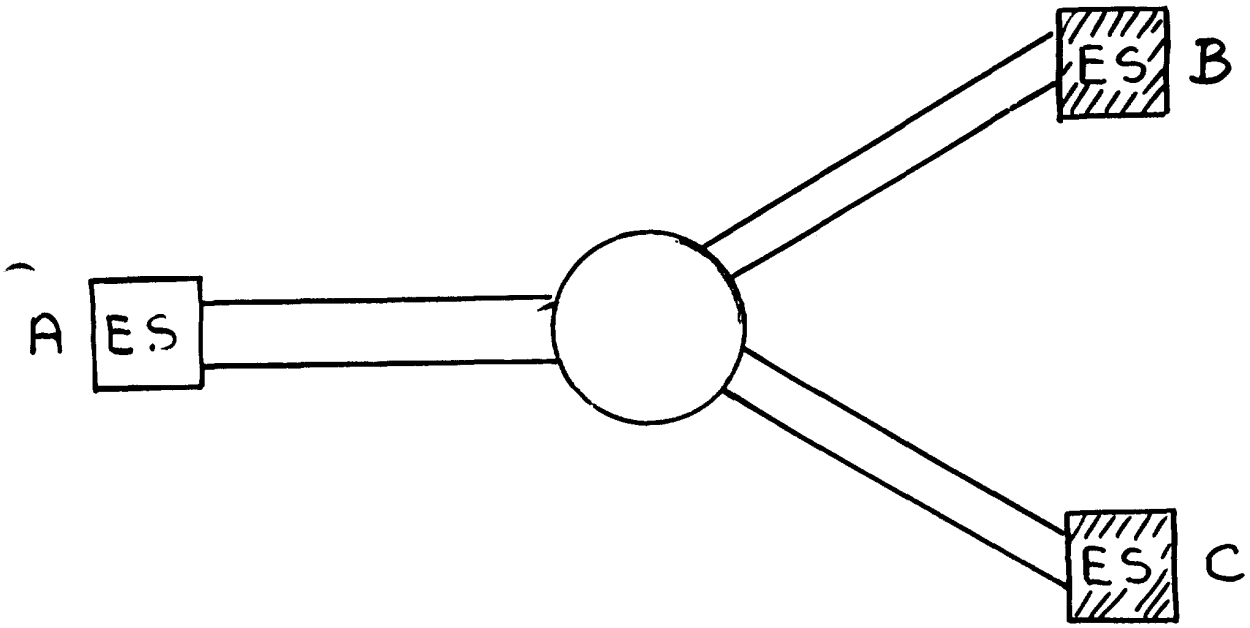
- "Invented" by P. Baran (Rand) in 1964

Examples:

- CERNET
- "X25" Networks
- ARPANET, SITA, ...
- "LANs" (Ethernet, Token Ring, ...)

Packet Switching

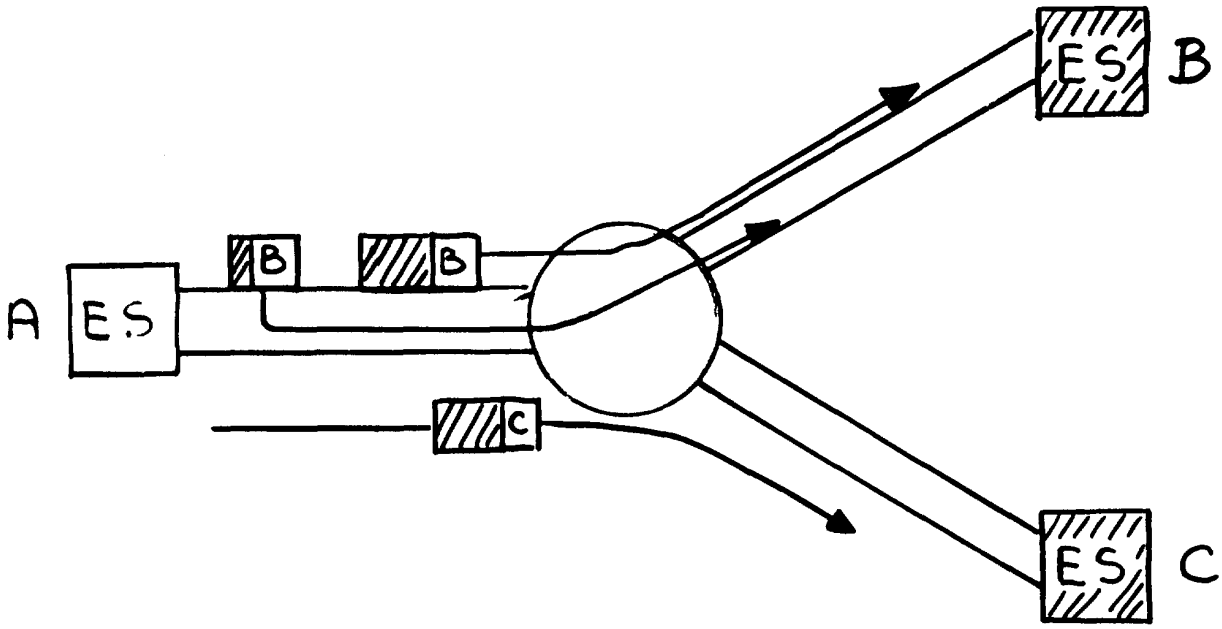
Datagrams vs Virtual Circuits



Packet Switching

Datagrams vs Virtual Circuits

* Datagrams



- each packet carries the full dest. address
- packets can be sent at any time without "prior connection"
- traffic unpredictable

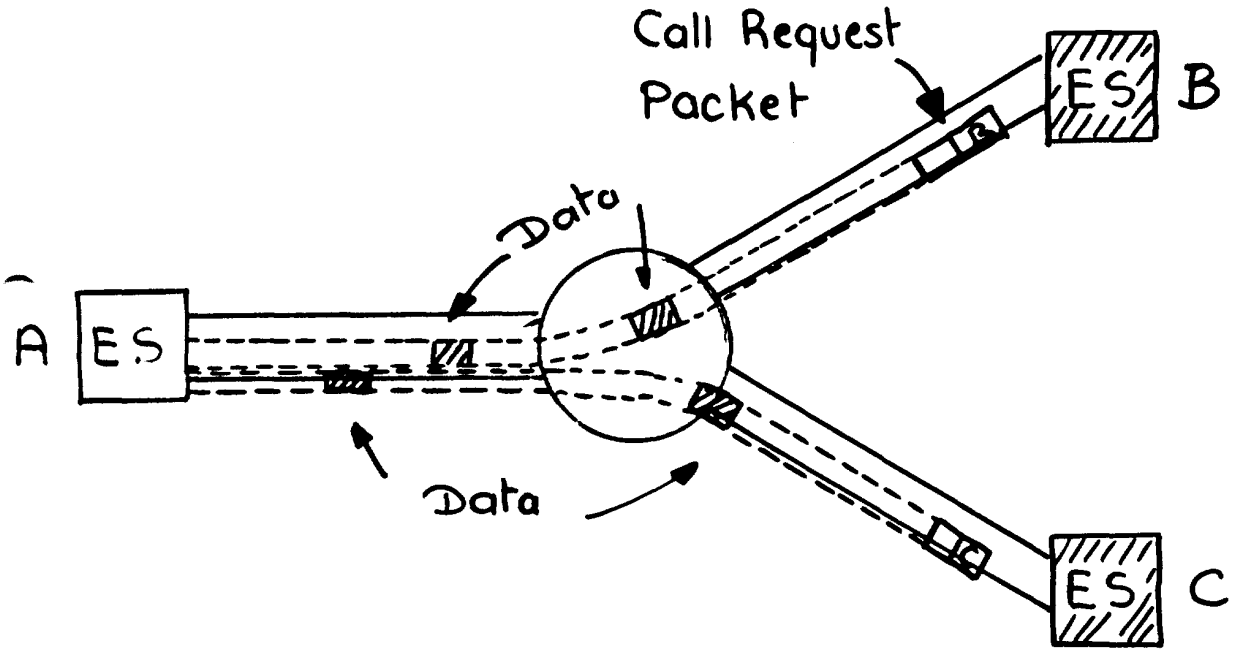
Examples : .CERNET

.LANs

Packet Switching

Datagrams vs Virtual Circuits

* Virtual Circuits (VC)



- Virtual circuits established and released when necessary
- Data Packets do not carry the full dest. address (only a reference to the VC)
- traffic more predictable

Examples : • X25 Networks

Switching Techniques

Circuit / Packet Comparison

	Circuit	Packet
Establishment of connection	mandatory	optional
Resource alloc.	Fixed allocation (even no traffic)	adaptative
Routes	Fixe	fixe or adaptative
Multiplexing	null or limited	high
Risk of congestion	very low	potentially high
Overhead of Protocol	null	non-negligable
Communication Transparency	very high	limited • pkt transit delay • risk of pkt loss/corrup.

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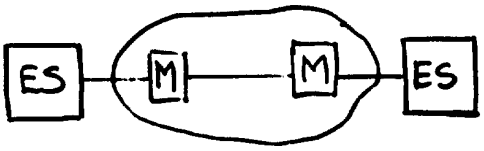
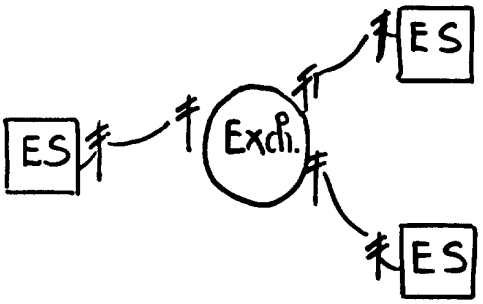
PTT offering for WANs

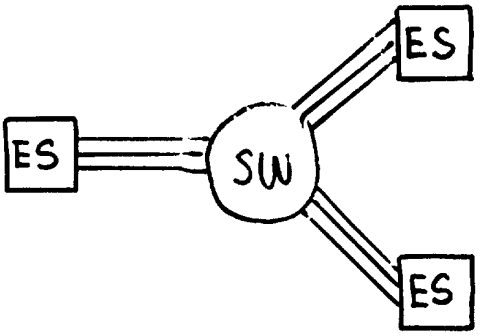
1. Point-to-Point Leased Lines



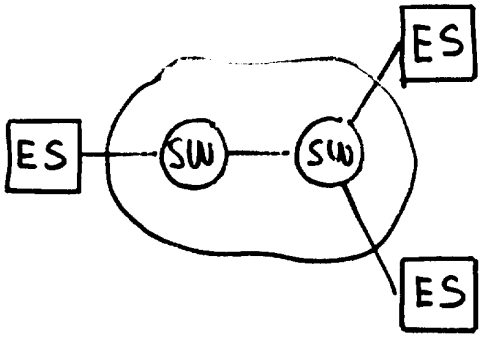
2. Public Circuit Switching Telephone Net. * (PCSTN)



3. Public Circuit Switching Data Net. * (PCSDN)



4. Public Packet Switching Data Net. * (PPSDN)



Point-to-Point Leased Lines

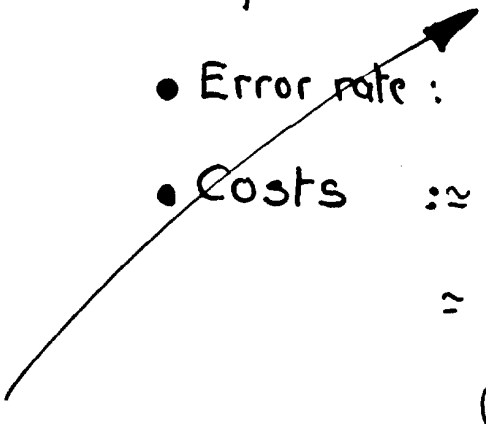
- Yesterday - Today

  Analog links :
  - Speed : 9.6 Kbps - 48 Kbps
  - Error rate : Medium
  - Costs : ≃ 60 KsF/year (9.6) (International)

  Terrestrian and Satellite

- Today - Tomorow : why ?

  Digital links :
  - Speed : 64 K - 2M - 144 Mbps
  - Error rate : Low
  - Costs : ≃ 120 KsF/year (64 K)
    ≃ 1,2 MSF/year (2 M) (International)



Digital telephone voice channels

Field of Application :

Point-to-Point
or High Volume
or continuous
} communications

PCSTN : Public Circuit Switching Telephone Net

(Dial Up call Service)

- Speed : 300 - 2400 bps
- Error rate : high
- Costs : Capital : Low

  Usage : Low for local

  High for international

  (Europe: 120 SF/hour
  Overseas: 500 SF / hour)

Field of Application :

- terminal access over local calls
  (e.g. : home work)
- when nothing else

PCSDN : Public Circuit Switching Data Nets

- Most follow the X21 Standard
- Cost of Usage : Connection duration only

- Today

  Terrestrian nets :
  - limited domestic services in a few european countries (F, G, Nordic)
  - 2.4 - 64 kbps

  Satellite nets :
  - TELECOM1 Service in France
  - succes difficult
  - 64k - 2 Mbps

- Tomorow

  ISDN
  - 64k → 2Mbps

Field of Application :

- high volume + bursty communications (e.g. : to absorb peaks)

PPSDN: Public Packet Switching Data Net.

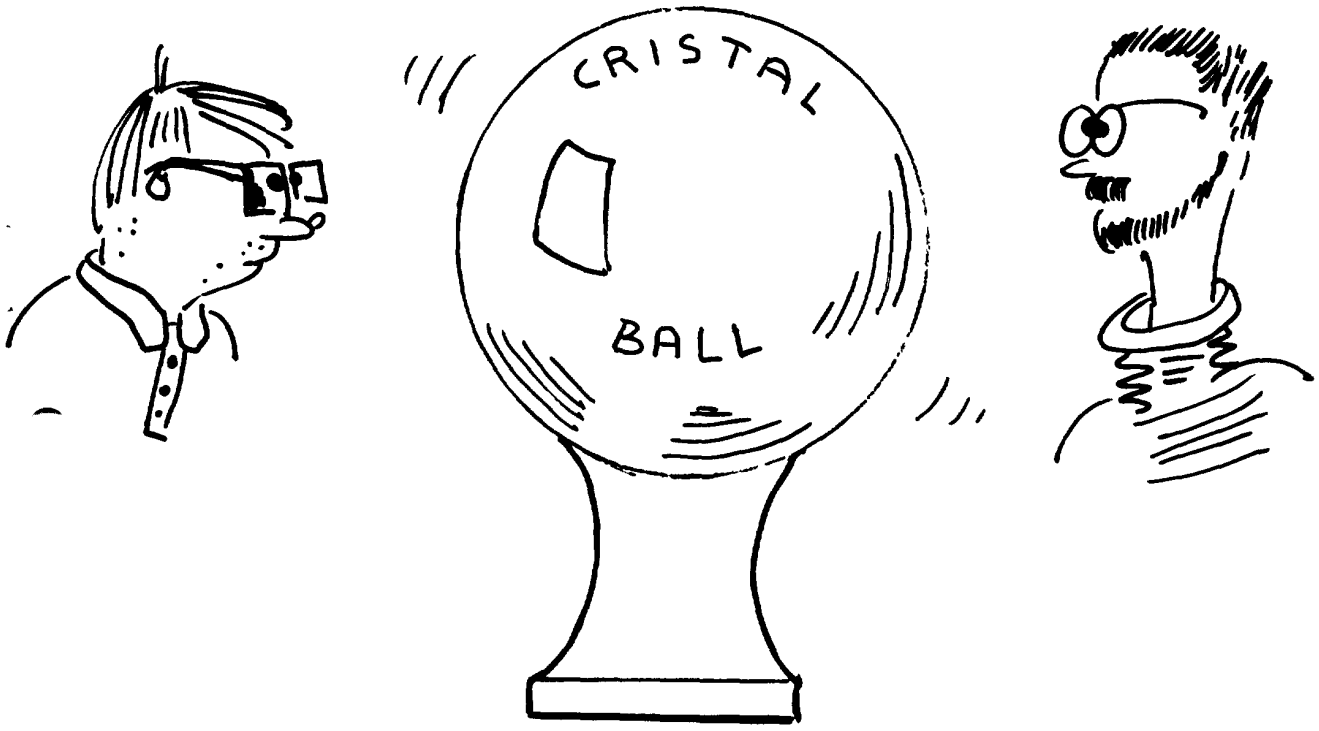
- All follow the X25 Standard
- Cost of usage : connection duration
  + data traffic

- Speed : 9.6 - 48 kbps
- Error rate : (in principle) very low
- Costs : subscription : 800 - 2000 SF/month
  usage (Europe): • 10 SF / 1 hour terminal
  • 10 SF / 100 K bytes
  (20 pages doc)
  (International)
- Connectivity : very high

Field of Application :

- Low - Medium speed interactive traffic
- Small size file transfer
- casual connections between very large communities

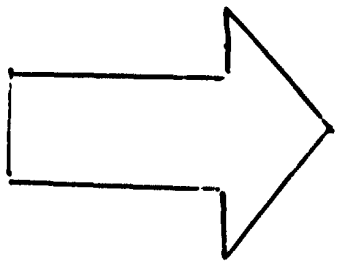
PTT Offering : Conclusions / Predictions



why?

PTT

Monopoly



OFfering
do not obey
market laws

PTT Offering : Possible Trends

for Data Communication :

- Telephone Net : obsolete

- Circuit Nets : negligeable impact
  except ISDN :
  promising but : . when ?
  . how much

- Packet Nets : if not improved
  (bandwidth, reliability)
  superseded
  in many cases by ...

- Digital Leased Lines: rental should continue
  to drop
  (but volume charging ?)

CERN : Infrastructure for External Communications

Today :

1. International Node for EARN in CH

2. International Node for EUNET in CH

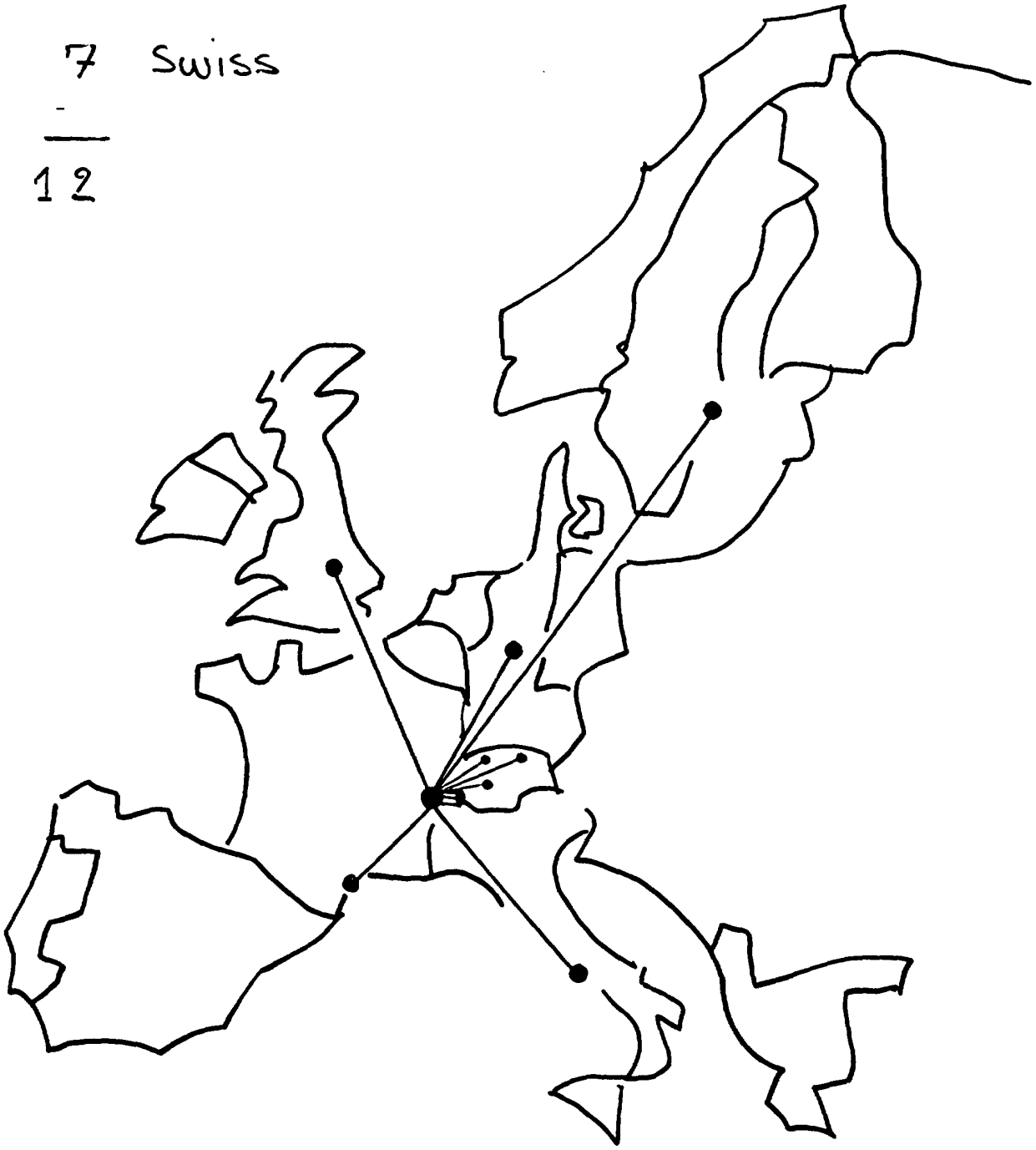
3. International Node for the World Wide
   "HEP-SPAN" DECNET
   (includes CHADNET)

4. International Gateway For MAIL (MINT/CERNVAX)

5 International EARN Leased Lines

7 Swiss

12

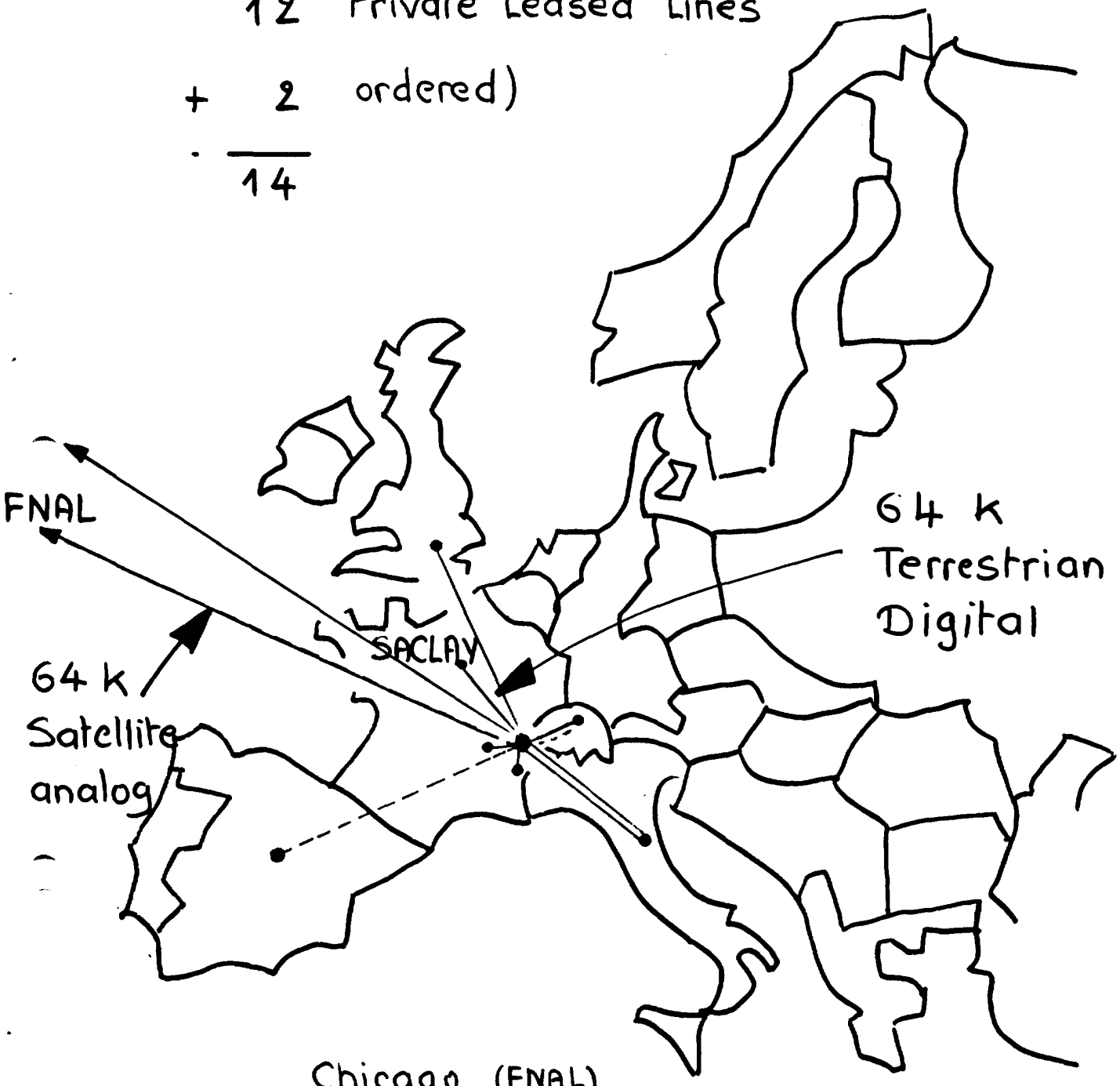


Internat: Oxford
Darmstadt
Rome
Stockholm
Montpellier

Switzerl: Geneva (3)
Bern
Lausanne
Zurich
Neuchatel

"HEP" Links

12 Private Leased Lines
+ 2 ordered)
14



Chicago (FNAL)
Geneva (UNI)
___ today : Annecy (LAPP) (2) --- tomorow: zurich (SIN)
Bologna (INFN) (2) Madrid
Lyon (IN2P3) (2)
Oxford (RAL)
Saclay (DPhPE)
Boston (MIT)
zurich (ETH)

Wide area Networking Infrastructure at CERN

Connection to the National Public X25 Networks

Computer Networks : Part 2

1 Network Components

2 Communication SubNetworks

- 2.1 Transmission technology
  - 2.1.1 Transmission Media
  - 2.1.2 Transmission Techniques
- 2.2 Network topologies
- 2.3 Switching techniques
  - 2.3.1 Circuit Switching
  - 2.3.2 Packet Switching
- 2.4 PTT offering for WANs

3 OSI Model

- 3.1 Basic principles of layering
- 3.2 Layer Services
- 3.3 The 7 Layers

4 Test Case : the X25 Protocols

OSI Model

Open Systems Interconnection

↓

- Issued by the ISO (78)

(H. Zimmerman - France)

↓

- Endorsed by the CCITT

↓

Not to confuse

OSI Model

Framework :

- principles of layering
- for "data com", a set of 7 layers

OSI Protocols

- contents of the framework

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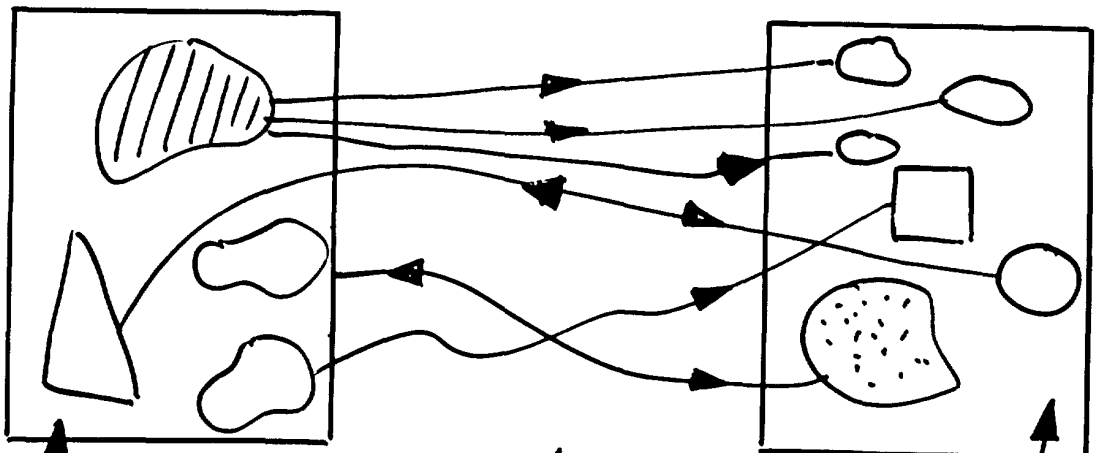
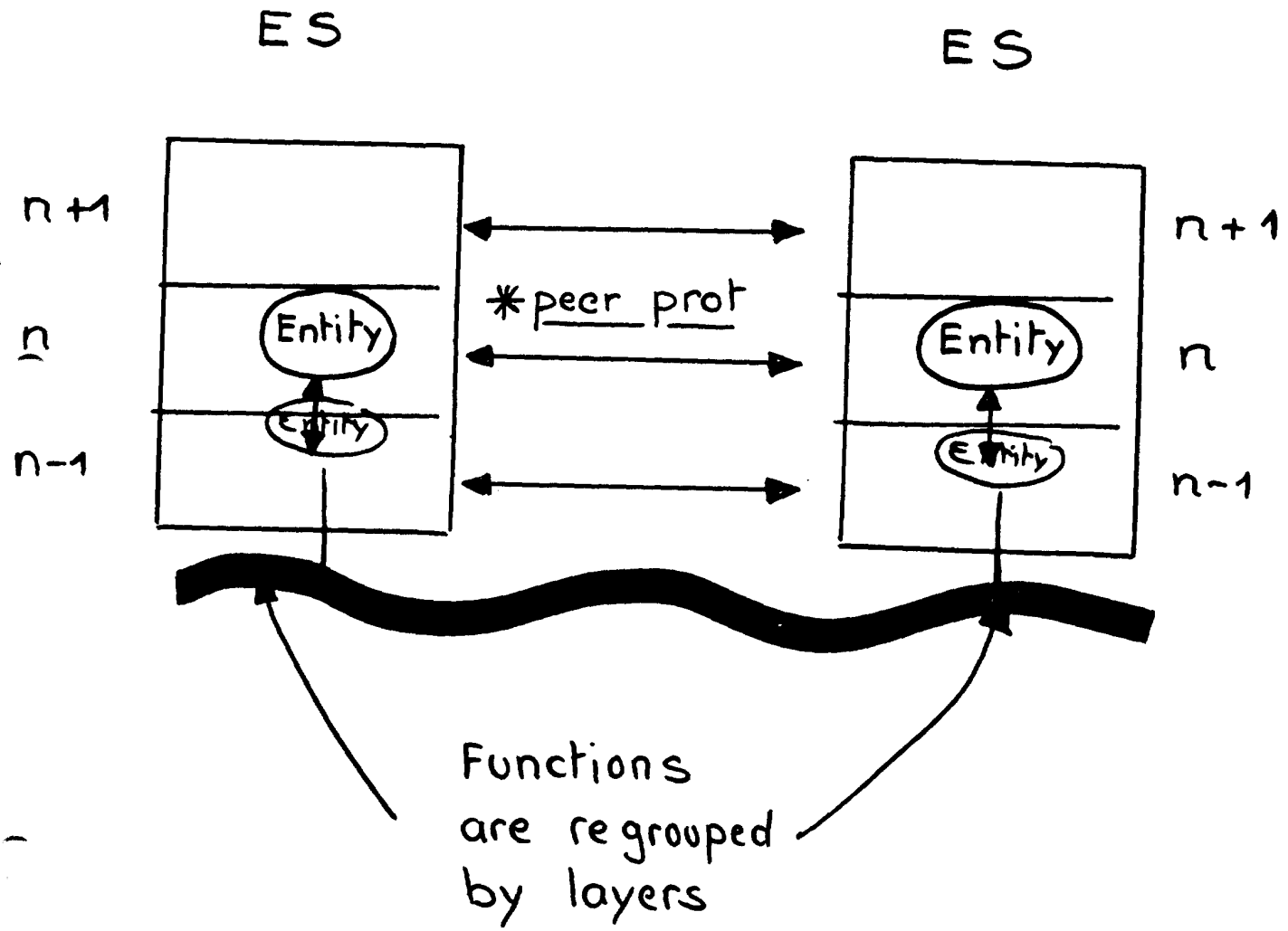
Basic principles of Layering



Communications obeying common rules

Objects (HW, SW) implementing the common rules

Basic principles of Layering



Layering existed before OSI :

- ARPANET in 68
- X25 in 74

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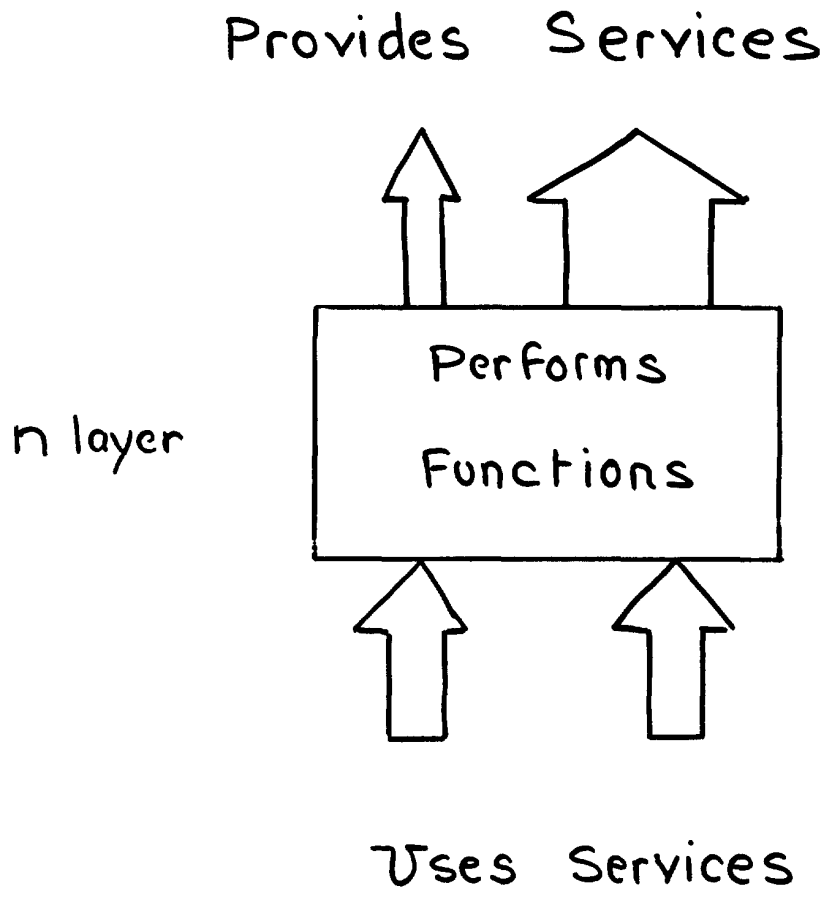
Basic Principles of Layering



OSI Layer Services

Possible Services

1* Connection Services

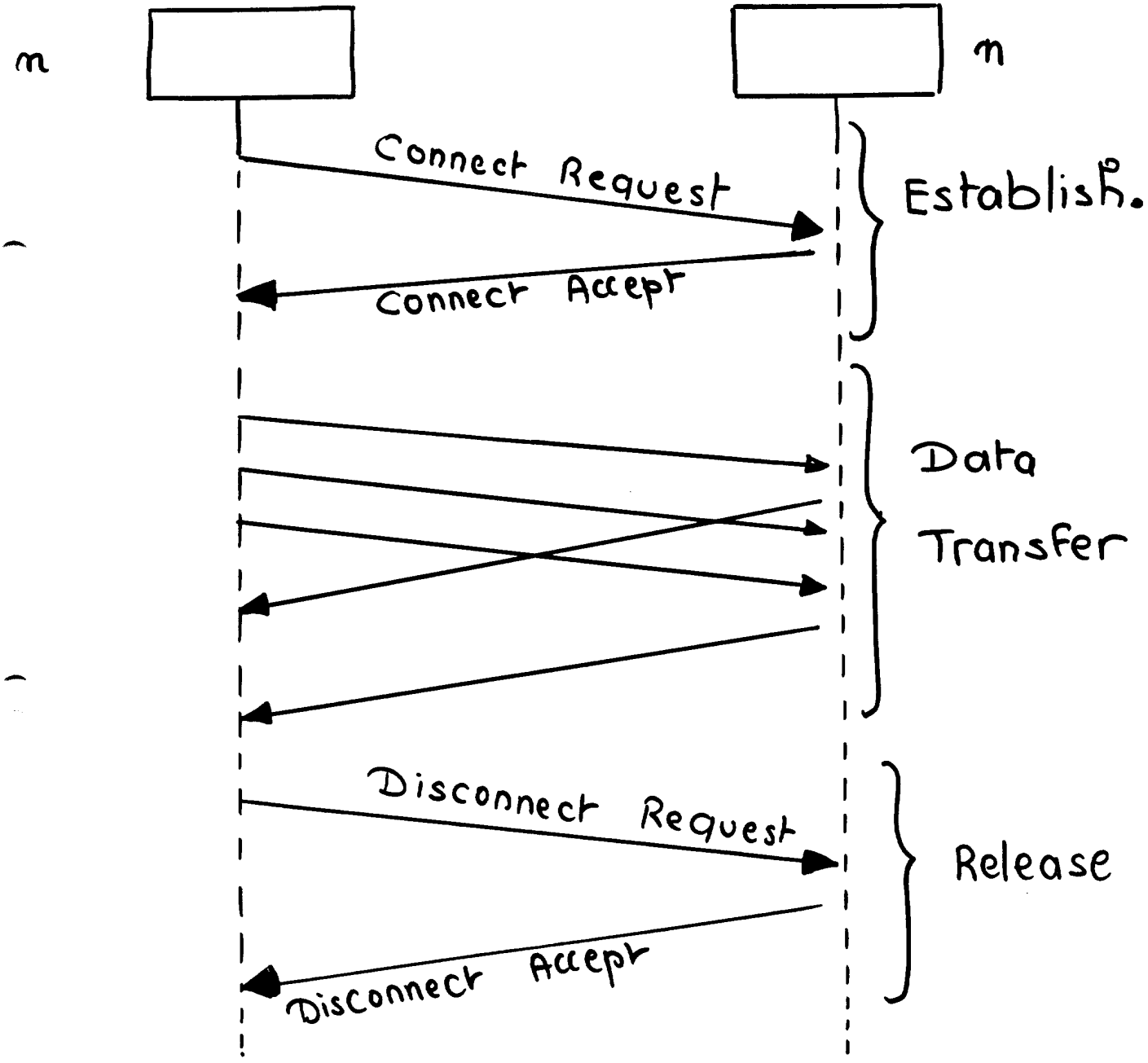
- Establishment / Release
- Multiplexing

2 Data transfer services

- Normal transfer
- * Expedited transfer
- * Flow control (speed matching)
- * Segmenting / Blocking

3 Error Functions

- Error Detection
- Error Notification
- Error Recovery
- * Re Synch.


n
n
Connect Request
Connect Accept
Establish.
Data
Transfer
Disconnect Request
Disconnect Accept
Release

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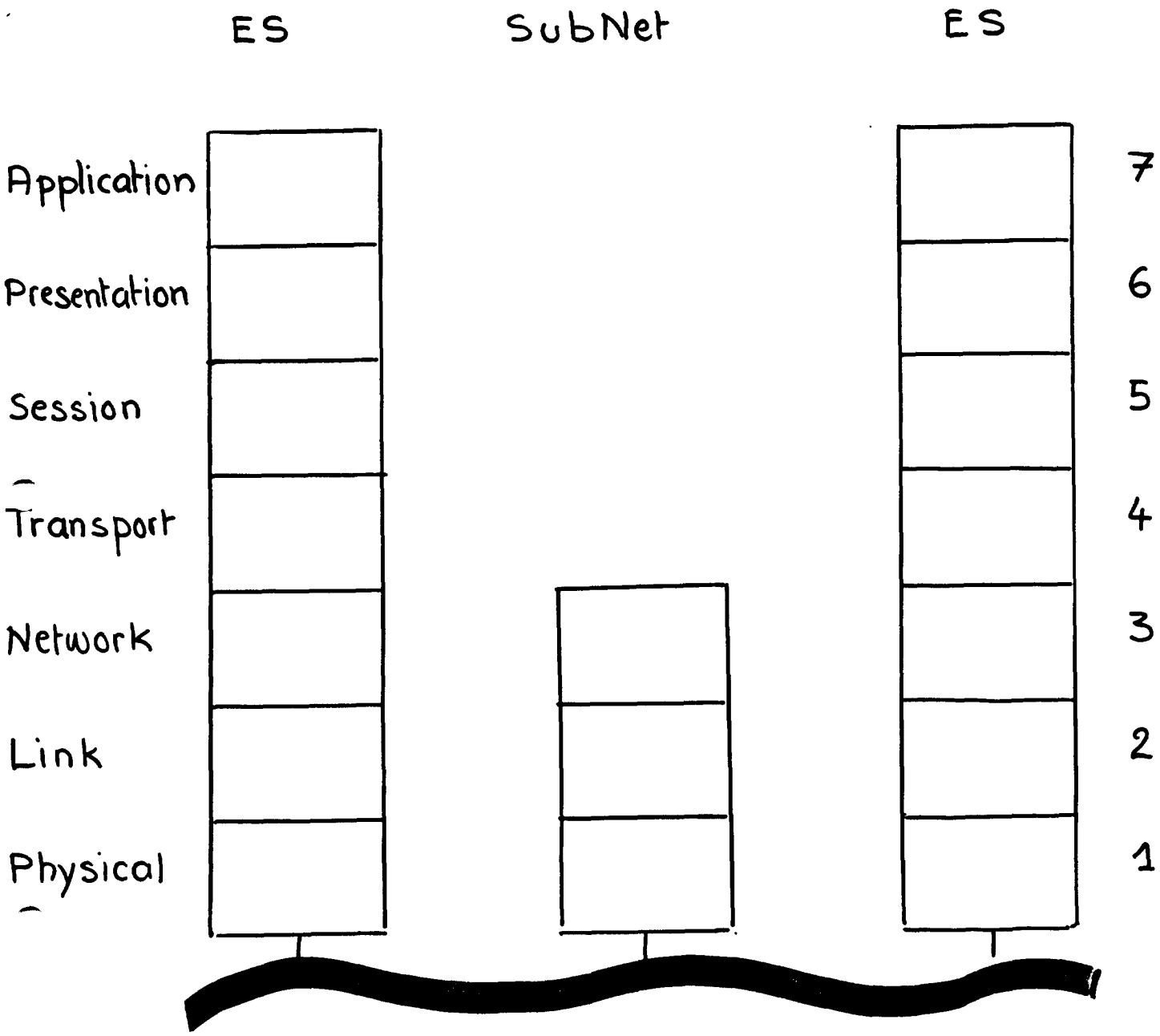
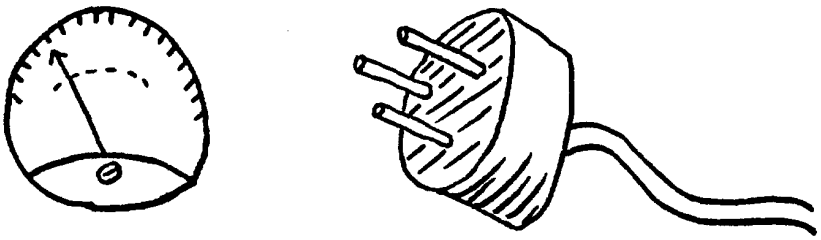
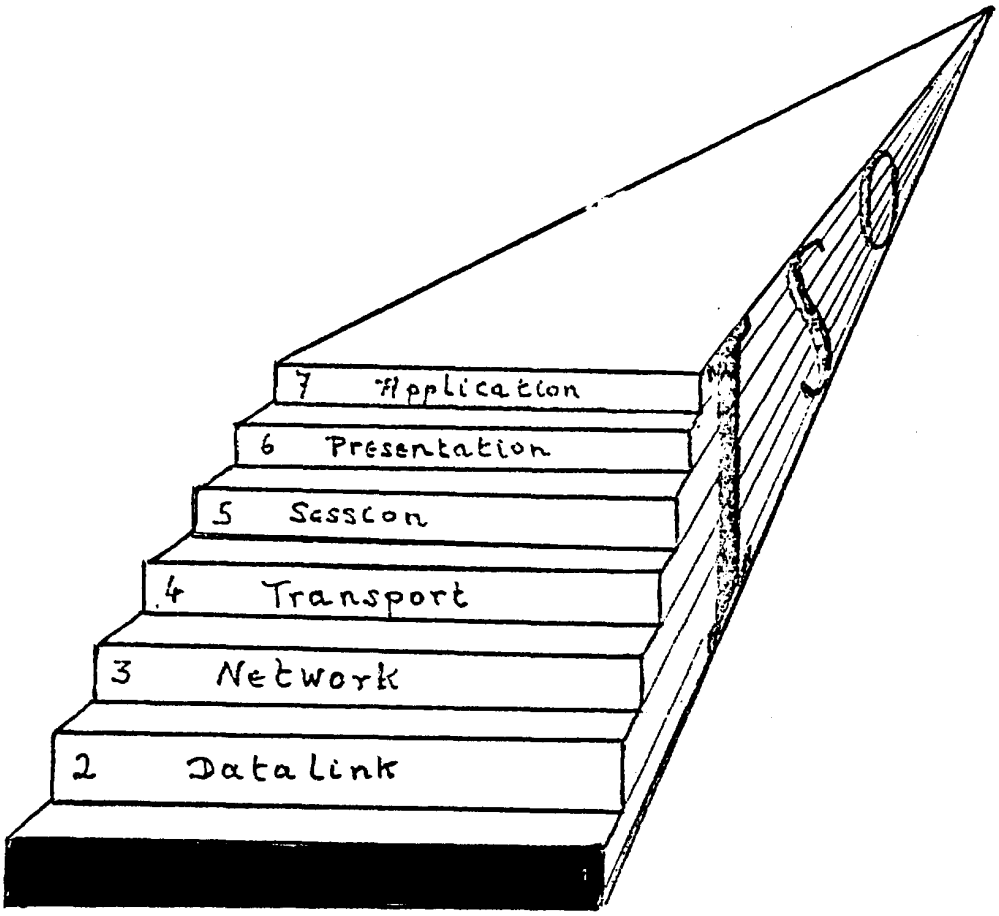
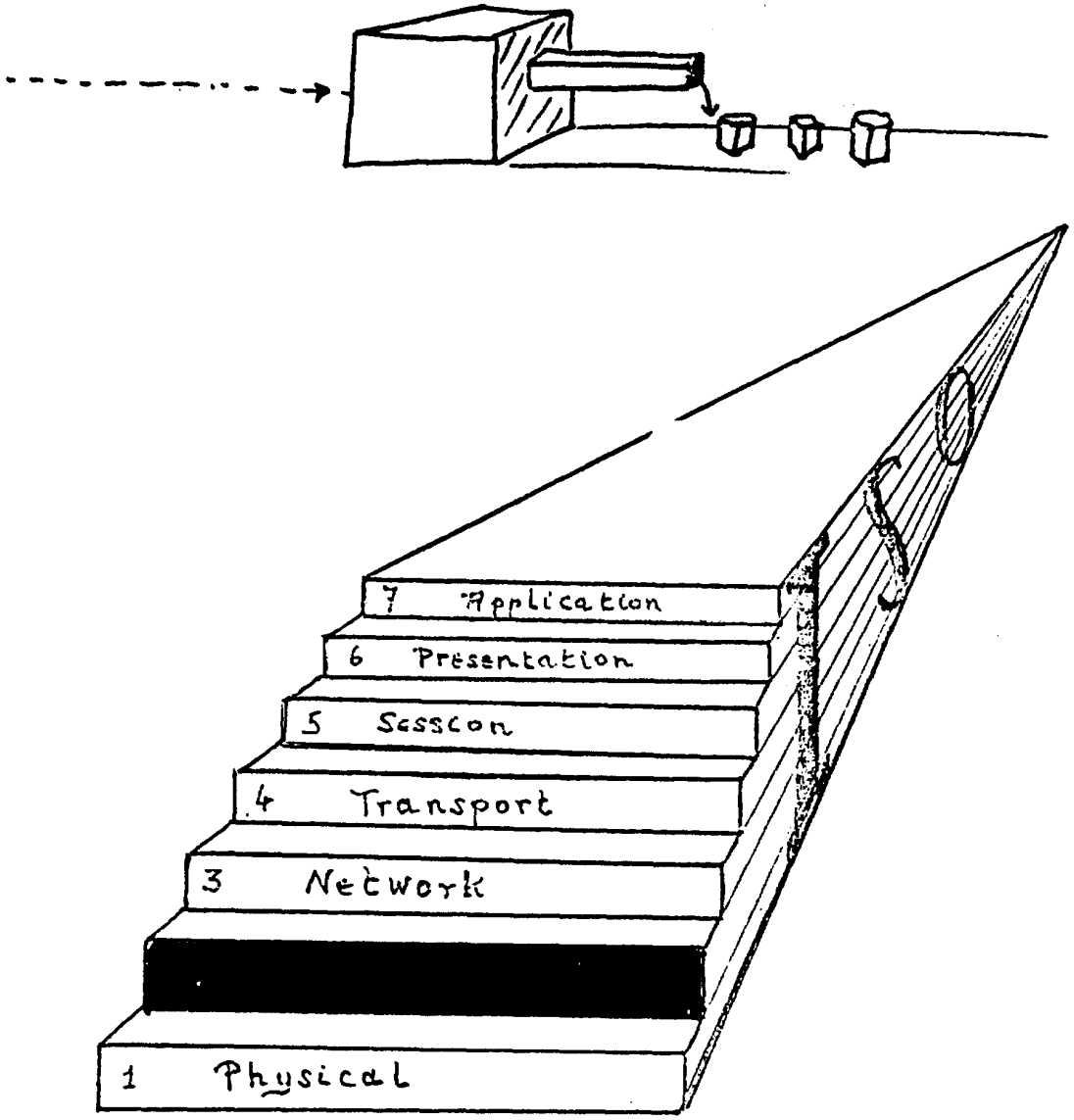
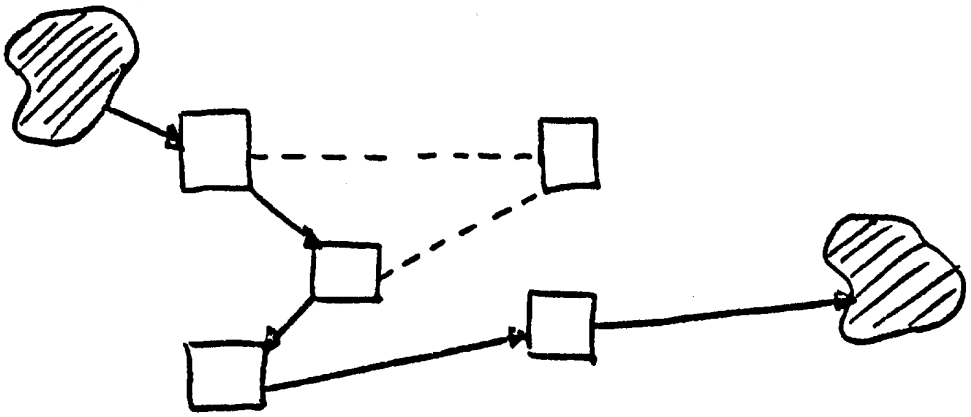
The OSI 7 Layers

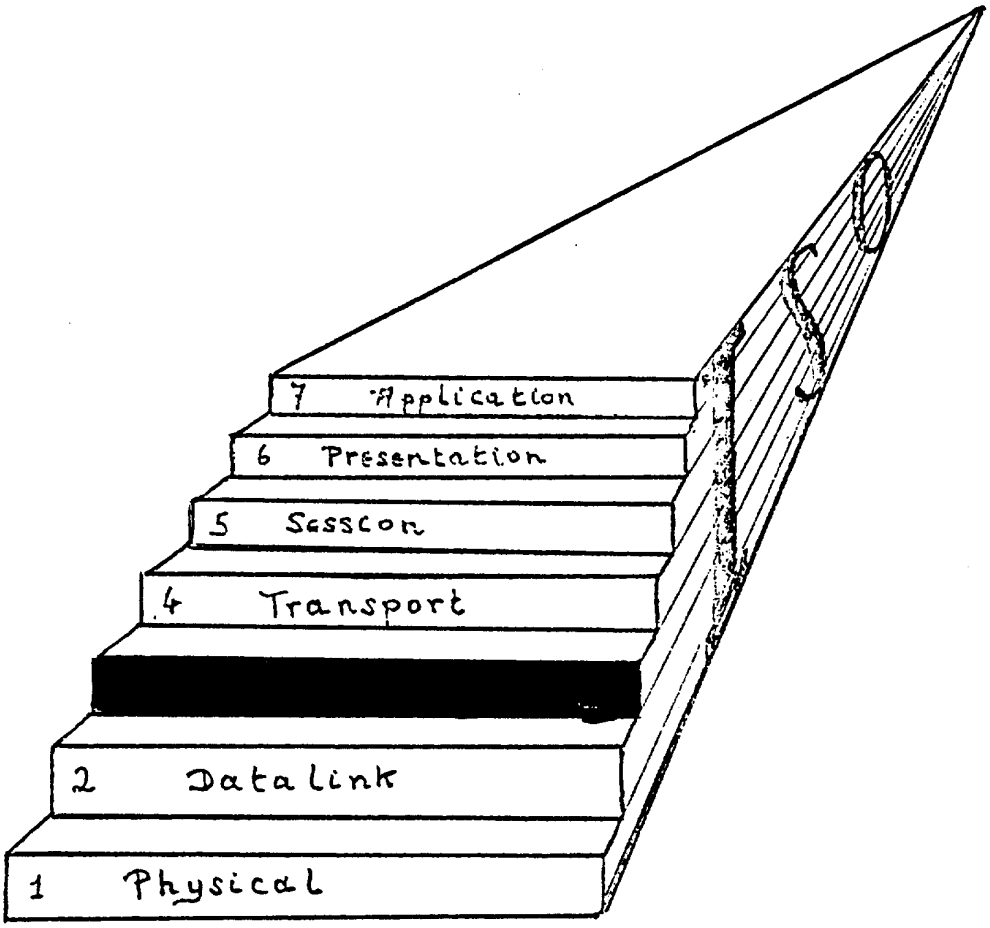


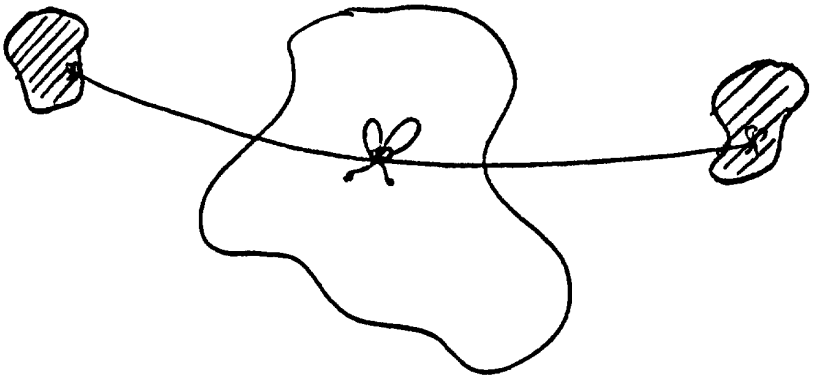


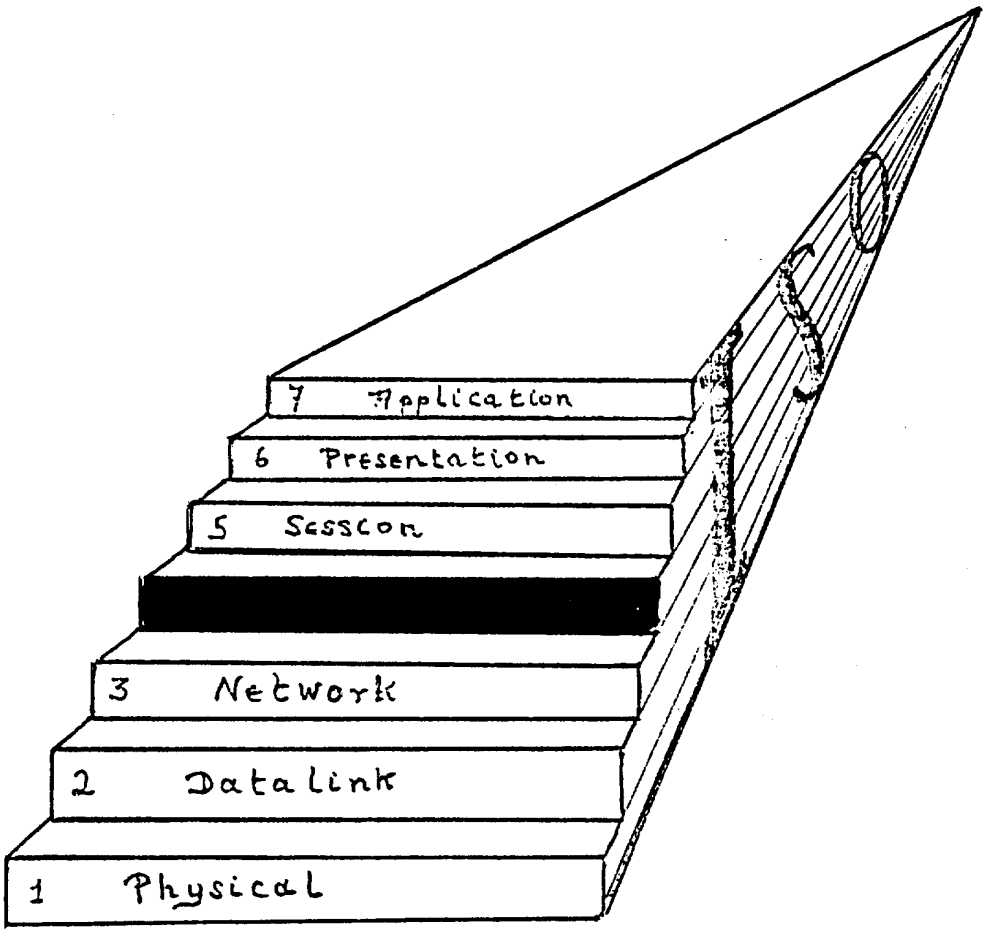

7 Application
6 Presentation
5 Session
4 Transport
3 Network
2 Data Link


7 Application
6 Presentation
5 Sesscon
4 Transport
3 Network
1 Physical




7 Application
6 Presentation
5 Sesscon
4 Transport
2 Datalink
1 Physical

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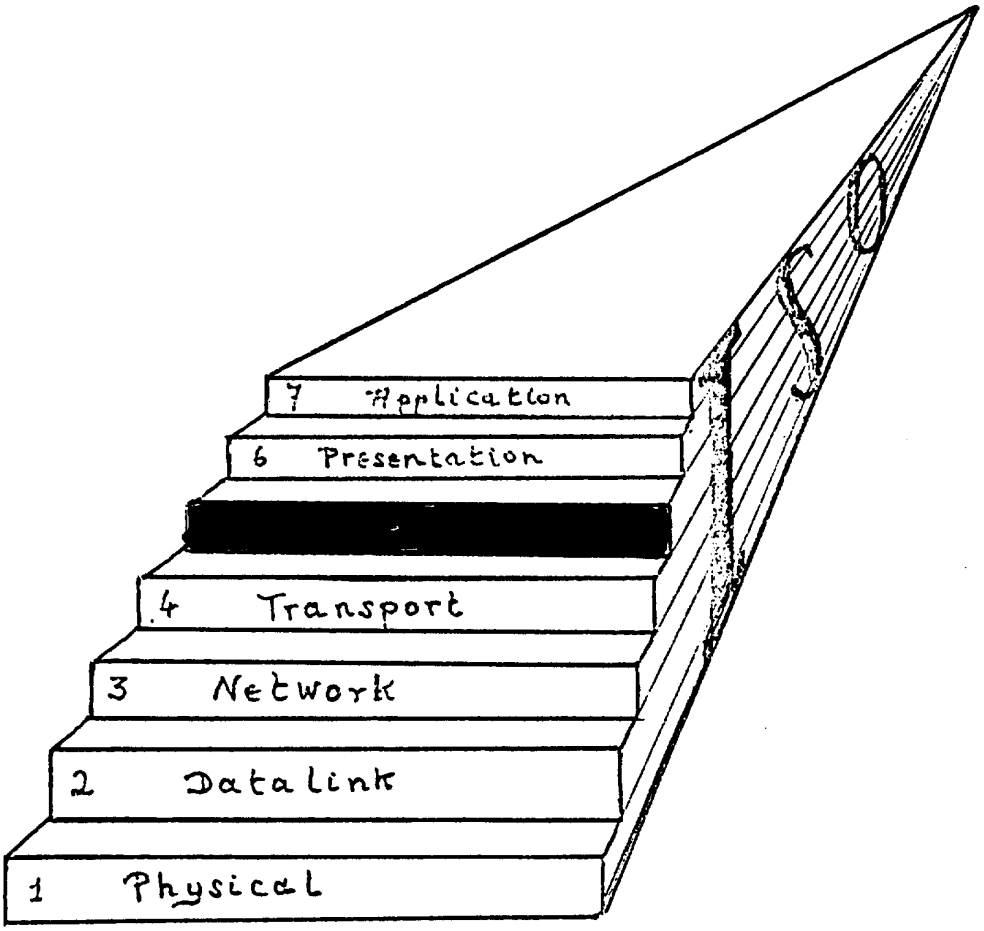
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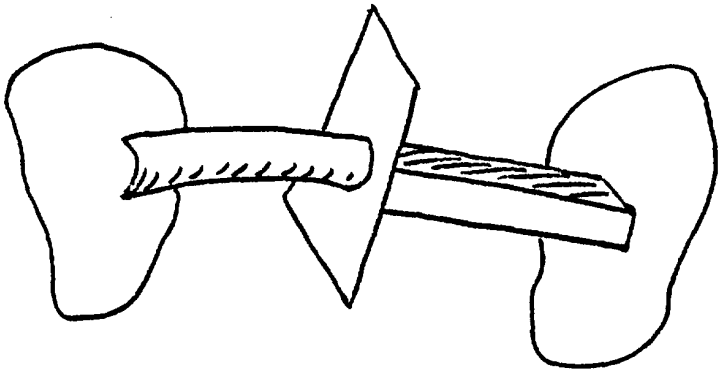

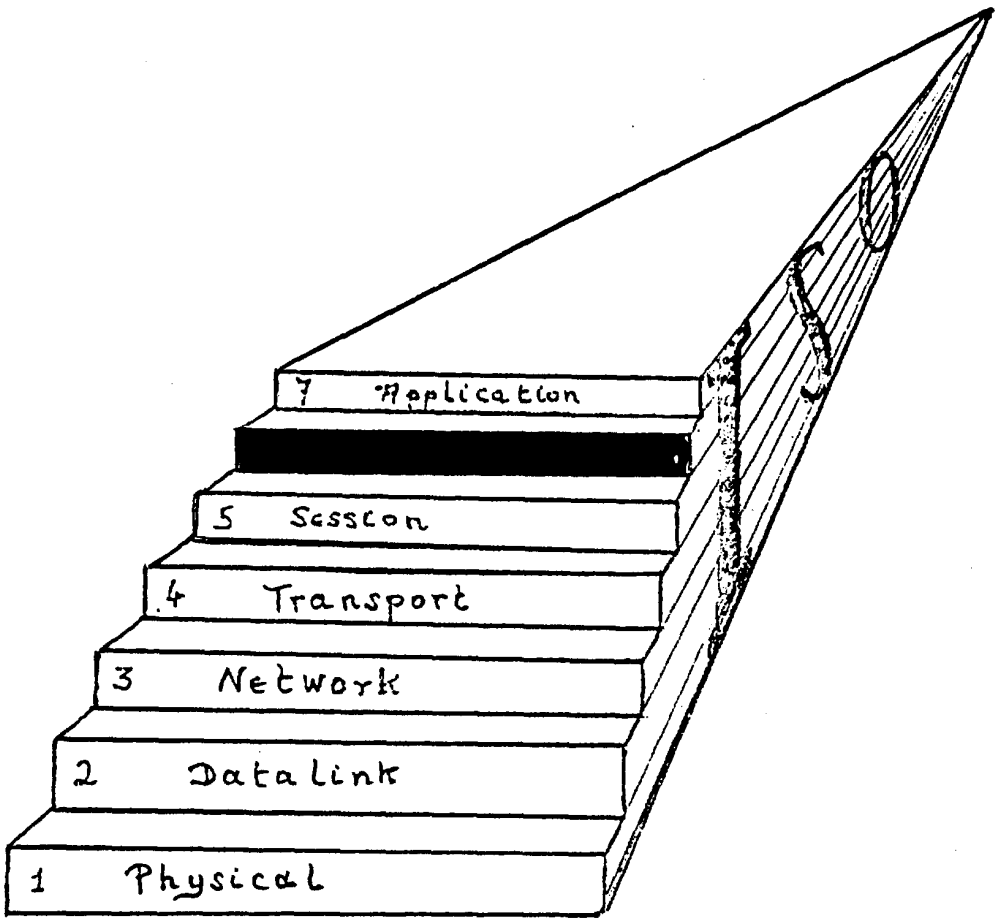
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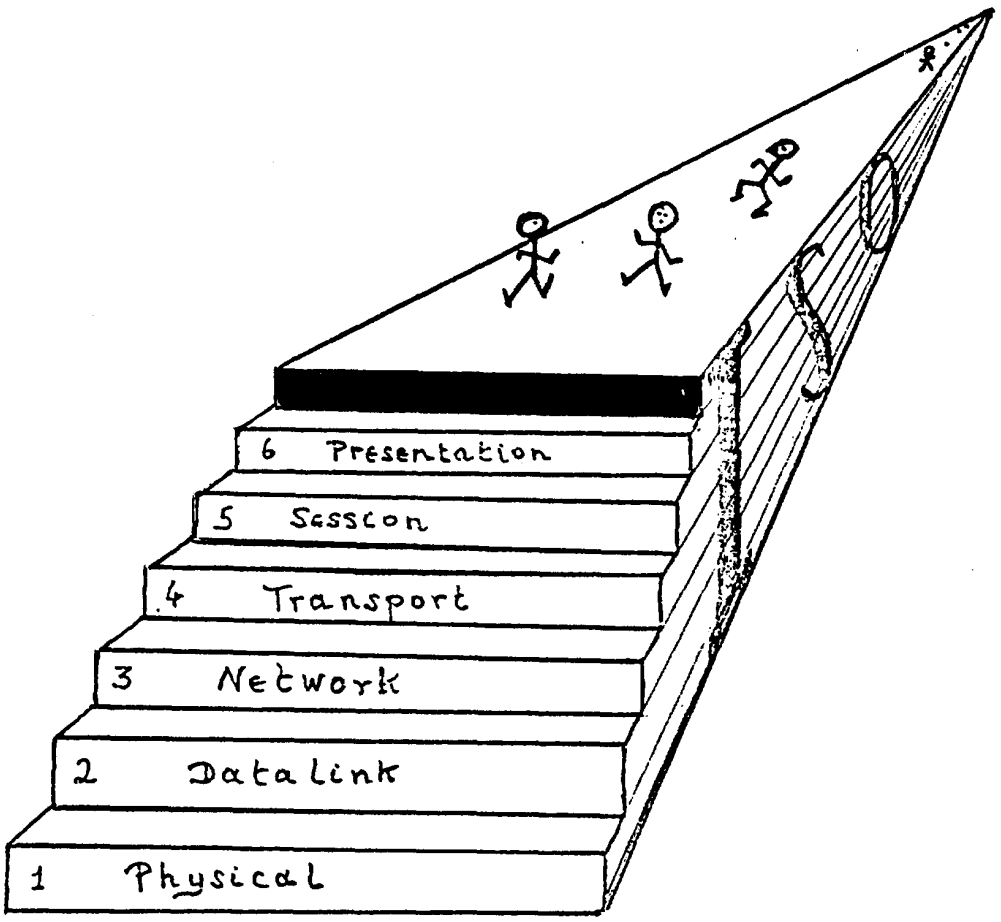
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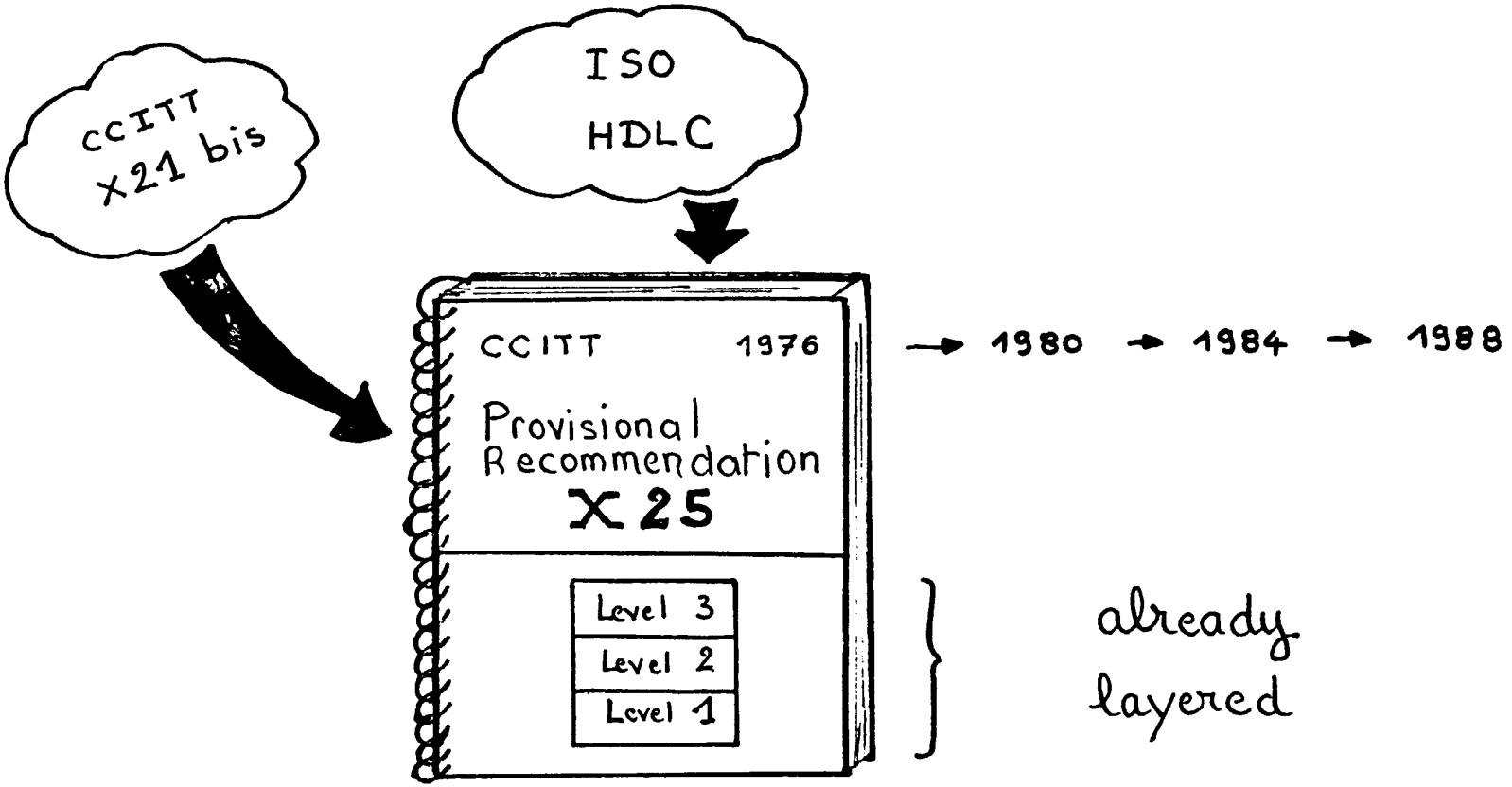
Example : X25 Protocols

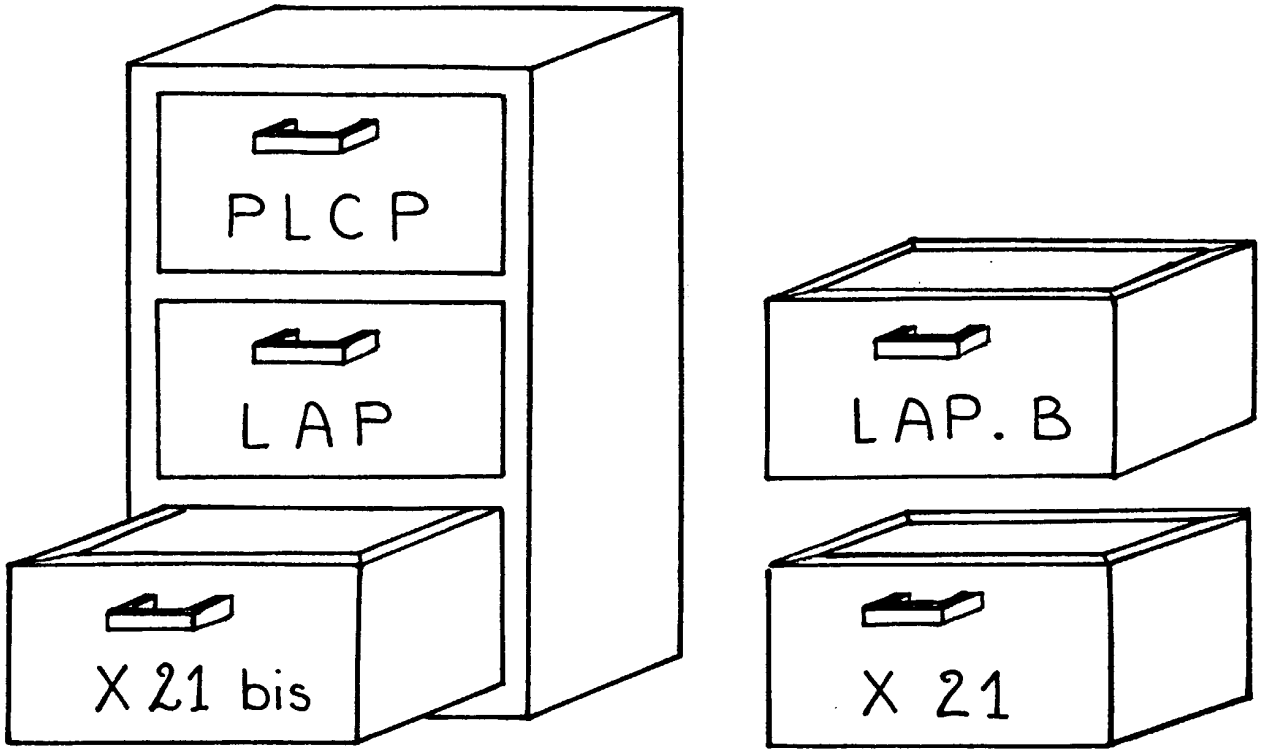
- Designed by the *CCITT
  (international standard organisation of the PTTs)

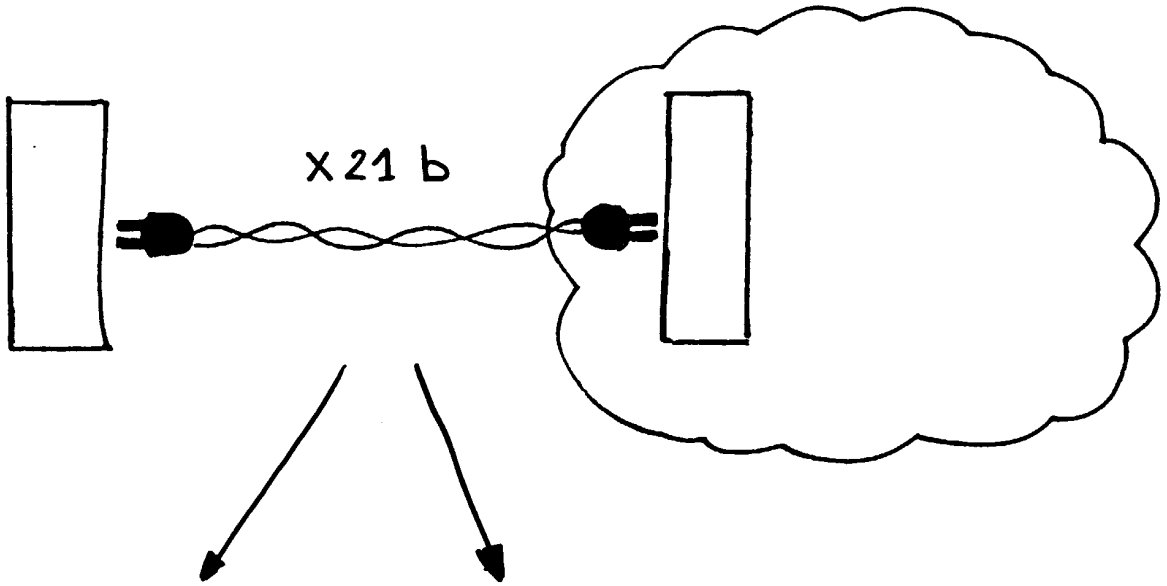
- For access to the PTT "PPSDN"

- The most widespread prot. in Europe
  For medium speed long distance communicat.


CCITT
X21 bis
ISO
HDLC
CCITT 1976
Provisional
Recommendation
X25
Level 3
Level 2
Level 1
→ 1980 → 1984 → 1988
already
layered

X25 LAYERING



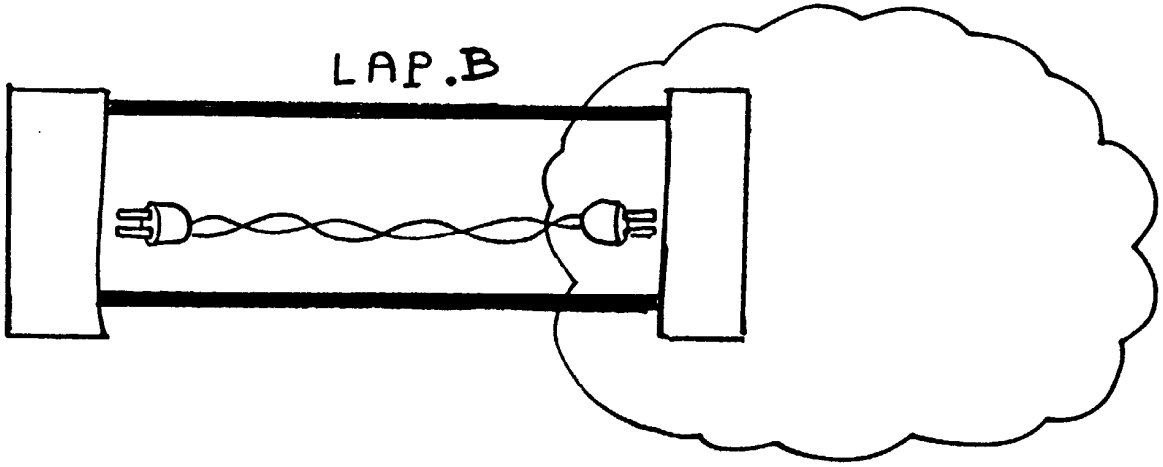


V24
(RS 232)

V35

300 → 19.2

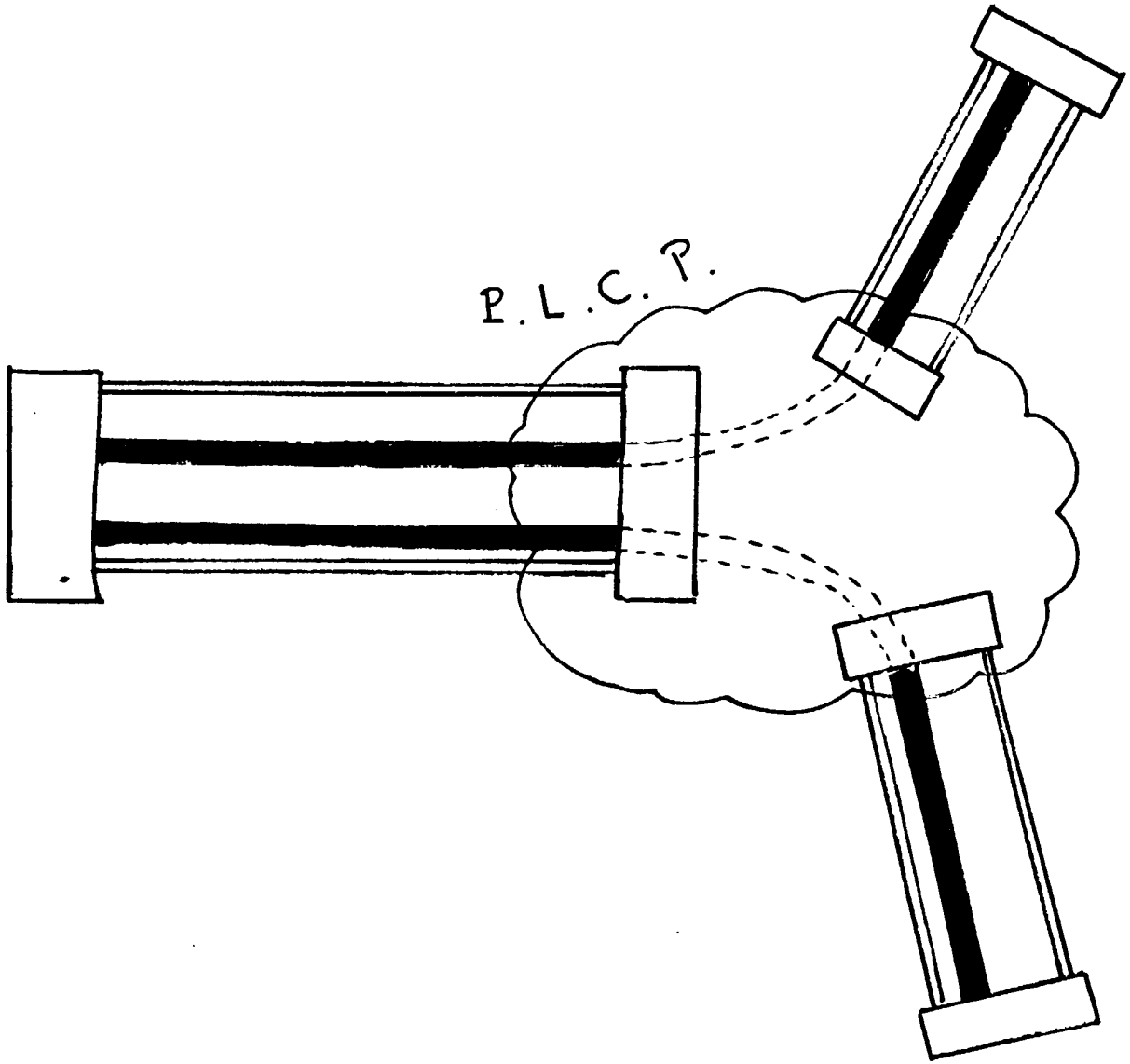
19.2 → 48


LAP.B

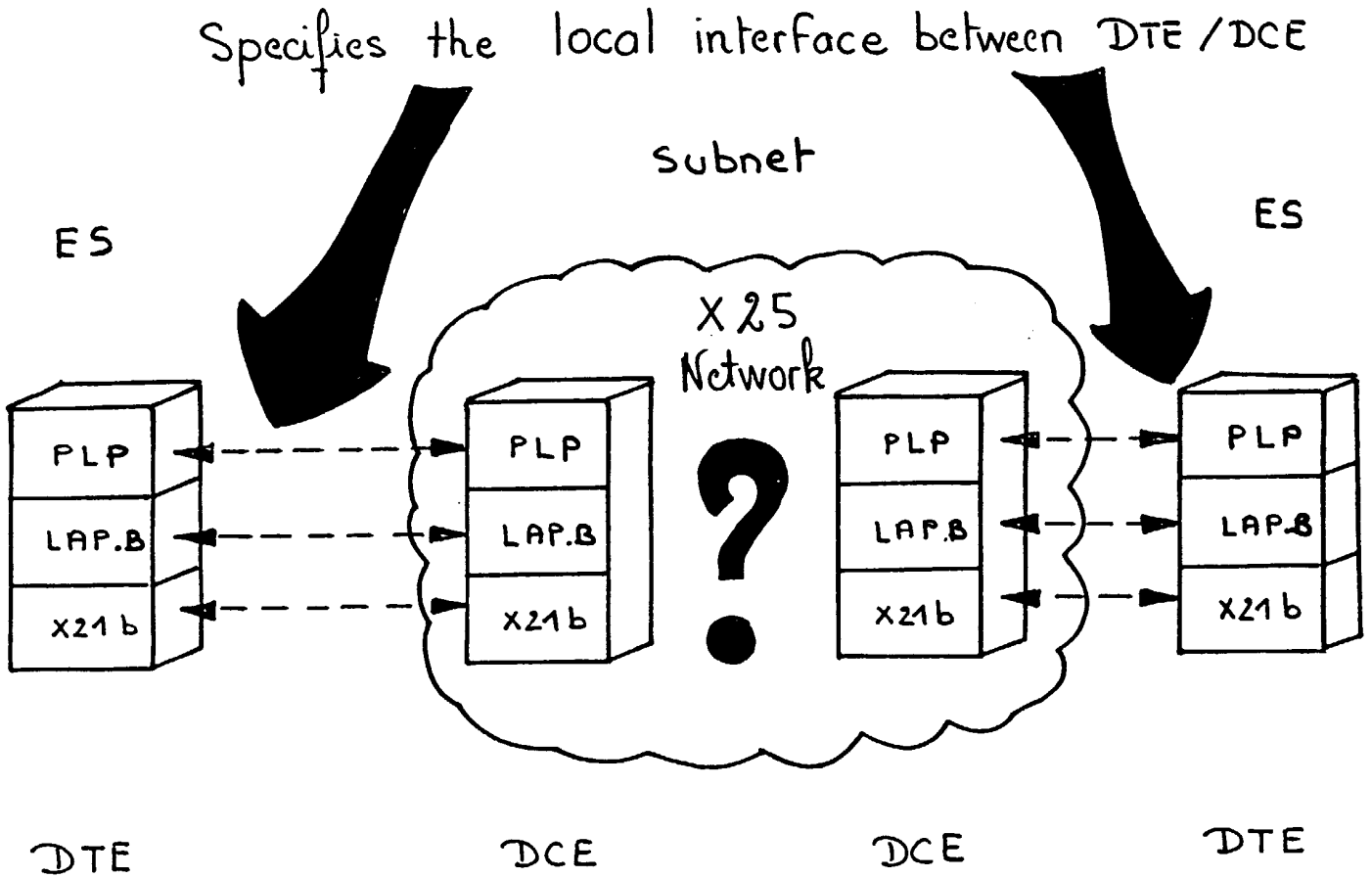
HDLC

High Level
Data
Link
Control

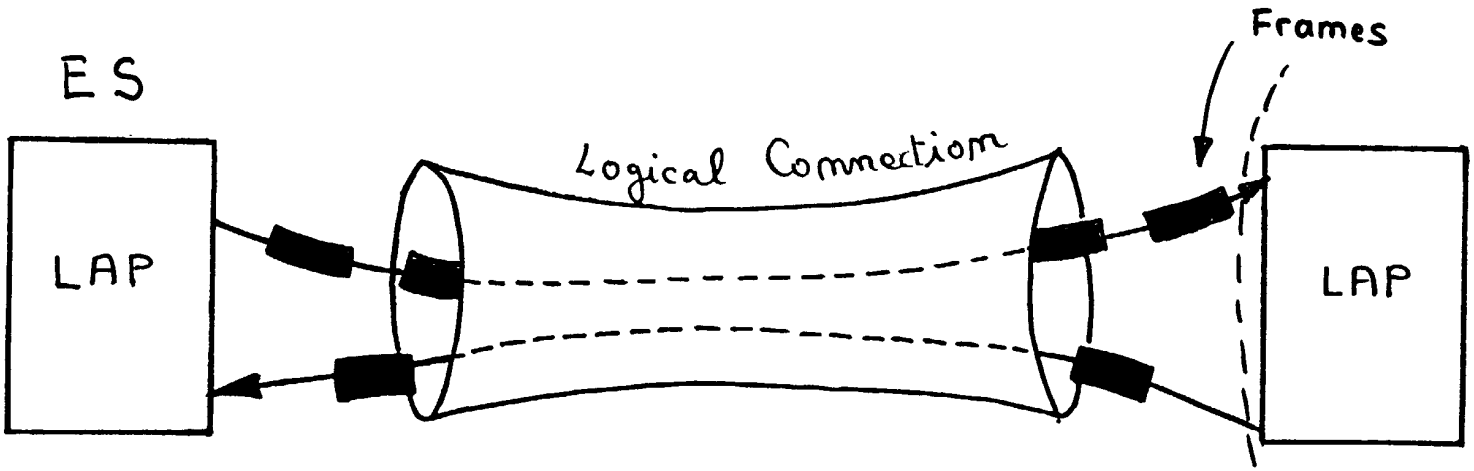
- Synchronous Level 2 Protocol
- ISO standard (slightly modified version of the IBM SDLC prot.)
- X25 level 2 (LAP.B) : subset of HDLC


P.L.C.P.

SCOPE of the Recommendation



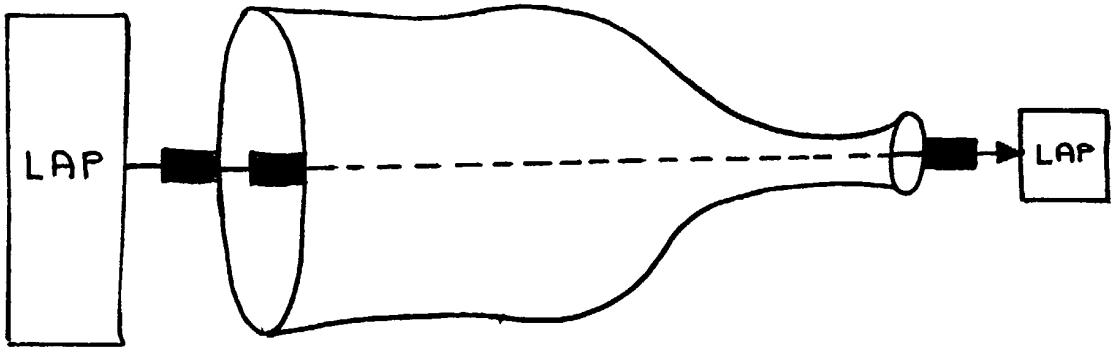
2. LAP : Connection Services



* [redacted] establishement and clearing

* [redacted] upward [redacted]

2. LAP : Data Transfer Services



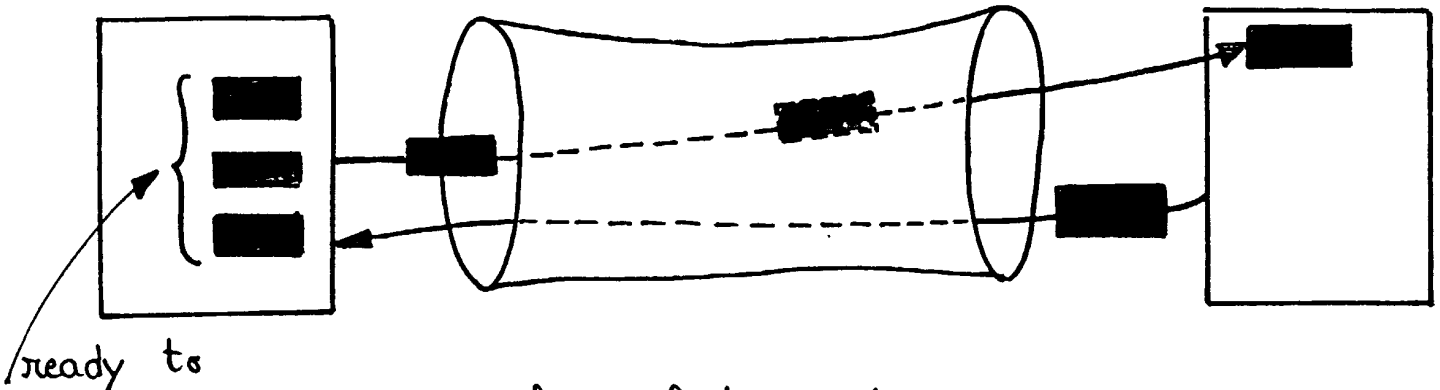
* [redacted] : numbering + credit (window)

* [redacted] guarantee

[redacted] Expedited transfer

[redacted] Segmenting / Blocking

2. LAP : Error Functions

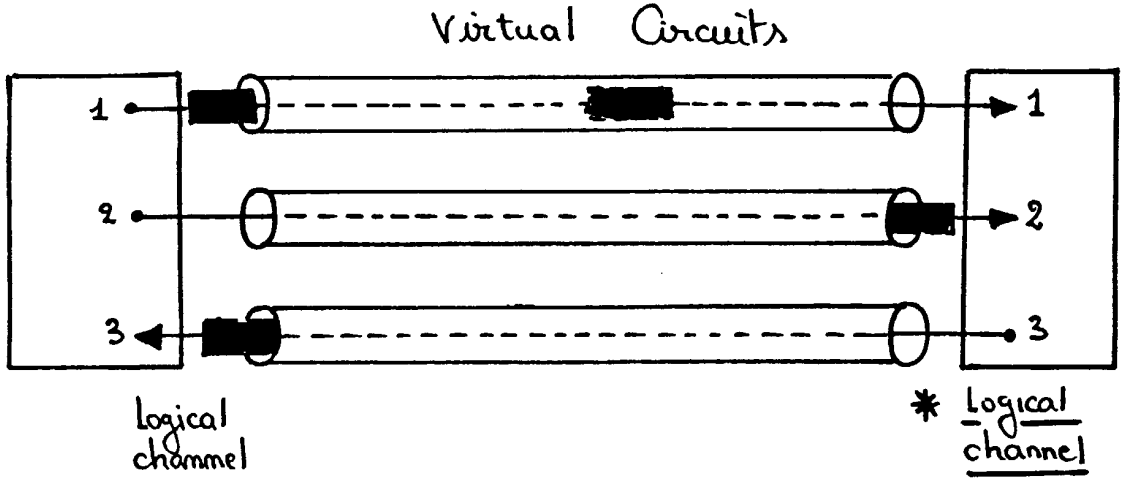


ready to retransmit

(Storage capacity required)

* [redacted]
* [redacted] detection (via *CRC : Residual error: 10^{-11})
* [redacted]
* [redacted]

3. P. L. : Connection Services

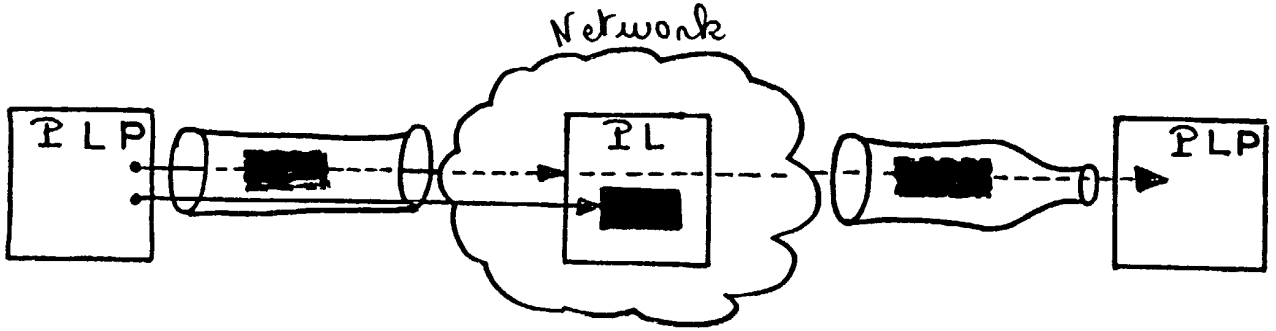


* [redacted] estab/clearing (Virtual Circuits)

* [redacted]

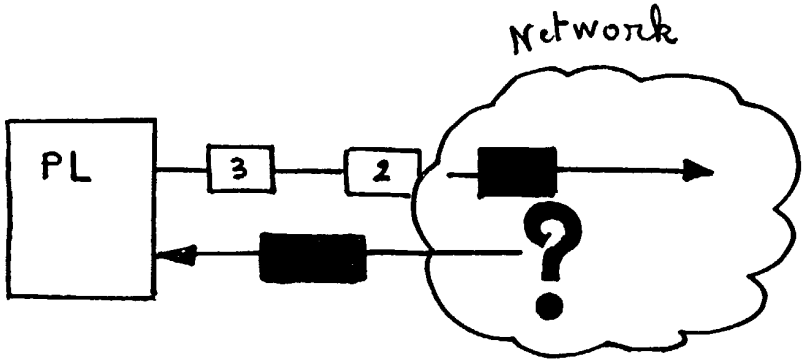
3. P.L. : Data Transfer Services

ensured between User System and Network System

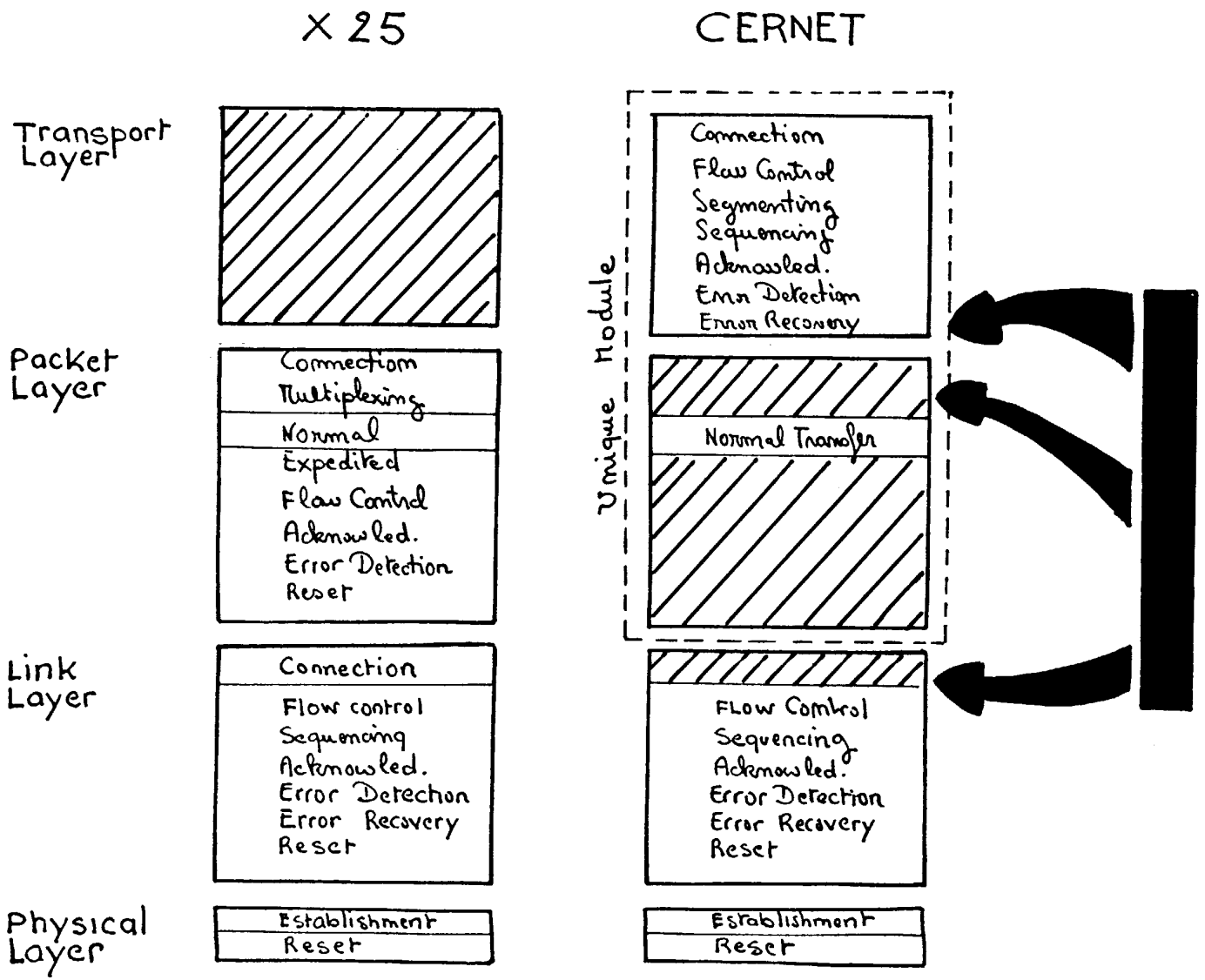


* [redacted] ; generally related within the network
* [redacted] transfer of data
* [redacted] guarantee
* [redacted] segmenting / blocking

P. L. : Error Functions



* acknowledgement : generally LOCAL
* error detection
* no error recovery
* reset


X 25
CERNET
Transport Layer
Packet Layer
Connection
Multiplexing
Normal
Expedited
Flow Control
Acknowled.
Error Detection
Reset
Link Layer
Connection
Flow control
Sequencing
Acknowled.
Error Detection
Error Recovery
Reset
Physical Layer
Establishment
Reset
Unique Module
Connection
Flow Control
Segmenting
Sequencing
Acknowled.
Error Detection
Error Recovery
Normal Transfer
FLOW Control
Sequencing
Acknowled.
Error Detection
Error Recovery
Reset
Establishment
Reset