Computer Networks I

Physical Layer

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Scope

Complementary Courses: Multimedia Systems, Distributed Systems, Mobile Communications, Security, Web, Mobile+UbiComp, QoS											
Applications	Transitions & Addressing	P2P	Email	Files	Telnet	Web	IP-Tel: Signal. H.323 SIP	Mobile IP	Mobile Communications	MM COM - QoS specific	**Media Data Flow** RT(C)P	Security
L5 **Application Layer** (Anwendung)												
L4 **Transport Layer** (Transport)		Internet: TCP, UDP									Transport	
L3 **Network Layer** (Vermittlung)		Internet: IP									Network	
L2 **Data Link Layer** (Sicherung)		LAN, MAN High-Speed LAN, WAN										
L1 **Physical Layer** (Bitübertragung)		Other Lectures of "ET/IT" & Computer Science										
Introduction												

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Physical Layer

Overview

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Physical Layer

1   Basics

- Characteristics

- Bit Rate and Baud Rate

- Operating Modes

1.1 Characteristics

ISO DEFINITION: the physical layer provides the
- mechanical,
- electrical,
- functional and
- procedural

FEATURES

to initiate, maintain and terminate physical CONNECTIONS
  BETWEEN
- Data Terminal Equipment (DTE) and
- Data Circuit Terminating Equipment (DCE, "postal socket")
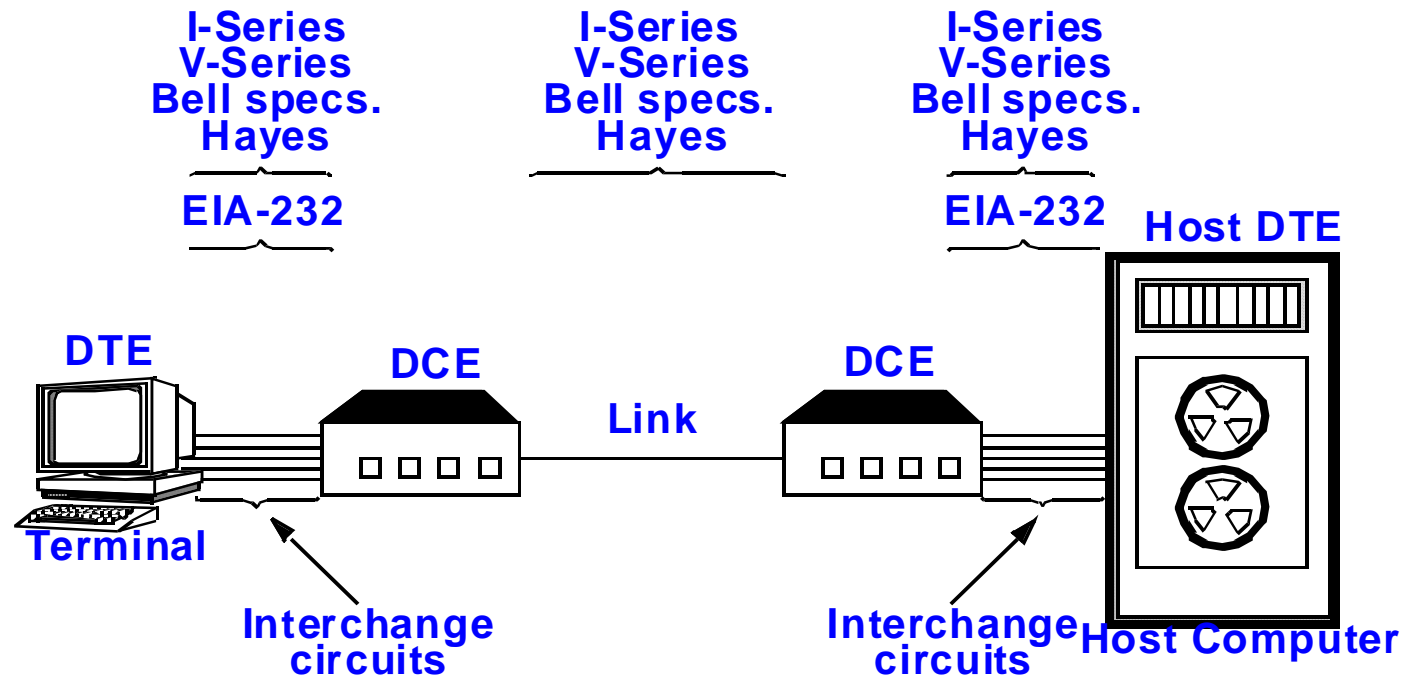- and/or data switching centers.

Using physical connections, the physical layer ensures the transfer of
  a TRANSPARENT BITSTREAM
  between DATA LINK LAYER-ENTITIES.

A PHYSICAL CONNECTION may permit either
- the duplex or
- the semi-duplex
transfer of a bitstream

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Physical Layer

I-Series
V-Series
Bell specs.
Hayes

EIA-232

I-Series
V-Series
Bell specs.
Hayes

I-Series
V-Series
Bell specs.
Hayes

EIA-232

Host DTE

DTE

DCE

Link

DCE

Terminal

Interchange
circuits

Interchange
circuits

Host Computer

DTE (Data Terminal Equipment = end-system)
DCE (Data Circuit-Terminating Equipment)
•modem, multiplexer, Digital Service Unit

Phyiscal layer deals with interfaces between
•DTE and DCE and
•DCE and DCE

Characteristics

MECHANICAL: size of plugs, allocation of pins, etc.
- e. g. ISO 4903:
- data transfer - 15 pin DTE/DCE connection and pin allocation

ELECTRICAL: voltage levels on wires, etc.
- e. g. CCITT X.27/V.11:
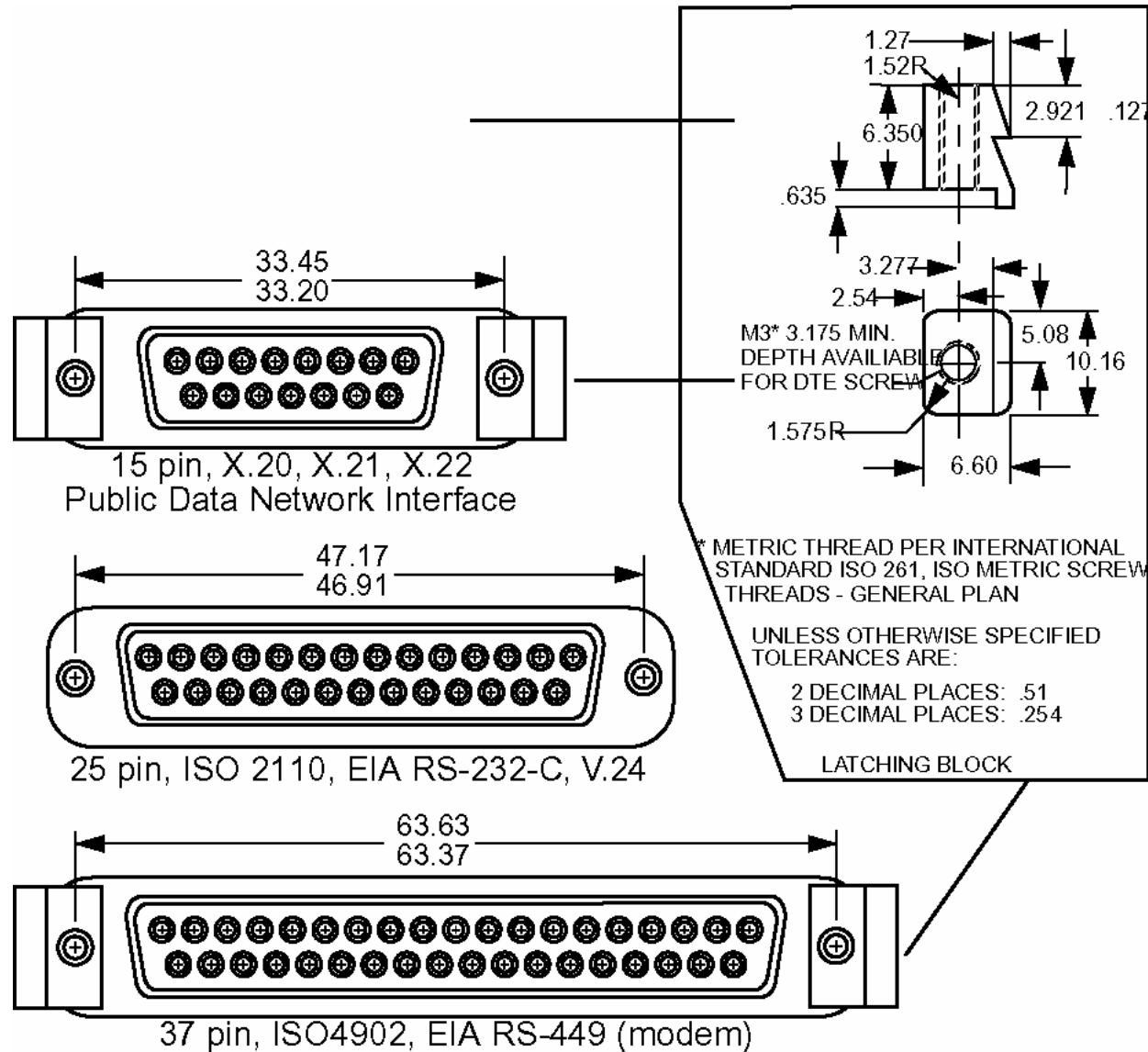- electrical features for the symmetrical transfer within the area of data communication

FUNCTIONAL: definition of switching functions; pin allocation (data, control, timing, ground)
- e. g. CCITT X.24:
- list of the switching functions between DTE und DCE in public data networks
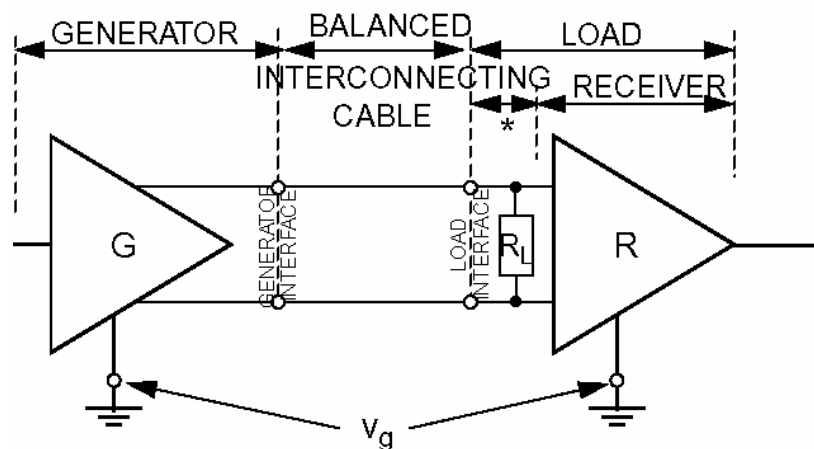
PROCEDURAL: rules for using switching functions
- e. g. CCITT X.21:
- protocol between DTE and DCE for synchronized data transfer in public data networks

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Mechanical

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15 pin, X.20, X.21, X.22
Public Data Network Interface

25 pin, ISO 2110, EIA RS-232-C, V.24

37 pin, ISO4902, EIA RS-449 (modem)
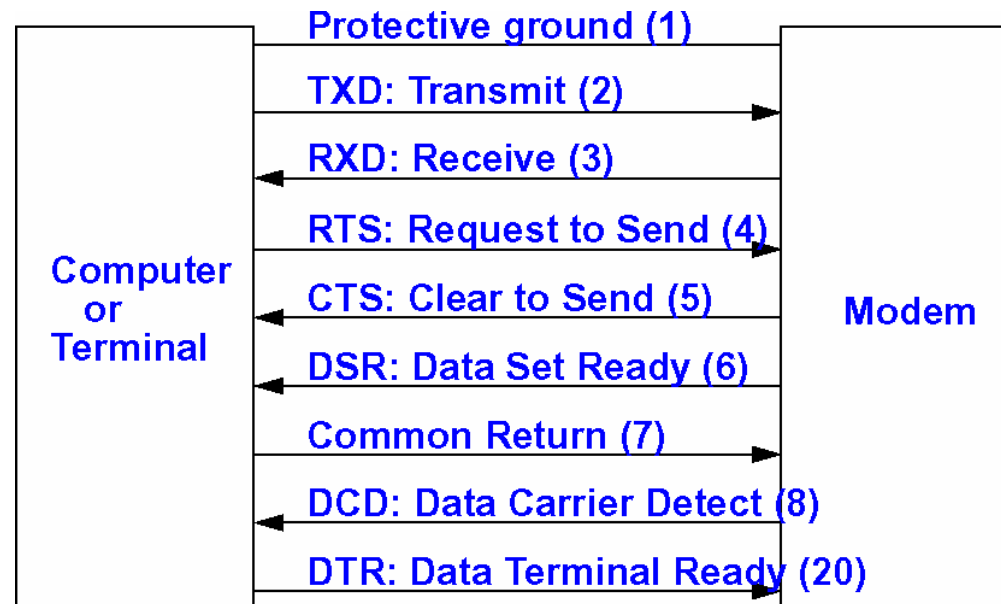
Physical Layer

Electrical

CCITT V.11 / X.27 (EIA RS -422-A)

e. g. .. "
- designed for IC Technology
- balanced generator
- differential receiver
- two conductors per circuit
- signal rate up to 10 Mbps
- distance: 1000m (at appr. 100 Kbps) to10m (at 10Mbps)
- considerably reduced crosstalk
- interoperable with V.10 / X.26 ..."

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Functional, Procedural

Protective ground (1)

TXD: Transmit (2)

RXD: Receive (3)

RTS: Request to Send (4)

Computer or Terminal

CTS: Clear to Send (5)

DSR: Data Set Ready (6)

Common Return (7)

DCD: Data Carrier Detect (8)

DTR: Data Terminal Ready (20)

Modem

Example RS-232-C, functional specification describes
- connection between pins
  - e.g. "zero modem" computer-computer-connection (Transmit(2) - Receive(3))
- meaning of the signals on the lines
  - DTR=1, when the computer is active, DSR=1, modem is active, ...
  - Action/reaction pairs specify the permitted sequence per event
  - e. g. when the computer sends an RTS, the modem responds with a CTS when it is ready to receive data

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1.2 Bit Rate and Baud Rate

BAUD RATE:
measure of number of symbols (characters) transmitted per unit of time
- signal speed, number of signal changes per second
  - changes in amplitude, frequency, phase
- each symbol normally consist of a number of bits
  - so the baud rate will only be the same as the bit rate when there is one bit per symbol.

BIT RATE: Number of Bits transferred per Second (bps)
- bit rate may be higher than baud rate ("signal speed")
  - because one signal value may transfer several bits

Example:

Two bits per signal   Three bits per signal

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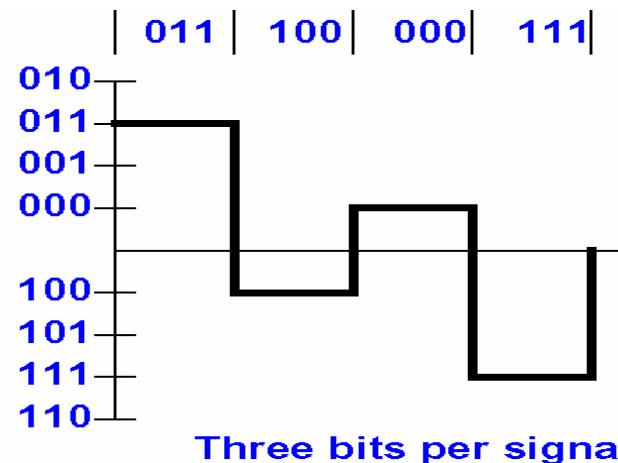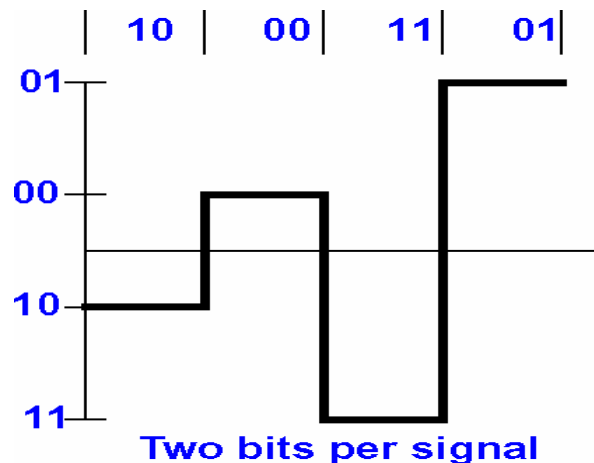
Basics

Bandwidth of a channel: $B = f_{max} - f_{min}$
f_{max}, f_{min} : maximum resp. minimum frequency

Examples:
- phone: min. 3000 Hz
- Coax: approx. 300 MHz
- fiber: approx. 10^8 MHz (visable light)

Nyquist theorem (noise free channel)
- max. bitrate = $2\,H \cdot \log_2 V$ bps
  - *H*... signal bandwidth (low pass filter)
  - *V*... discrete levels

Example:
3000 Hz channel, binary signal (*V*=2):
  - max. bitrate = 6000 bps

Basics

Shannon theorem (noisy channel)
max bitrate = $H \cdot \log_2 (1 + S/N)$

- *H*...   signal bandwidth (low pass filter)
- *S*/N . . .   Signal to Noise ratio

- 10 $\log_{10}$ *S/N decibels*

Example:
- **3000 Hz channel,**
- ***S*/N = 1 000 (30 dB)**
    - **max. bitrate = 30 000 bps**

independent of number of levels !

This is an upper bound!
- **real systems rarely achieve it**

1.3 Operating Modes

Transfer directions (temporal parallelism)

- simplex communication:
    - data is always transferred into one direction only
- (half-duplex) semi-duplex communication
    - data is transferred into both directions
    - but never simultaneously
- full-duplex communication
    - data may flow simultaneously in both directions

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Serial and parallel transmission

- parallel:
  - signals are transmitted simultaneously over several channels

- serial:
  - signals are transmitted sequentially over one channel

Serial

0
1
0
0
0
0
0
1

1 0 0 0 0 0 1 0

time

Parallel

0
1
0
0
0
0
0
1

Symbol
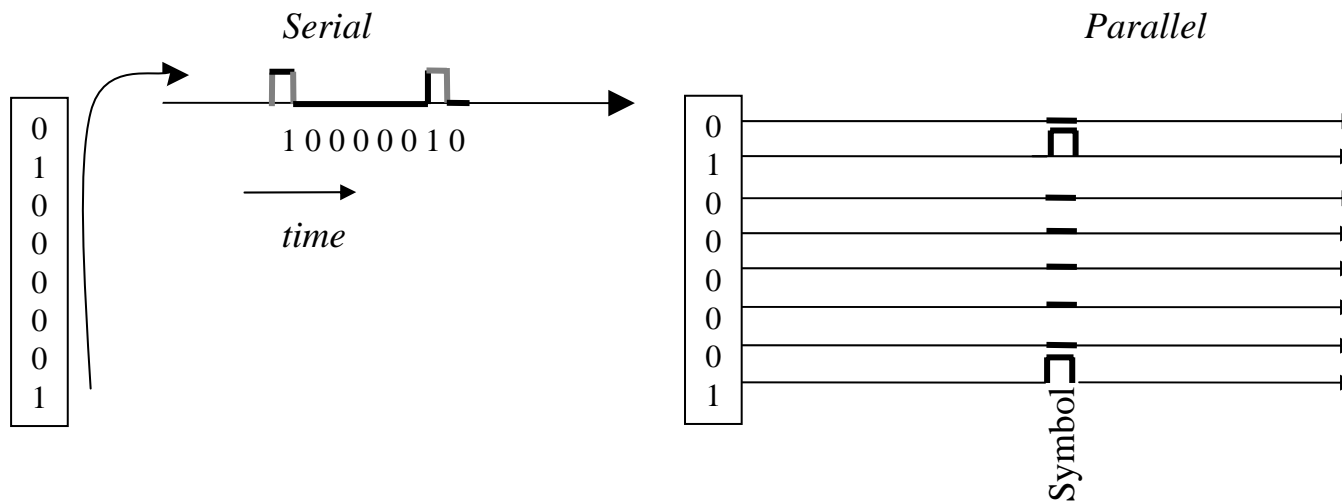
Operating Modes: Synchronous Transmission

Definition
- the point in time at which the bit exchange occurs is pre-defined by a regular clock pulse (requires synchronization)
- whereby the clock pulse lasts as long as the transmission of a series of multiple characters takes

Implementation
- receiving clock pulse
  - on a separate line (e. g. X.21) or
  - gained from the signal
- bit synchronous or frame synchronous (frames in fact on data link level)
  - special characters
    e. g.
    ```
    SOH    Start of Header
    STX    Start of Text
    ETX    End of Text
    ```

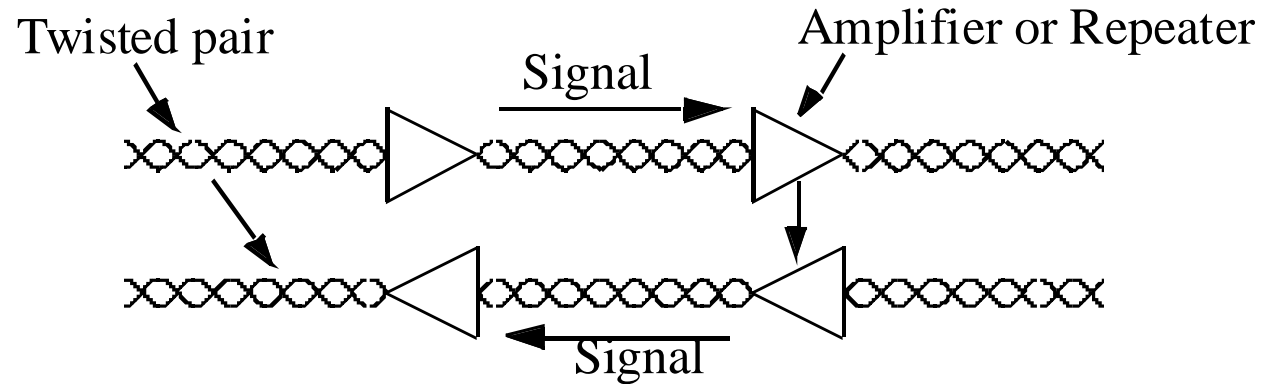# Operating Modes: Asynchronous Transmission

Definition
- clock pulse fixed for the duration of a signal
- termination marked by
  - Stop signal (bit) or
  - number of bits per signal
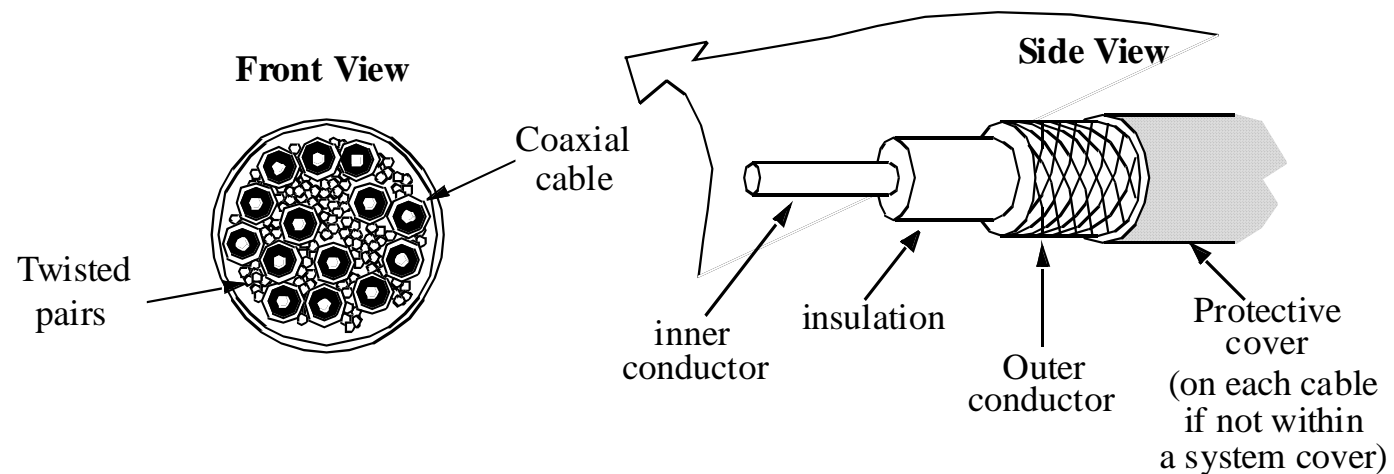
Implementation
- simple:
  - sender and receiver generate the clock pulse independently from each other
- frame size usually approx. 9 bit
  (of this approx. 70% reference data)
  - example:
    ```
    7 Bit ASCII reference data
    1 Parity Bit (odd, even, or unused)
    1 Start-Bit
    1 Stop-Bit
    ```
- example: RS-232-C
  - UART (universal asynchronous receiver and transmitter) IC module
  - often between
    - computer and printer or
    - computer and modem

# 1.4 Guided Transmission Media: Twisted Pair and Coax

UTP: unshielded twisted pair

Twisted pair

Amplifier or Repeater

Signal

Signal

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Coaxial cable

Front View

Side View

Coaxial cable

Twisted pairs

inner conductor

insulation

Outer conductor

Protective cover
(on each cable
if not within
a system cover)

Fiber Optics

Three examples of a light ray from inside a silica fiber impinging on the air/ silica boundary at different angles
Light trapped by total internal reflection

Air/silica
boundary

β_1 β_2 β_3

α_1 α_2 α_3

Silica

Total internal
reflection

Light source
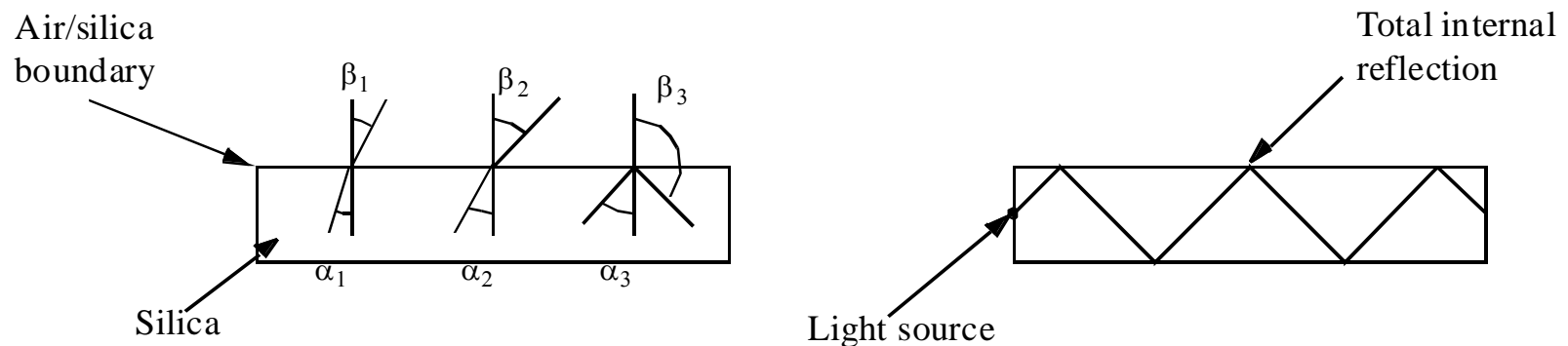
Types:
- **Multimode**
  - several rays with different angles ('modes')
- **Monomode**
  - fiber diameter reduced to few wavelengths of light
  - light can propagate in straight line

2 Analog and Digital Information Encoding and Transmission

Variants and examples:

		Transmission	
		analog	digital
Information Coding	analog (voice, music)	"old" telephone system (POTS) ➔ AM, FM	ISDN (voice service) Internet Audio ➔ PCM, DM, …
	digital (texts, images)	modem (modulator demodulator) at analog telephone connection Radio Data System RDS ➔PAM, PPM, PFM, … and V.21, V.22 bis, …, V.32 bis, V.34.	traditional computer networks and applications ISDN (data service) ➔ Manchester Encoding, …

Digital Information – Digital Transmission

Digital information at end system
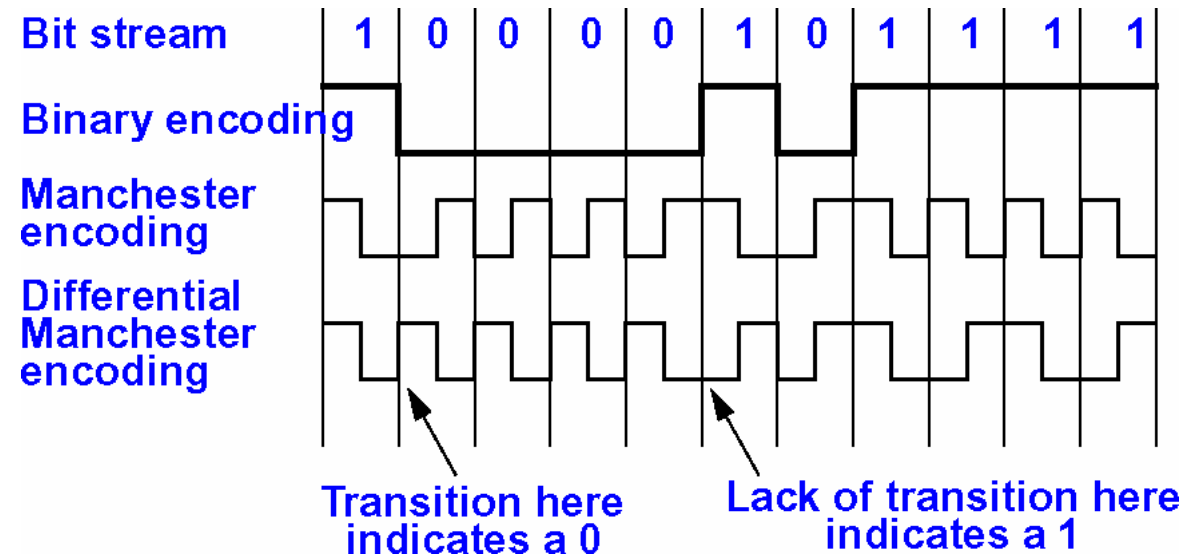- usually TTL-Logic ("1" : 3V, "0" : 0V)

Digital transmission
- sender/receiver synchronization
- signal levels around 0V (lower power)
- → Conversion

Coding techniques
- binary encoding, nonreturn to zero-level (NRZ-L)
    - 1: high level
    - 0: low level
- return to zero (RZ)
    - 1: clock pulse (double frequency) during interval
    - 0: low level
- ...
- Manchester Encoding
- Differential Manchester Encoding
- ...

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Binary Encoding

Bit stream | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1

Binary encoding

Manchester encoding

Differential Manchester encoding

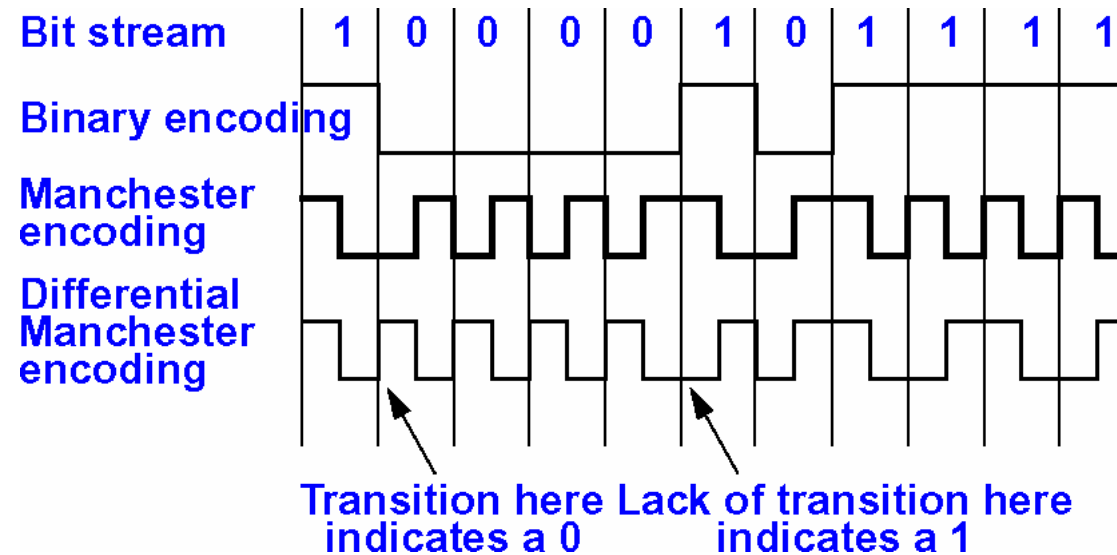Transition here indicates a 0

Lack of transition here indicates a 1

Binary encoding (Nonreturn to zero):
- "1": voltage on high
- "0": voltage on low

i. e.

+   simple, cheap

+   good utilization of the bandwidth (1 bit per Baud)

-   no "self-clocking" feature

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Manchester Encoding

Bit stream	1	0	0	0	0	1	0	1	1	1	1

Binary encoding

Manchester encoding

Differential Manchester encoding

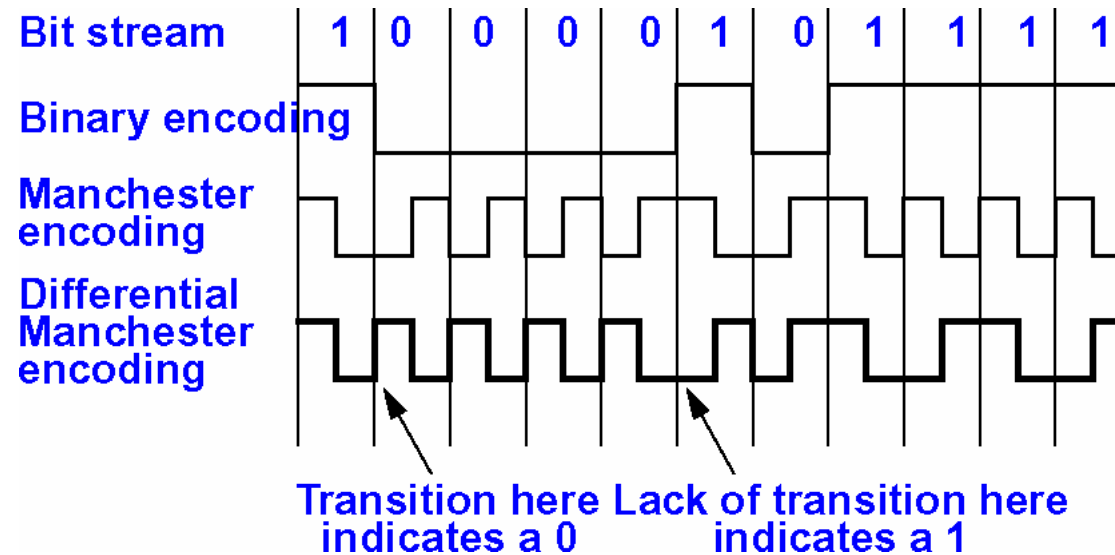Transition here indicates a 0   Lack of transition here indicates a 1

Bit interval is divided into two partial intervals: I1, I2

- "1":   I1: high, I2: low
- "0":   I1: low, I2: high
+   good "self-clocking" feature
-   0,5 bit per Baud

Application: 802.3 (CSMA/CD)

Differential Manchester Encoding

Bit stream 1 0 0 0 0 1 0 1 1 1 1

Binary encoding

Manchester encoding

Differential Manchester encoding

Transition here indicates a 0   Lack of transition here indicates a 1

Differential Manchester Encoding:
- bit interval divided into two partial intervals:
    - "1": no change in the level at the beginning of the interval
    - "0": change in the level
    + good "self-clocking" feature
    + low susceptibility to noise because only the signal's polarity is recorded. Absolute values are irrelevant.
    - 0,5 bit per Baud
    - complex

3   Multiplexing Techniques

The cost for implementing and maintaining either a narrowband or a wideband cable are almost the same

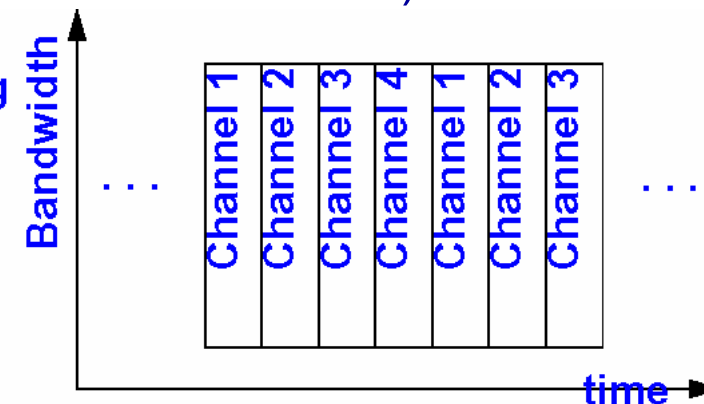➔   multiplexing many conversations onto one channel

Two procedural classes:

- FDM (FREQUENCY DIVISION MULTIPLEXING)

Frequency Division Multiplexing (FDM)

Bandwidth

Channel 1 (f1)

Channel 2 (f2)

Channel 3 (f3)

Channel 4 (f4)
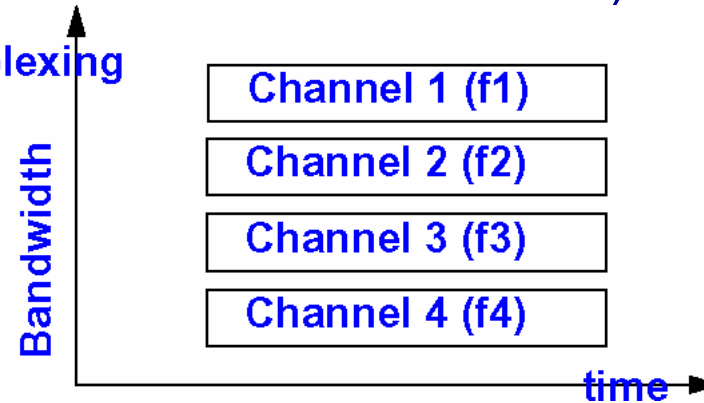
time

- TDM (TIME DIVISION MULTIPLEXING)

Time Division Multiplexing (TDM)

Bandwidth

. . . Channel 1 Channel 2 Channel 3 Channel 4 Channel 1 Channel 2 Channel 3 . . .

time

Physical Layer

Frequency Multiplexing

Principle:
- frequency band is split between the users
- each user is allocated one frequency band

Application:
- example: multiplexing of voice telephone channels: phone, cable-tv
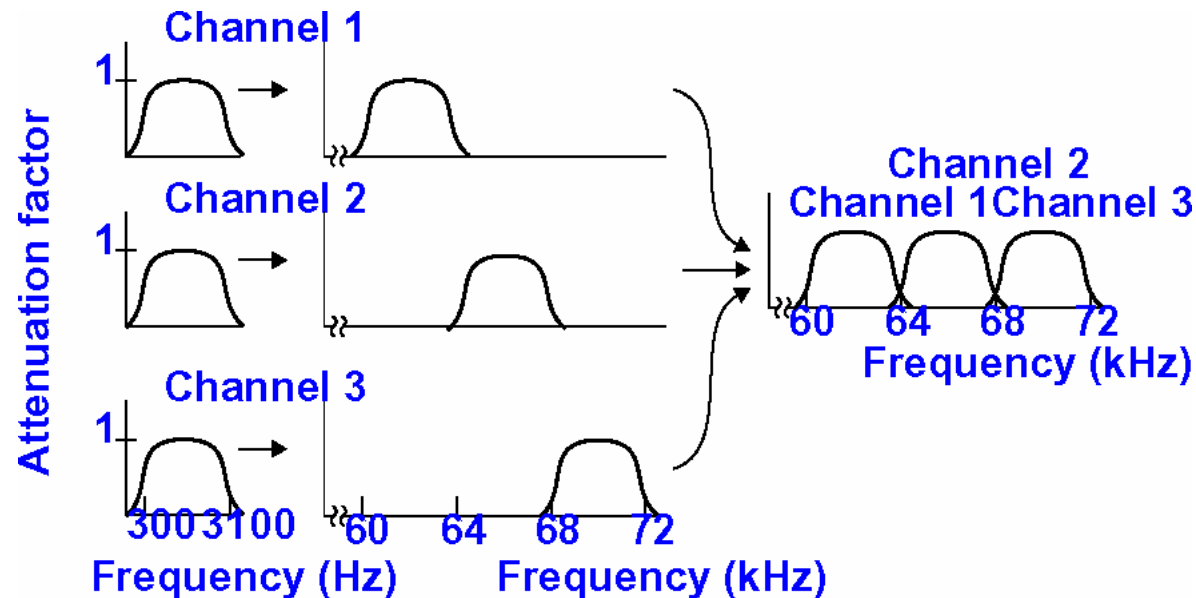
- filters limit voice channel to 3 000 Hz bandwidth
- each voice channel receives 4 000 Hz bandwidth
  - 3 000 Hz voice channel
  - 2 x 500 Hz gap (guard band)

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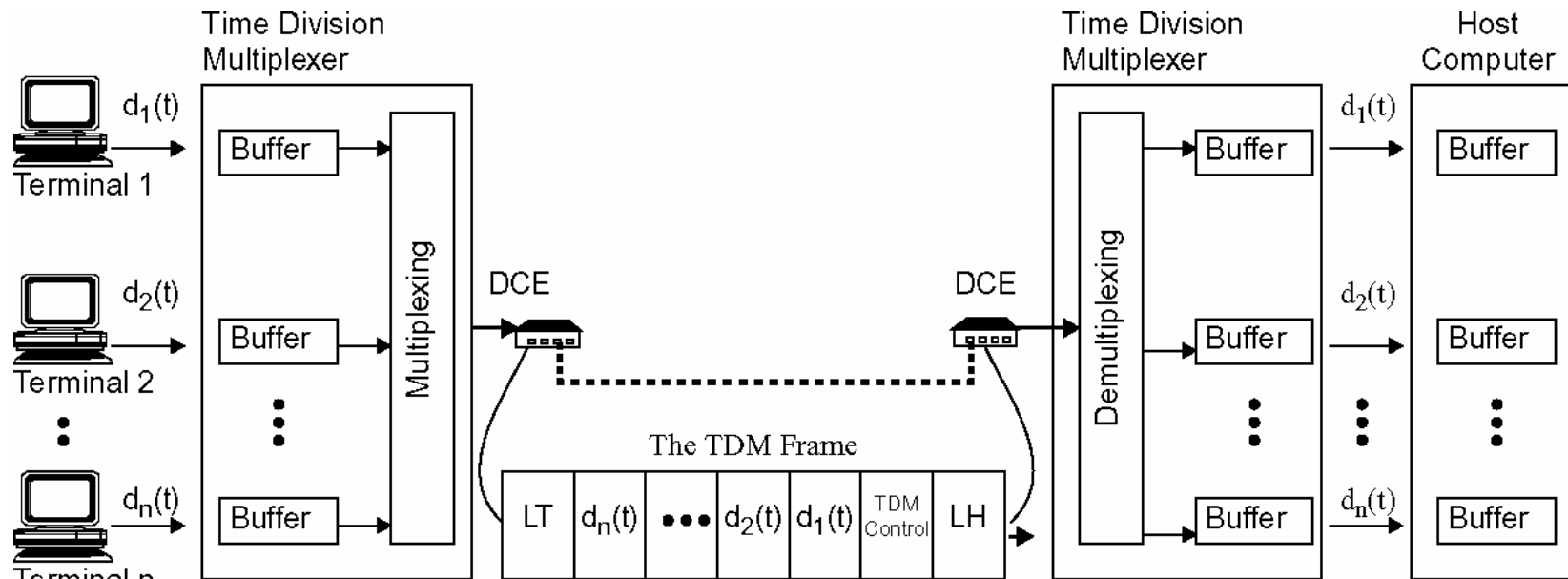→ despite guard band adjacent channels overlap, noise

Time Division Multiplexing

Principle:
- user receives a time slot
- during this time slot he has the full bandwidth

$$\sum_{i=1}^{n} d_i(t) = d_0(t)$$

Application:
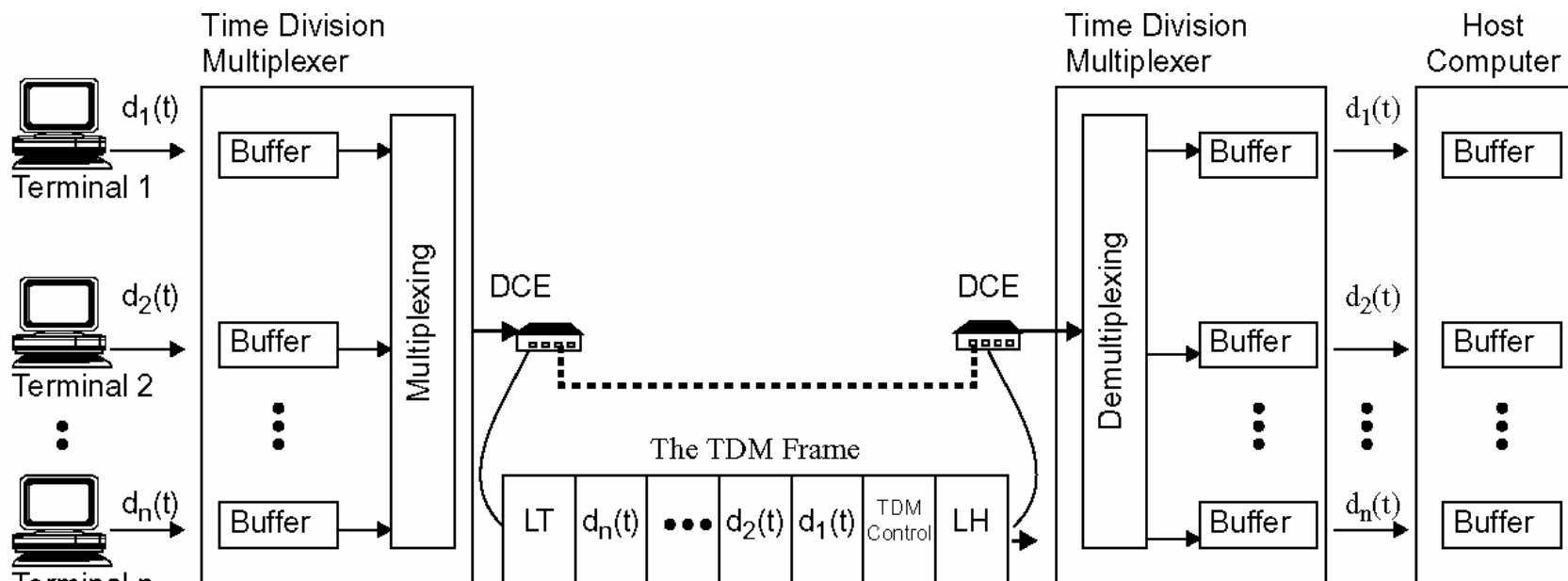- multiplexing of end systems, but also
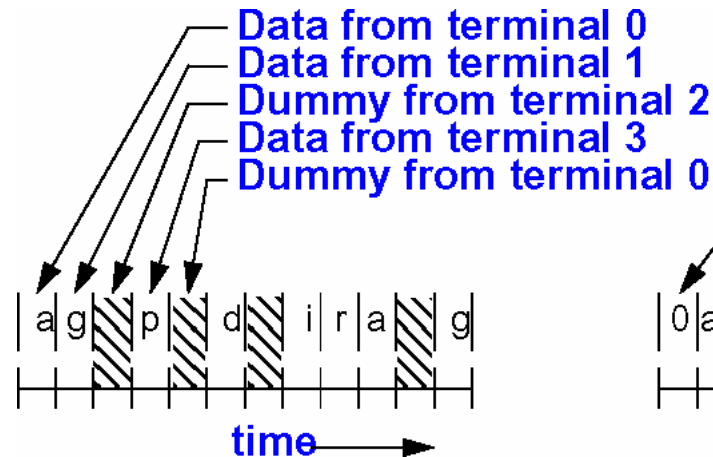- in transmission systems

LT: Link Trailer, LH: Link Header, $d_n(t)$: Fixed, predetermined slots for each device,
TDM Control: Identification of specific TDM controls (may not exist on some TDMs)
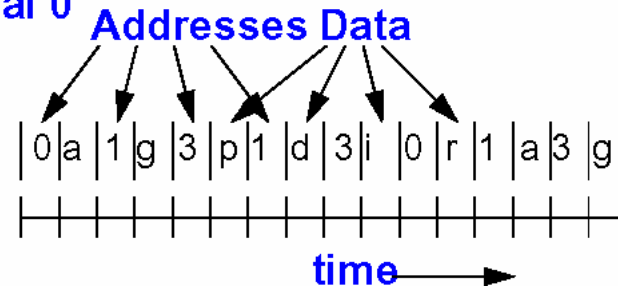
Multiplexer and Concentrator

MULTIPLEXER:
- INPUT from various links in predefined order
- OUTPUT at one single link in the same order

$$\sum_{i=1}^{n} c_i^{IN} = c^{OUT}$$

Disadvantage: waste of time slots if station is not sending

Multiplexer and Concentrator

Multiplexer: Concentrator:

Data from terminal 0
Data from terminal 1
Dummy from terminal 2
Data from terminal 3
Dummy from terminal 0

Addresses Data

| a | g | | p | | d | | i | r | a | | g |

time ➝

| 0 a | 1 g | 3 p | 1 | d | 3 i | 0 | r | 1 | a | 3 | g |

time ➝

Concentrator:
- INPUT from several links
- OUTPUT at one single link
- no fixed slot allocation,
  instead sending of (station addresses, data)

$$\sum_{i=1}^{n} c_i^{IN} > c^{OUT}$$

PROBLEM: All stations use maximum speed for sending
- "Solution": internal buffers