Electrical Signal Transmission

Noise, attenuation and amplifiers.

Sending bits:

Acoustic couplers

Modern Modems
Channel Limits

Nyquist: \[ D = 2 \, B \, \log_2(K) \]

- \( D \) = bits / second
- \( B \) = Bandwidth (Hz)
- \( K \) = number of encoded levels
  - \( \log_2(K) \) = bits of encoding

Shannon: \[ C = B \, \log_2(1 + S/N) \]

- \( C \) = channel capacity (bits / second)
- \( S/N \) = signal / noise ratio
Connecting Computers: Signals

(a) Data

(b) Signal
Connecting Computers: Signals

Phase Shift Modulation
Connecting Computers

Comer *The Internet*: Chapters 4, 5, 6
RS 232 (DB25 connector)
Computer transmits on pin 2, receives on pin 3
(Modem transmits on pin 3, receives on pin 2)
Ground: pin 7
ISO OSI Stack

stack on computer 1

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical (network hardware)

stack on computer 2

- Application
- Presentation
- Session
- Transport
- Network
- Data Link
Networking Computers
Multiplexing
ISO OSI Stack

stack on computer 1
- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical (network hardware)

stack on computer 2
- Application
- Presentation
- Session
- Transport
- Network
- Data Link
- Physical (network hardware)
## Protocol Stacks

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Stack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Novell Corporation</td>
<td>Netware</td>
</tr>
<tr>
<td>Banyan System Corporation</td>
<td>VINES</td>
</tr>
<tr>
<td>Apple Computer Corporation</td>
<td>AppleTalk</td>
</tr>
<tr>
<td>Digital Equipment Corporation</td>
<td>DECNET</td>
</tr>
<tr>
<td>IBM</td>
<td>SNA</td>
</tr>
<tr>
<td>(many vendors)</td>
<td>TCP/IP</td>
</tr>
</tbody>
</table>
Local Area Networks

Point-to-Point Connections
Facts About LANs

• LANs are incompatible.
• Many LANs and fewer WANs
• The desirability of a single network.
LAN Taxonomy Tree

- Access Control
- Transmission Media
- Topology
- Transmission Technique
- Typical data rates
Point-to-Point Network

Point-to-Point Connections over a Network
Star Topology

computers connected to network

hub
Ring Topology

connection from one computer to another
Bus Topology

Bus (shared cable)
Ethernet began at Xerox PARC - 1970’s

DEC, Intel, Xerox cooperated on “standards”

IEEE now controls Ethernet standard

- multiple versions
- originally shared coaxial cable (ether)
- 10Mb/s
- Fast Ethernet: 100Mb/s
Ethernet Data Flow
LAN Connectivity

- Bridges
- Routers
- Gateways
- Servers
Networks send data as “packets”

Small blocks of data

Helps give fair access to all

Minimizes delays
Time-Division Multiplexing

Networks send data as “packets”

Sources take “turns”

Packets interleaved on channel

Packets grouped into “frames”
Packet Multiplexing

(a) Computer 1 using channel to send a packet
(b) Computer 2 using channel to send a packet

multiplexing occurs
Packet, Frames, ...

Headers and trailers (soh, eoh, …)

Error Control: Parity bits, checksums, ...
ISO OSI Stack

stack on computer 1
- Application
- Presentation
- Session
- Transport
- Network
- Data Link

Physical (network hardware)

stack on computer 2
- Application
- Presentation
- Session
- Transport
- Network
- Data Link
<table>
<thead>
<tr>
<th><strong>Layer</strong></th>
<th><strong>Data Unit</strong></th>
<th><strong>Connection Device</strong></th>
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<tbody>
<tr>
<td>Application</td>
<td>Message</td>
<td></td>
</tr>
<tr>
<td>Presentation</td>
<td>Packet</td>
<td>Router</td>
</tr>
<tr>
<td>Session</td>
<td>Frame</td>
<td>Bridge</td>
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<td>Transport</td>
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</tr>
<tr>
<td>Network</td>
<td></td>
<td>Router</td>
</tr>
<tr>
<td>Data Link</td>
<td>Symbol (bit)</td>
<td>Modem/Repeater</td>
</tr>
<tr>
<td>Physical</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Networking

Local Area Network (or modem to ISP)

Wide Area Network(s)

“Backbone”

Wide Area Network(s)

Local Area Network (or modem to ISP)
Carrier Sense Multi Access (LAN)

Coordinates Transmission

Signal = “Carrier”

If Carrier is “sensed”, don’t transmit

If clear, send packet
Collisions....

Listening is not enough
(other sender may have already started transmitting)

All senders must monitor channel

If collisions occur, will hear “garbled” signal
“Collision Detect”

CSMA/CD
Collisions....

If collision detected, stop and wait for clear channel

After delay “t” and channel is clear, resend

“t” randomly selected at each source, less than “d”

double “d” if collisions occur on next attempt to send

“exponential back-off”
Token-Ring LAN

- Computer not holding the token passes bits.
- Destination passes and makes a copy.
- Sender holding token transmits bits of frame.
- Sender receives bits of the frame.
Token-Ring LAN

No Collisions

Transmission controlled by token-passing

Token is a special, reserved message

Each user allowed to send one frame

Frame sent to next computer in ring
Token-Ring LAN

Access is fair

Speed depends on ring hardware, not computers

Failure of one machine disables network

IBM Token Ring = 16 M bits/sec
FDDI Token-Ring LAN

Fiber Distributed Data Interconnect
100 Mbits/sec
“Self-healing”
Switches (ATM)
Switches (ATM)

Independent Connections

No Collisions