Communication Systems
Physical Layer

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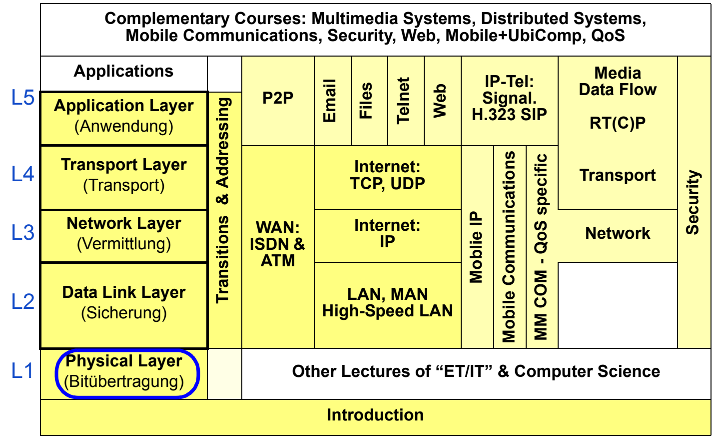
IBR (Institut für Betriebssysteme und Rechnerverbund) – TU Braunschweig
Kommunikationssysteme: Physical Layer

Scope



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Overview

1. **Function**
2. **Basics**
3. **Analog and Digital Information Encoding and Transmission**
4. **Multiplexing Techniques**

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Kommunikationssysteme: Physical Layer

1. Function

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

FEATURES,

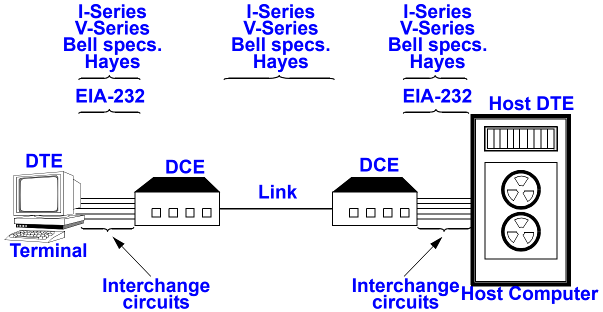
to initiate, maintain and terminate physical CONNECTIONS BETWEEN
- **Data Terminal Equipment (DTE) and**
- **Data Circuit Terminating Equipment (DCE, "postal socket")**
- **and/or data switching centers.**

Using physical connections, the phyiscal 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

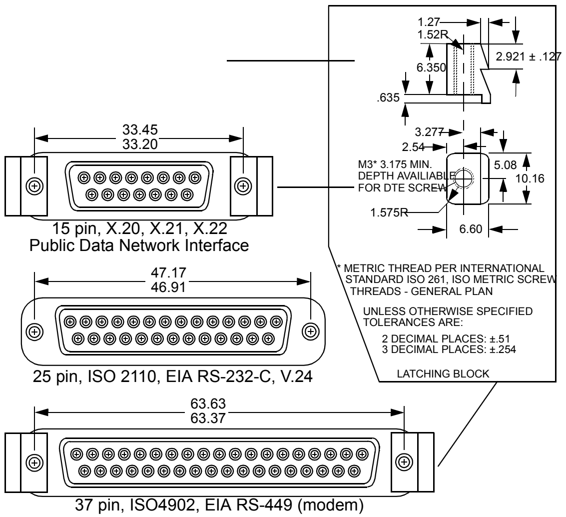
MECHANICAL: measurements of plugs, allocation of pins, etc.
- e.g., ISO 4903:
- data transfer - 15 pin DTE/DCE connection and pin allocation

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

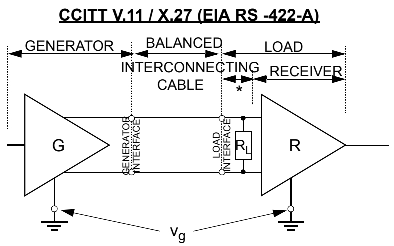
FUNCTIONAL: definition of switching functions; pin allocation (data, control, timing, ground)
- e.g., CCITT X.24:
- list of the switching functions between DTE und DCE in public data networks

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

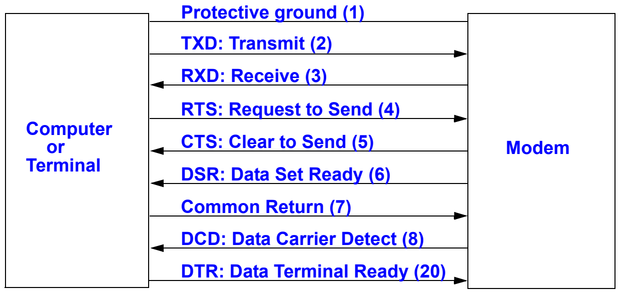


e.g., "...
- **designed for IC Technology**
- **balanced generator**
- **differential receiver**
- **two conductors per circuit**
- **signal rate up to 10 Mbps**
- **distance: 1000m (≤100 Kbps) to 10m (at 10Mbps)**
- **considerably reduced crosstalk**
- **interoperable with V.10 / X.26 ..."**

Functional, Procedural

Example RS-232-C, functional specification describes

- **connection between pins**
  - e.g., "zero modem" computer-computer-connection (intersects: T(2)-R(3)
- **meaning of the signals on the lines**
  - DTR=1, when the computer is active, DSR=1, when the 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

2. Basics

Signal speed: number of signal changes per second (Baud).

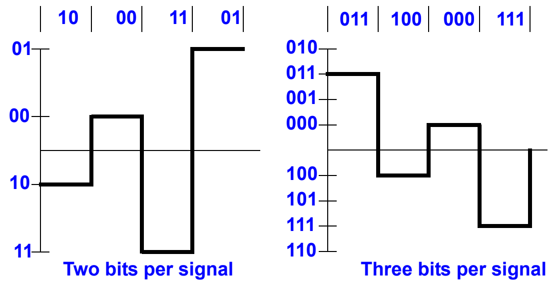
Changes in

- **amplitude, frequency, phase**

BITRATE: NUMBER OF BITS TRANSFERED PER SECOND (BPS)

- **bit rate may be higher than signal speed,**
- **because one signal value may transfer several bits.**

Example:



Basics (2)

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):**

$\Rightarrow$ **max. bitrate = 6000 bps**

Basics (3)

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)**

$\Rightarrow$ **max. bitrate = 30 000 bps**

- **independent of number of levels !**

This is an upper bound!

- **real systems rarely achieve it**

Operating Modes

Transfer directions (temporal parallelism)
- **simplex communication:**
  - data is always transfered into one direction only
- **semi-duplex communication**
  - data is transfered into both directions
  - but never simultaneously
- **fully-duplex communication**
  - data can 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
  - receiving clock pulse 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 (4)

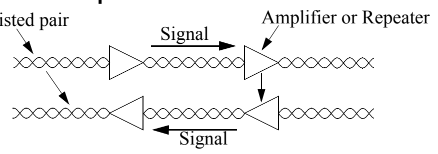
Definition
- clock pulse fixed for the duration of a signal
- termination marked by
  - stopsignal (bit) or
  - number of bits per signal
- **implementation**
  - simple: sender and receiver generate the clock pulse independently from each other
  - example:

```
7 Bit ASCII reference data
1 Parity Bit (odd, even, or unused)
1 Start-Bit
1 Stop-Bit
```

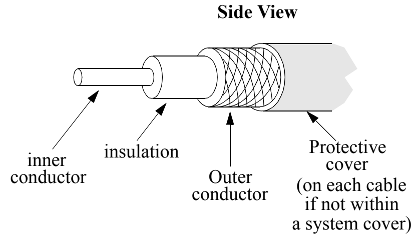
- **example: RS-232-C**
  - UART (universal asynchronous receiver and transmitter) IC module
  - often between
    - computer and printer or
    - computer and modem

2.1 Guided Transmission Media: Twisted Pair and Coax

UTP: unshielded twisted pair

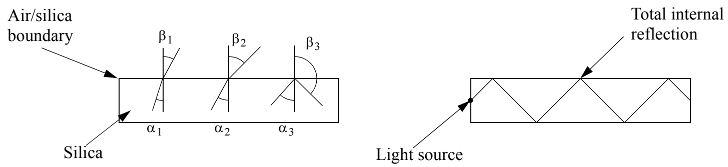


Coaxial cable



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 og light
  - light can propagate in straight line

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3. 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, ...

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Digital Information - Digital Transmission

Digital information in the end-system
- **usually TTL-Logik ("1" : 3V, "0" : 0V)**

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

⇒ **Conversion**

Coding techniques
- **binary encoding, non-return 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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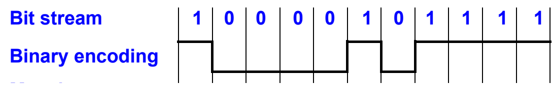
Digital Information - Digital Transmission (2)

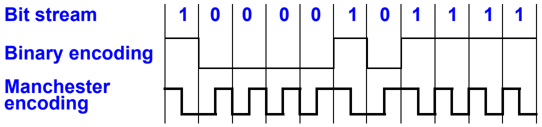


Binary encoding (Nonreturn to zero):
- "1": voltage on high
- "0": voltage on low

i.e.,

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

Digital Information - Digital Transmission (3)



MANCHESTER ENCODING:

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

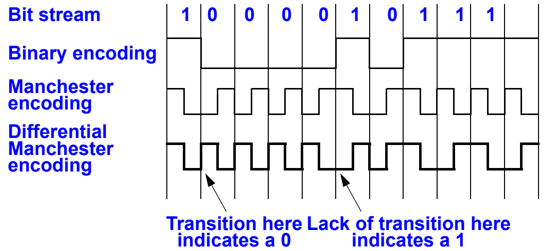
- "1": I1: high, I2: low
- "0": I1: low, I2: high

\+ **good "self-clocking" feature**

\- **0,5 bit per Baud**

Application: 802.3 (CSMA/CD)

Digital Information - Digital Transmission (4)



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**

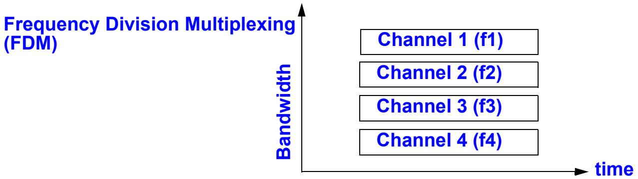
4. Multiplexing Techniques

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

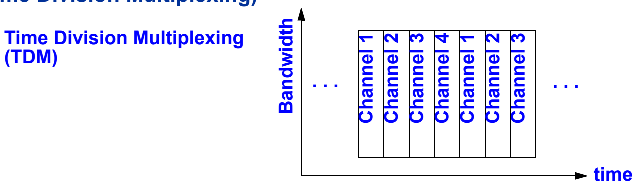
⇒ **multiplex many conversations onto one channel**

Two procedural classes:

- **FDM (Frequency Division Multiplexing)**



- **TDM (Time Division Multiplexing)**



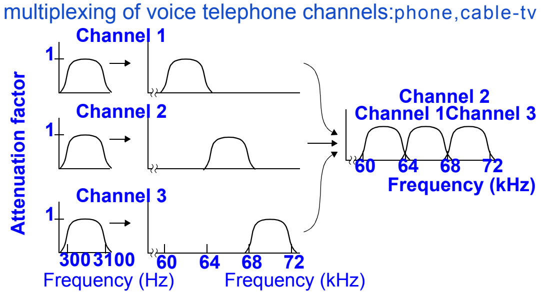
Frequency Multiplexing

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



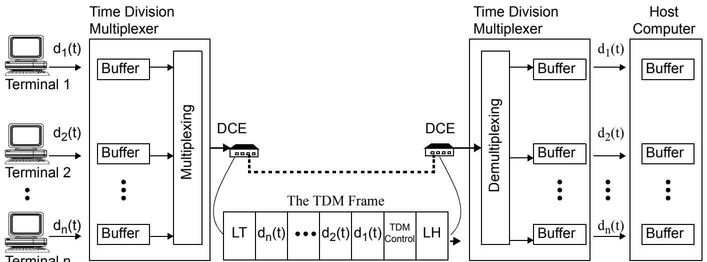
- **filters limit voice channel to 3 000 Hz bandwidth**
- **each voice channel receives 4 000 Hz bandwidth**
  - 3 000 Hz voice channel
  - 2 x 500 Hz gap (guard band)

⇒ **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

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)

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

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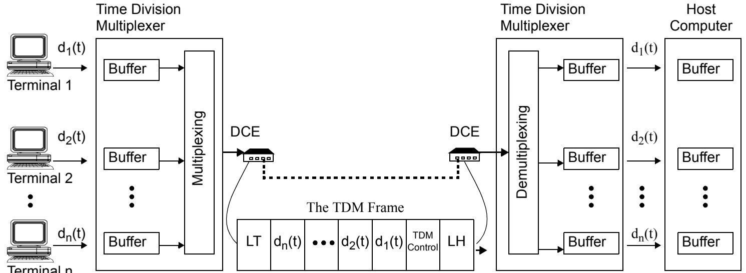
Multiplexer and Concentrator

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

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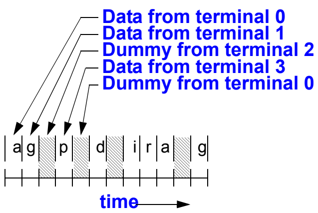
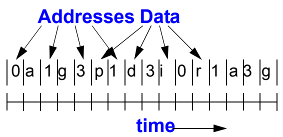
Multiplexer and Concentrator (2)

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