# Computer Networks I

## Physical Layer

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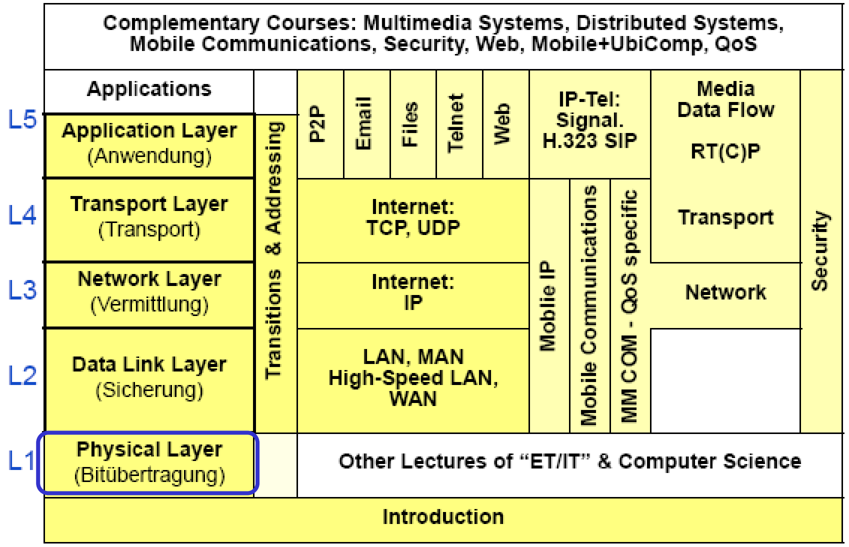
## Scope








## Overview







## 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.

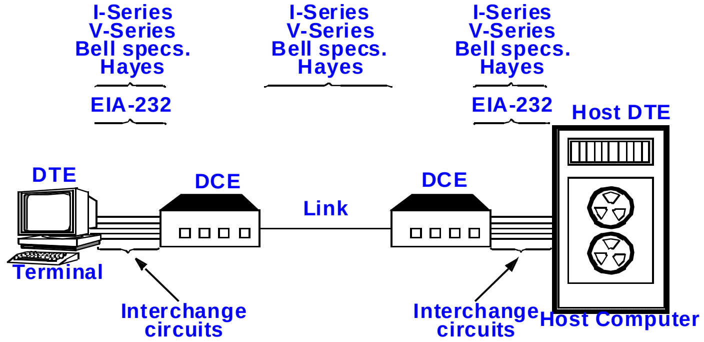
A PHYSICAL CONNECTION may permit either
- the duplex or
- the semi-duplex

transfer of a bitstream





## Physical Layer




**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

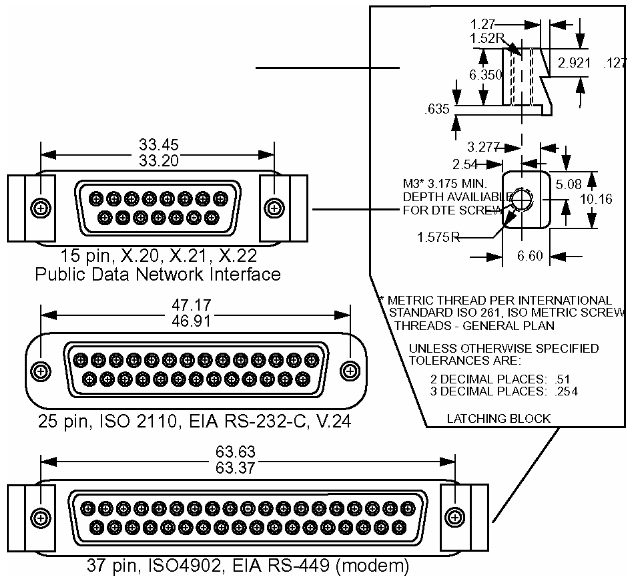
FUNCTIONAL: definition of switching functions; pin allocation (data, control, timing, ground)
- e. g. CCITT X.24:
- list of the switching functions between DTE und DCE in public data networks

PROCEDURAL: rules for using switching functions
- e. g. CCITT X.21:
- protocol between DTE and DCE for synchronized data transfer in public data networks

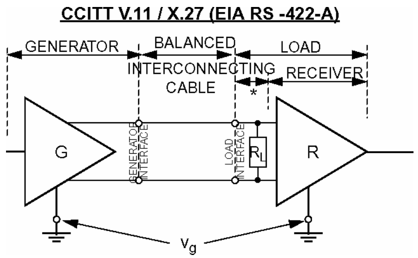




## Mechanical



## Electrical



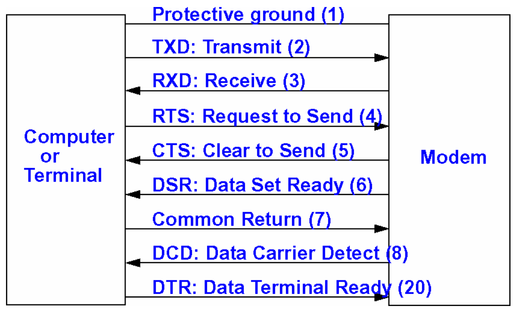

e. g. .. "

- 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 ..."





## Functional, Procedural




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





## 1.2 Bit Rate and Baud Rate

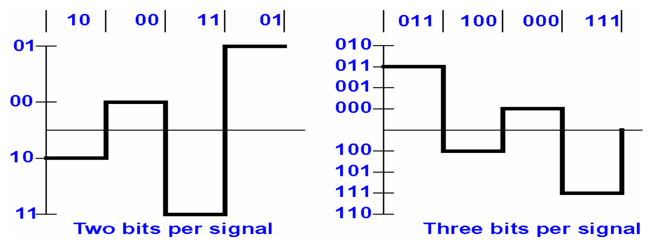
BAUD RATE:
measure of number of symbols (characters) transmitted per unit of time

- 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:








## 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 = $2\ H \bullet \log_2 V$ 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

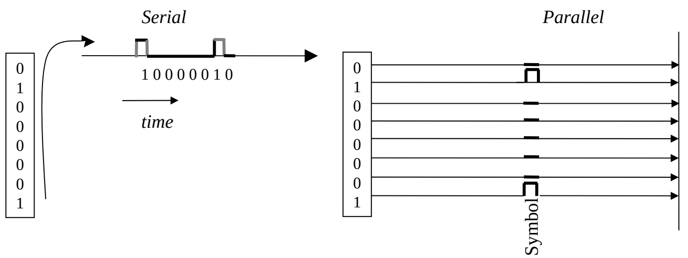


# Serial and parallel transmission



- parallel:
  - signals are transmitted simultaneously over several channels

- serial:
  - signals are transmitted sequentially over one channel






# 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
```

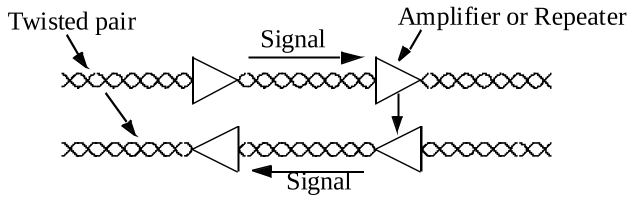
- example: RS-232-C
  - UART (universal asynchronous receiver and transmitter) IC module
  - often between
    - computer and printer or
    - computer and modem



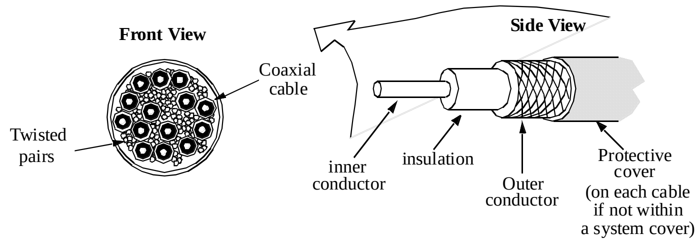


## 1.4 Guided Transmission Media: Twisted Pair and Coax

**UTP: unshielded twisted pair**




**Coaxial cable**

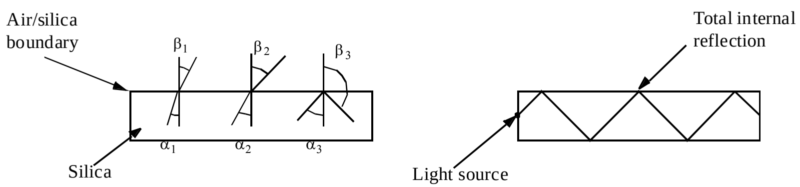







## Fiber Optics

**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**




**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)

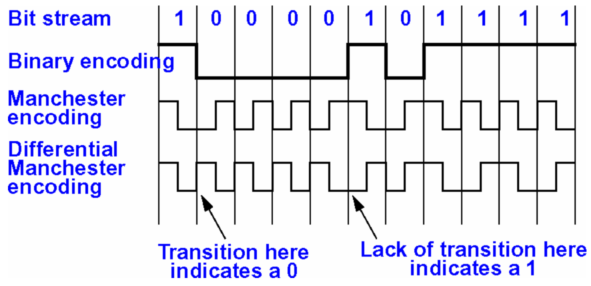
➔ Conversion

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
- ...





## Binary Encoding




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

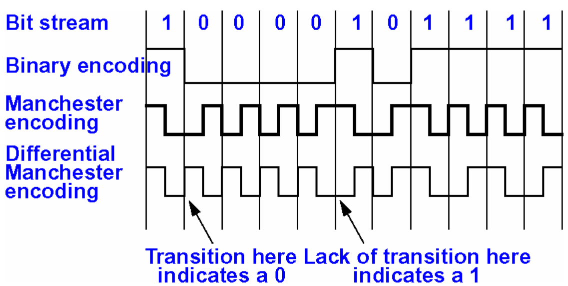
i. e.

\+ simple, cheap
\+ good utilization of the bandwidth (1 bit per Baud)
\- no "self-clocking" feature





## Manchester Encoding




Bit interval is divided into two partial intervals: I1, I2
- "1": I1: high, I2: low
- "0": I1: low, I2: high

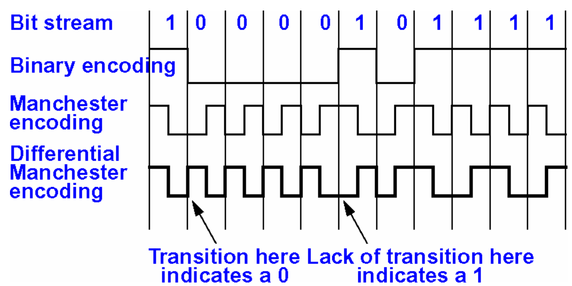
\+ good "self-clocking" feature
\- 0,5 bit per Baud

Application: 802.3 (CSMA/CD)





## Differential Manchester Encoding




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

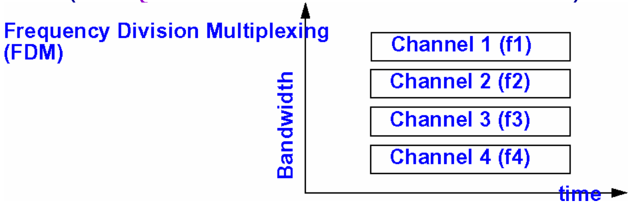
# 3 Multiplexing Techniques

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

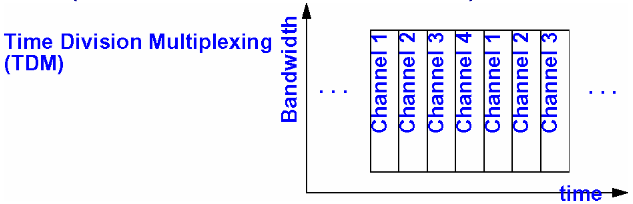
➔ multiplexing many conversations onto one channel

Two procedural classes:

- FDM (FREQUENCY DIVISION MULTIPLEXING)




- TDM (TIME DIVISION MULTIPLEXING)







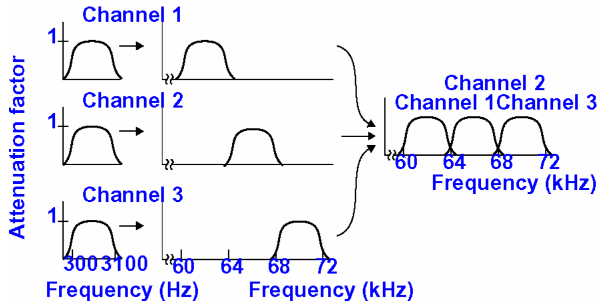

# Frequency Multiplexing

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)

➔ despite guard band adjacent channels overlap, noise





# Time Division Multiplexing

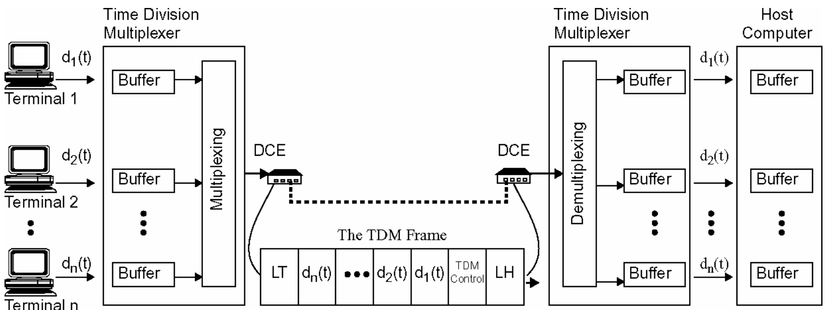
Principle:

- 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)



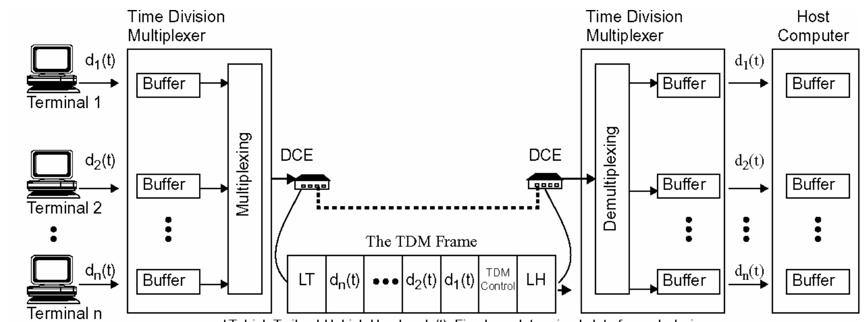


# Multiplexer and Concentrator

MULTIPLEXER:

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

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

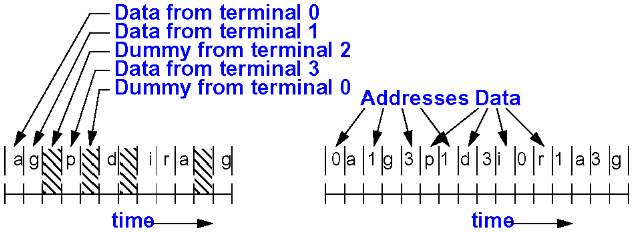



LT: Link Trailer, LH: Link Header, $d_n(t)$: Fixed, predetermined slots for each device, TDM Control: Identification of specific TDM controls (may not exist on some TDMs)

**Disadvantage: waste of time slots if station is not sending**

# Multiplexer and Concentrator

Multiplexer: Concentrator:




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