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.
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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4 Test Case: The X25 Protocols
Network Components

Model

* End Systems

Communication Sub Network

Switch

End Systems: where the Service is provided

Communication: collection of *transmission
Sub Net

and *switching equipment
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
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4 Test Case: The X25 Protocols
Transmission Technology

- Transmission media
- Transmission techniques
Major Transmission Media

All use electric or electro-magnetic transmission

"Physical"

- Cables
- Fibres
- Pairs
- Grouped pairs
- Coaxial
- Optical fibres

"Aerial"

- Radio
- Satellite
# Major Transmission Media

## Basic Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Pairs</th>
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<tbody>
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**OK for modest performances**
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**Performant**

OK FOR LANS
## Major Transmission Media

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- Highly performant
- The media of the 80's (90's ?)
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- Performance Problems
- Only for short distance and/or broadcast
## Major Transmission Media

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- The most controversial
- Seems to be superseded by Fibres
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   3.1 Basic principles of layering
   3.2 Layer Services
   3.3 The 7 Layers

4 Test Case: the X25 Protocols
Communication SubNetwork

Transmission Techniques

Simplest: *Parallel Transmission

Example: Buses, Flat Cables

Problems: Unaffordable
  - Attenuation, Noise => Limited distances
- cheaper media (less wires)

+ 

- higher distances
  error protections

3 types of
"Magic Boxes"

1 2 3
Communication SubNetwork

Transmission Techniques

* Communic.  * "Modem"
  
  Interface

Parallel  * Serial Cable

Single Pair / Coax

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 concentration
1. PTTs use mainly TDM and FDM for sharing their media.

2. Called a circuit (or sometimes channel).

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
Computer Networks : Part 2

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4 Test Case : The X25 Protocols
Communication SubNetwork

* 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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4 Test Case: The X25 Protocols
Switching Techniques

Circuit Switching

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

The historical switching technique

Examples:
- TELEPHONE networks
- INDEX at CERN
- "X21" Networks
- Future ISDN networks
Communication SubNetwork

Switching Techniques

* Circuit Switching
* Packet Switching
Computer Networks : Part 2

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4 Test Case : the X25 Protocols
Switching Techniques

Packet Switching

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

Packet Switching

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

"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

<table>
<thead>
<tr>
<th>Establishment of connection</th>
<th>Circuit</th>
<th>Packet</th>
</tr>
</thead>
<tbody>
<tr>
<td>mandatory</td>
<td></td>
<td>optional</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Resource alloc.</th>
<th>Fixed allocation (even no traffic)</th>
<th>adaptative</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Routes</th>
<th>Fixed</th>
<th>fixe or adaptative</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Multiplexing</th>
<th>null or limited</th>
<th>high</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Risk of congestion</th>
<th>very low</th>
<th>potentially high</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Overhead of Protocol</th>
<th>null</th>
<th>non-negligable</th>
</tr>
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<th>Communication Transparency</th>
<th>very high</th>
<th>limited</th>
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<tr>
<td></td>
<td></td>
<td>- pkt transit delay</td>
</tr>
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<td></td>
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<td>- risk of pkt loss/corrup.</td>
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4 Test Case: The X25 Protocols
1. **Point-to-Point Leased Lines**

   ![Diagram of Point-to-Point Leased Lines]

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

   ![Diagram of Public Circuit Switching Telephone Net.]

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

   ![Diagram of Public Circuit Switching Data Net.]

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

   ![Diagram of Public Packet Switching Data Net.]
Point-to-Point Leased Lines

- Yesterday - Today
  Analog links: 
  - Speed: 9.6 Kbps - 48 Kbps
  - Error rate: Medium
  - Costs: \( \approx \) 60 KsF/year \((9.6)\) (International)

  Terrestrial and Satellite

- Today - Tomorrow: Why?
  Digital links: 
  - Speed: 64 K - 2M - 144 Mbps
  - Error rate: Low
  - Costs: \( \approx \) 120 KsF/year \((64K)\)
  \( \approx \) 1,2 MSF/year \((2M)\)
  (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.: Homework)
- When nothing else
PCSDN: Public Circuit Switching Data Nets

- Most follow the X.21 Standard
- Cost of Usage: Connection duration only

Today

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

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

Tomorrow

ISDN
- 64k → 2 Mbps

Field of Application:
- high volume + bursty communications (e.g.: to absorb peaks)
PPSDDN: 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: 800-2,000 SF/month
  usage (Europe): .10 SF/1 hour terminal
  .10 SF/100 Kbytes
- 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: negligible 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 ?)
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

Switzerland: Geneva (3)
Bern
Lausanne
Zurich
Neuchatel
"HEP" Links

12 Private Leased Lines
+ 2 ordered

14

Chicago (FNAL)
Geneva (UN1)
Annecy (LAPP) (2) --- tomorrow: Zürich (SIN)
Bologna (INFN) (2)
Lyon (IN2P3) (2)
Oxford (RAL)
Saclay (DPhPE)
Boston (MIT)
Zürich (ETH)
Wide area Networking Infrastructure at CERN

Connection to the National Public X25 Networks
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4 Test Case: The X.25 Protocols
Open Systems Interconnection

- Issued by the ISO (78)
  (H. Zimmerman - France)
- Endorsed by the CCITT

Not to confuse

OSI Model  OSI Protocols

Framework:

- principles of layering
- for "data com",
  a set of 7 layers
- contents of the framework
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4 Test Case: The X.25 Protocols
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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4 Test Case: The X25 Protocols
Basic Principles of Layering

Provides Services

Performs Functions

Uses Services
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.
Connect Request

Connect Accept

Establish.

Data Transfer

Disconnect Request

Disconnect Accept

Release
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4 Test Case: The X25 Protocols
1 Physical
2 Datalink
3 Network
4 Transport
5 Session
6 Presentation
7 Application

Diagram showing the seven layers of the OSI model.
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
Example: X25 Protocols

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

- For access to the PTT "PPSDN"

- The most widespread in Europe
  for medium speed long distance communication
X25 LAYERING

Diagram showing a filing cabinet labeled "PLCP" and "LAP" with smaller boxes labeled "X21 bis", "LAP.B", and "X21".
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
SCOPE of the Recommendation

Specifies the local interface between DTE/DCE

2. LAP: Connection Services

* Connection establishment and clearing
* Not upward multiplexing
2. LAP: Data Transfer Services

* **Time-Contract**: numbering + credit (window)

* **Sequencing guarantee**

**No** Expedited Transfer

**No** Segmenting / Blocking
2. LAP: Error Functions

- retransmit
- detection (via CRC: Residual error: 10^{-11})
- retransmit
- (storage capacity required)
3. P.L.: Connection Services

Virtual Circuits

* Connection estab/clearing
  (Virtual Circuits)

* Demultiplexing
3. P.L. : Data Transfer Services

- Controlled; generally relayed within the network
- Prefered; transfer of data
- Guaranteed
- Segmenting/Blocking
P. L. : Error Functions

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