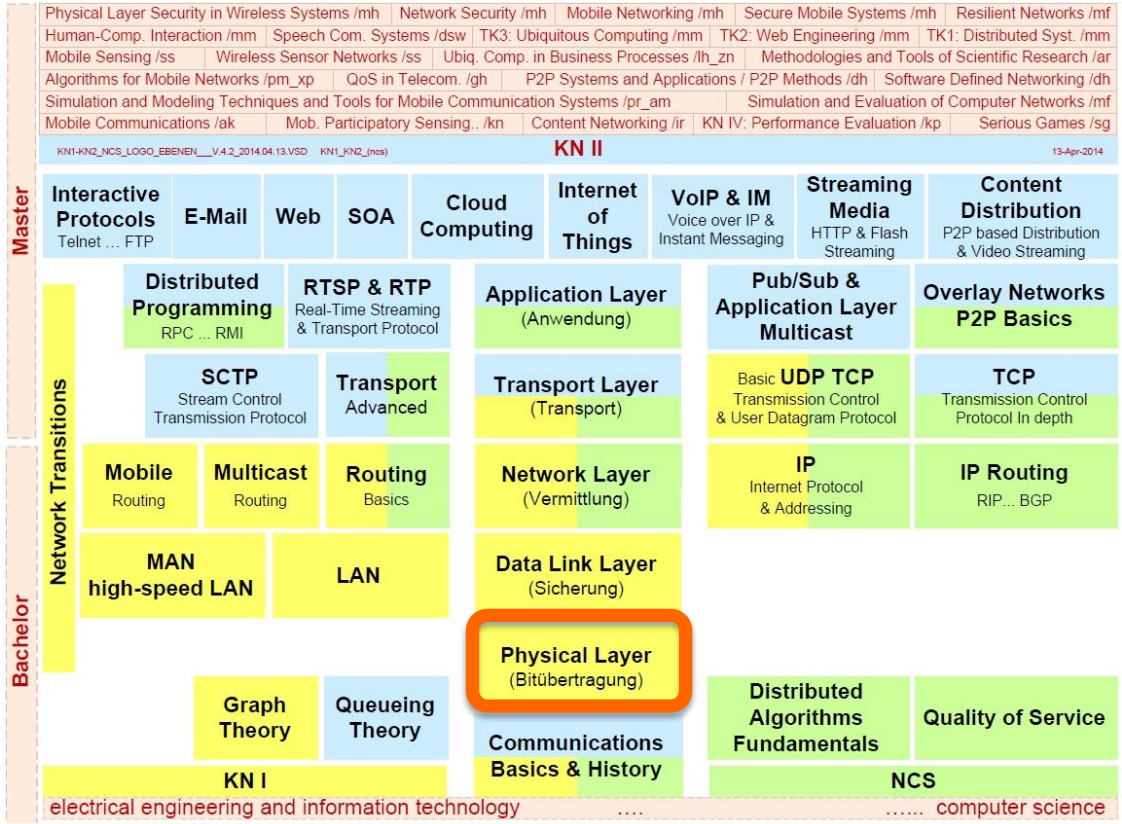
Communication Networks I

Physical Layer Fundaments



Prof. Dr.-Ing. **Ralf Steinmetz**
KOM - Multimedia Communications Lab

Overview

TECHNISCHE UNIVERSITÄT DARMSTADT

1.1 Characteristics

International Standarts

ISO DEFINITION: the physical layer provides the following features…

- Mechanical
- Electrical
- Functional
- Procedural

… 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 permits transfer of a bitstream in the modes

- Duplex or
- Semi-duplex

Characteristics

TECHNISCHE UNIVERSITÄT DARMSTADT

MECHANICAL: size of plugs, allocation of pins, etc.

- e. g. ISO 4903:
- data transfer - 15 pin DTE/DCE connection and pin allocation

ELECTRICAL: voltage, etc.

- e. g. CCITT X.27/V.11:
- electrical features for the symmetric data transfer

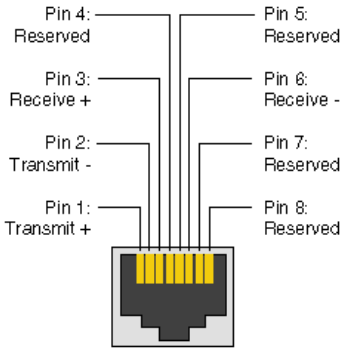
FUNCTIONAL: definition of switching functions; pin allocation (data, control, timing, ground)

- e. g. CCITT X.24:
- list of the switching functions between DTE und DCE in public data networks

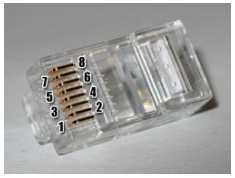
PROCEDURAL: rules for using switching functions

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

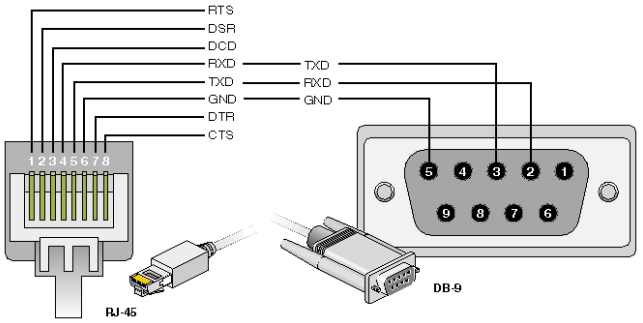
Mechanical



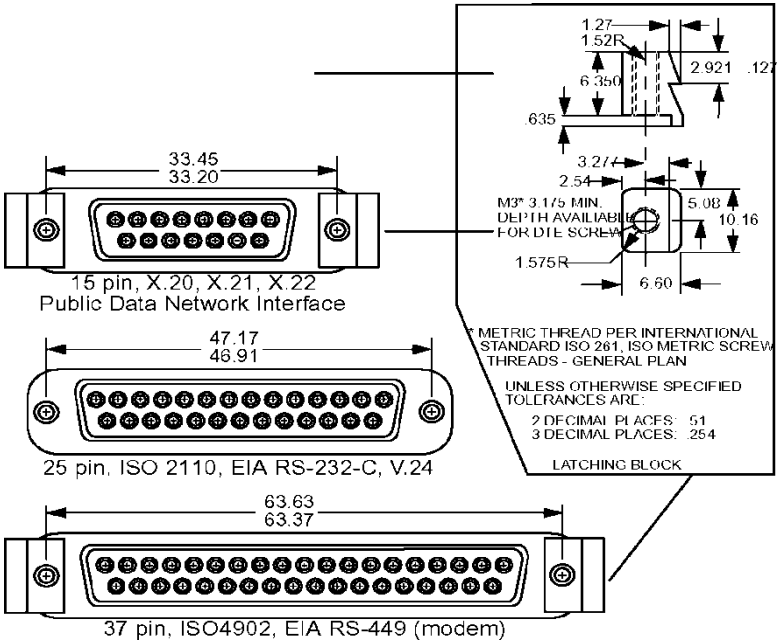
Source: http://techpubs.sgi.com

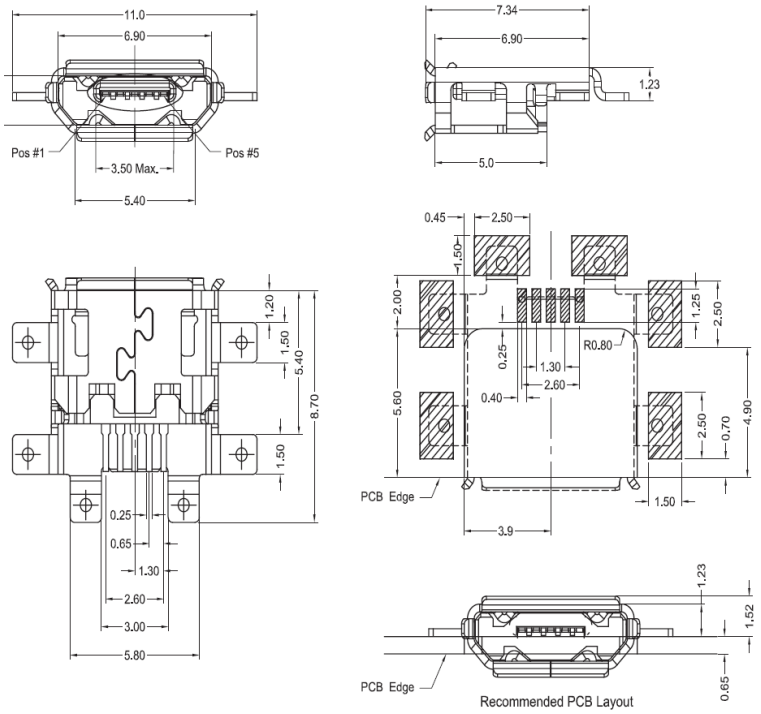


Source: wikipedia.org



Source: http://techpubs.sgi.com



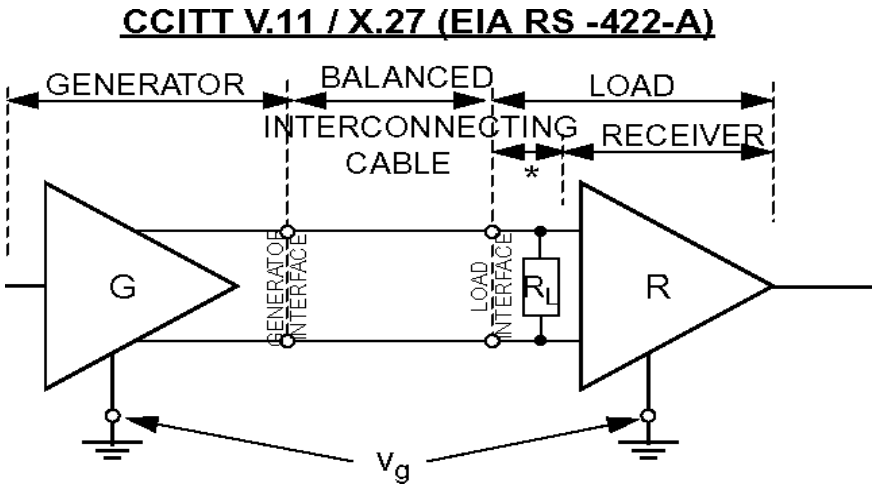


Source: http://de.mouser.com/images/microsites/Kycondimen.png

Electrical

Properties

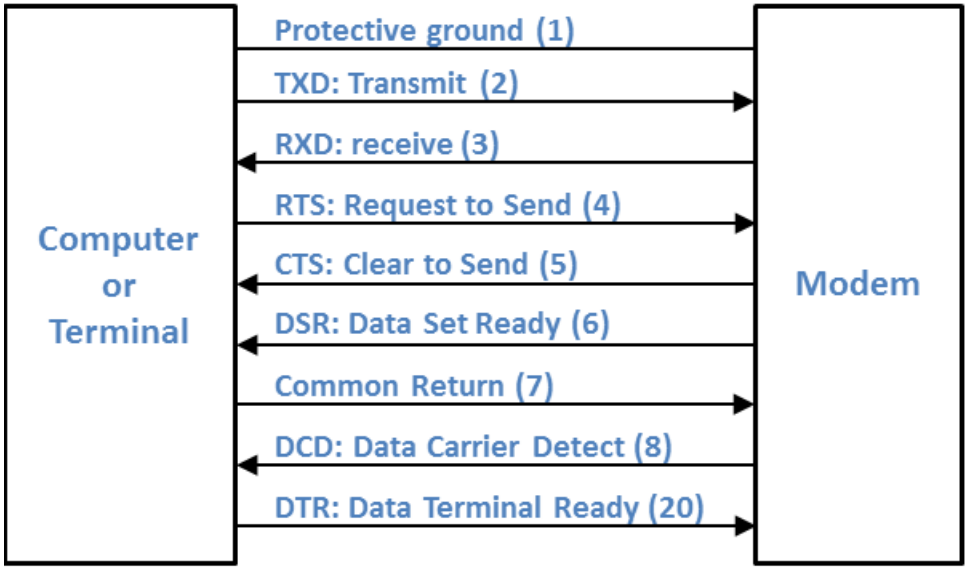
- Designed for IC Technology
- Balanced generator
- Differential receiver
- Two conductors per circuit
- Signal rate up to 10 Mbps
- Distance: 1000m (at appr. 100 Kbps) to10m (at 10Mbps)
- Considerably reduced crosstalk
- Interoperable with V.10 / X.26 ...”

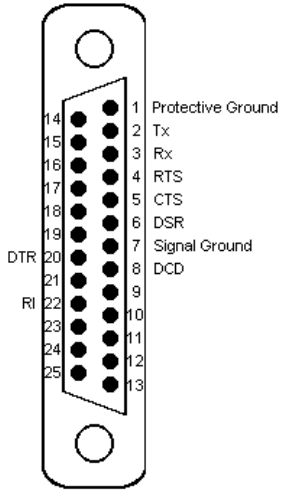


Functional, Procedural

Example RS-232-C (25pins), 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





Source: http://www.takacszoltan.eu

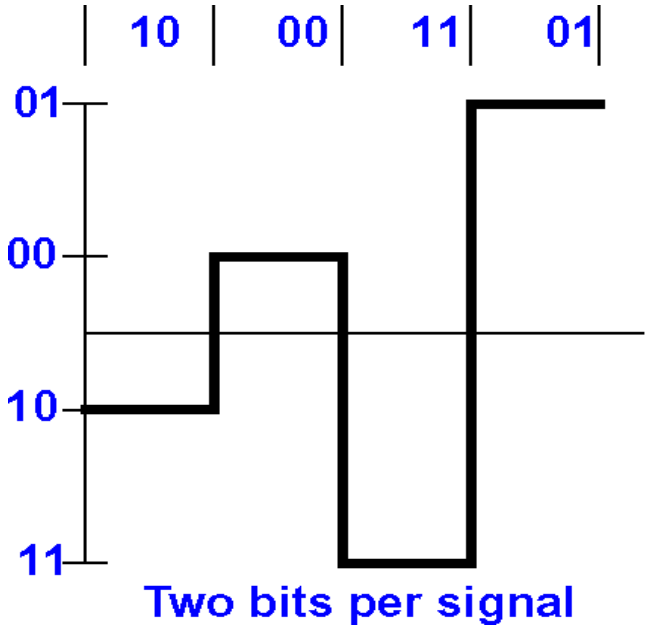
1.2 Bit Rate and Baud Rate

BAUD RATE = Number of symbols (characters) transmitted per unit of time

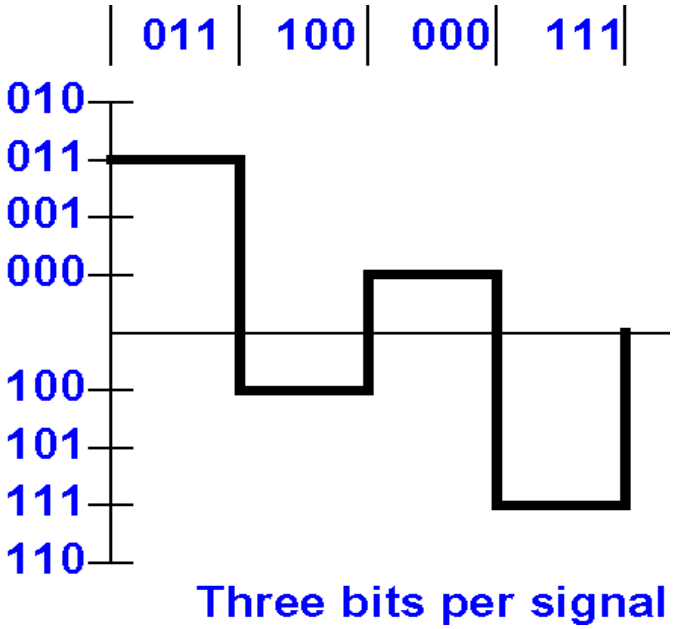
- Signal speed = number of signal changes per second
- Changes in amplitude, frequency, phase
- Each symbol represents of a number of bits
- Baud rate = Bit rate only when there is 1bit/symbol

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
- E.g. below same baud rate, but different bit rate (assuming x-axes have same dimension)

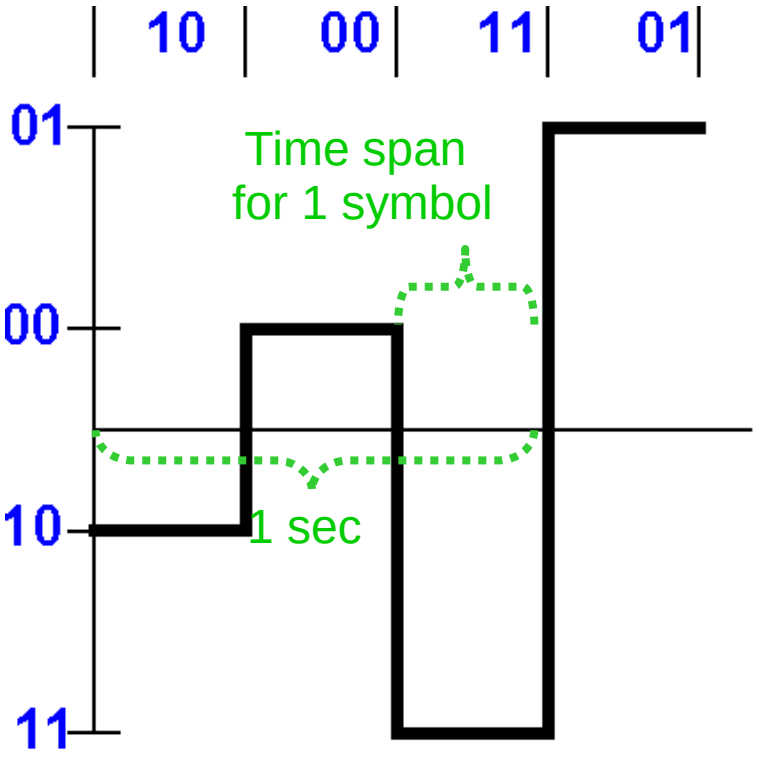


Two bits per signal



Three bits per signal

Bit Rate and Baud Rate: Example

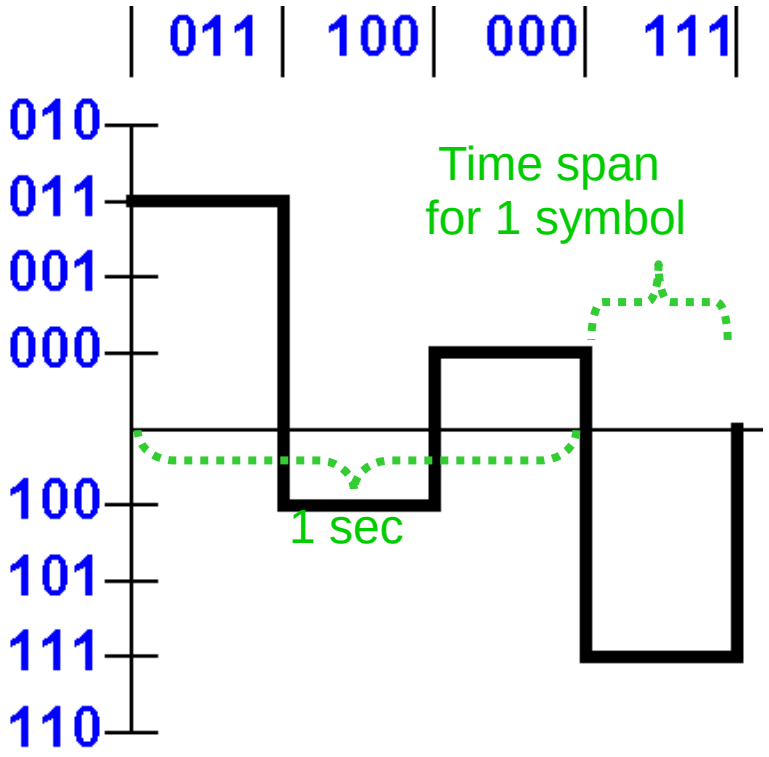


We encounter

- 4 possible values per symbol
- i.e each value encoded with 2 bits (per symbol)
- 3 symbols per sec.

Baud Rate: 3 Bd

Bit Rate: 3 Bd * 2 bit/symbol = 6 bit per sec



We encounter

- 8 possible values per symbol
- i.e. each value encoded with 3 bits (per symbol)
- 3 symbols per sec.

Baud Rate: 3 Bd

Bit Rate: 3 Bd * 3 bit/symbol = 9 bit per sec

Transfer directions (temporal parallelism)

- Simplex
  - Data is always transferred into one direction only
- Semi-duplex (half-duplex)
  - Data is transferred into both directions
  - But never simultaneously
- Full-duplex
  - 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

TECHNISCHE UNIVERSITÄT DARMSTADT

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

TECHNISCHE UNIVERSITÄT DARMSTADT

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

TECHNISCHE UNIVERSITÄT DARMSTADT

Variants and examples

		Transmission	
		Analog	**Digital**
Information Coding	**Analog** (voice, music)	"Plain old" telephone service (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

TECHNISCHE UNIVERSITÄT DARMSTADT

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, 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
- ...

2.1 Binary Encoding

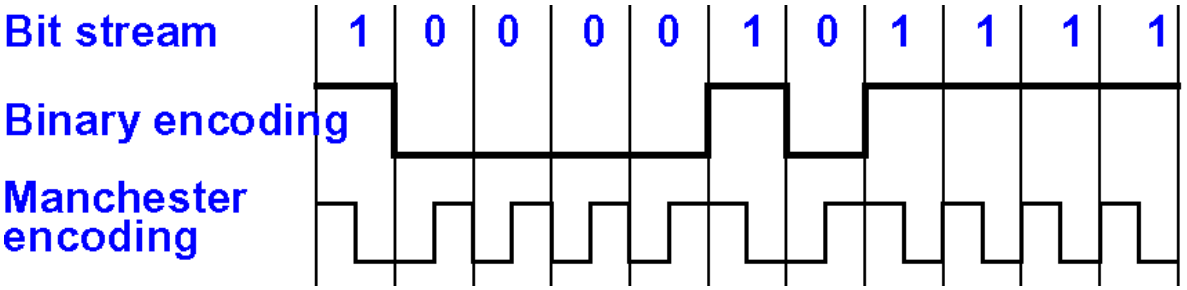
Binary encoding (Nonreturn to zero):

- "1": voltage on high
- "0": voltage on low

Pros and Cons

+ Simple, cheap
+ Good utilization of the bandwidth (1 bit per Baud)
- No "self-clocking" feature

2.2 Manchester Encoding



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

- "1":

  I1: high → I2: low 

- "0":

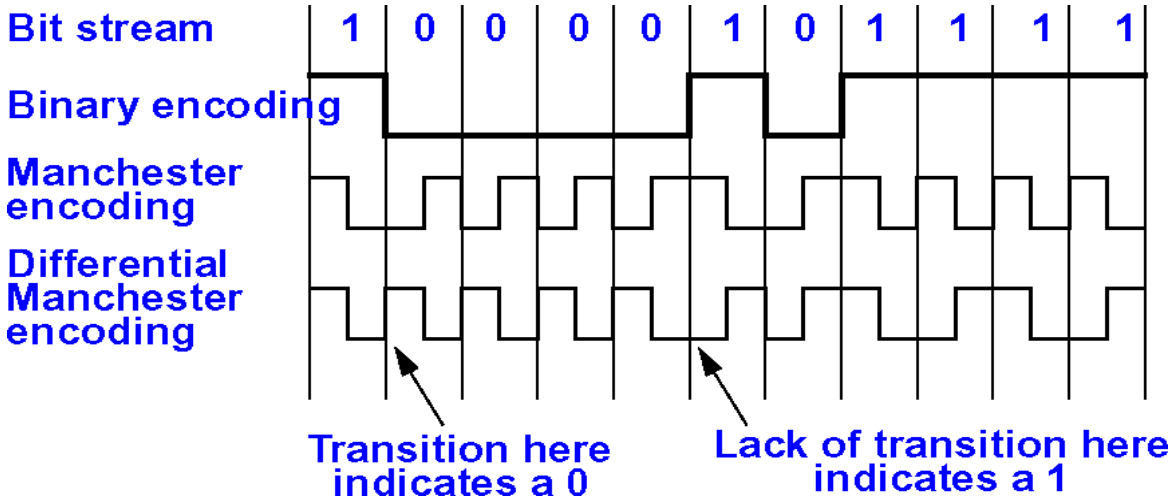
  I1: low → I2: high 

Pros and Cons

+ good "self-clocking" feature
- 0.5 bit/Baud

Application: 802.3 (CSMA/CD)

2.3 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

Pros and Cons

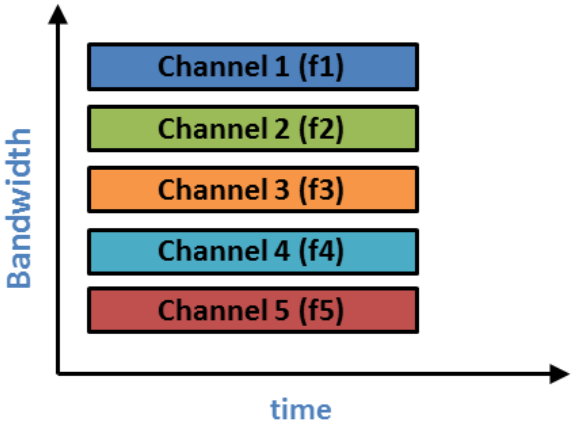
+ Good "self-clocking" feature
+ Low susceptibility to noise because only the signal's polarity is recorded; absolute values are irrelevant
- 0.5bit/Baud
- Complex

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

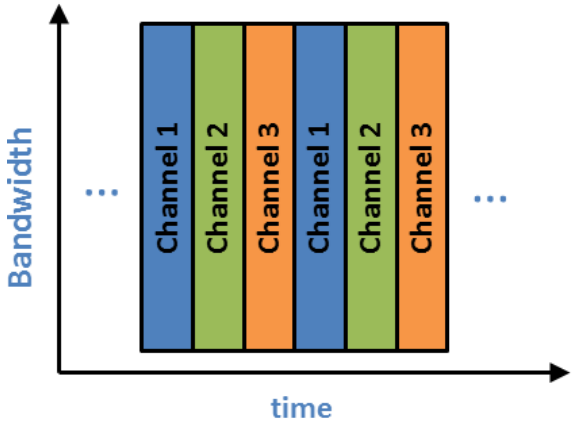
→ Multiplexing many conversations onto one channel

Two types

- Frequency Division Multiplexing (FDM)



- Time Division Multiplexing (TDM)



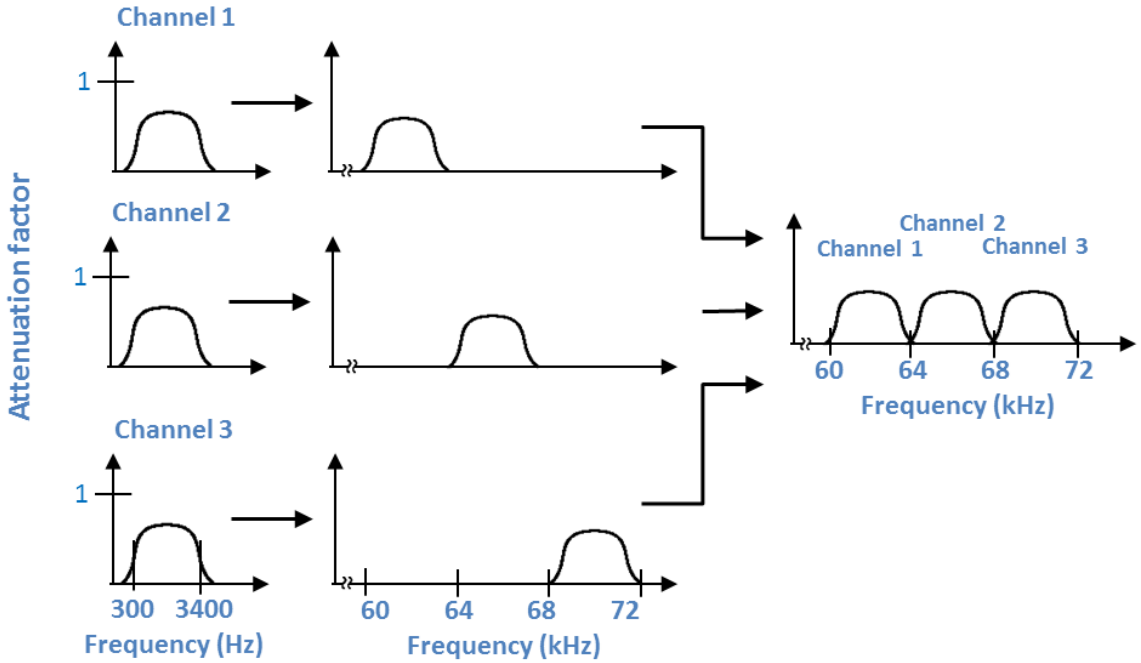
3.1 Frequency Multiplexing

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 ~3000 Hz bandwidth
- Each voice channel receives 4000 Hz bandwidth
  - 3 000 Hz voice channel
  - 2 x 500 Hz gap (guard band)



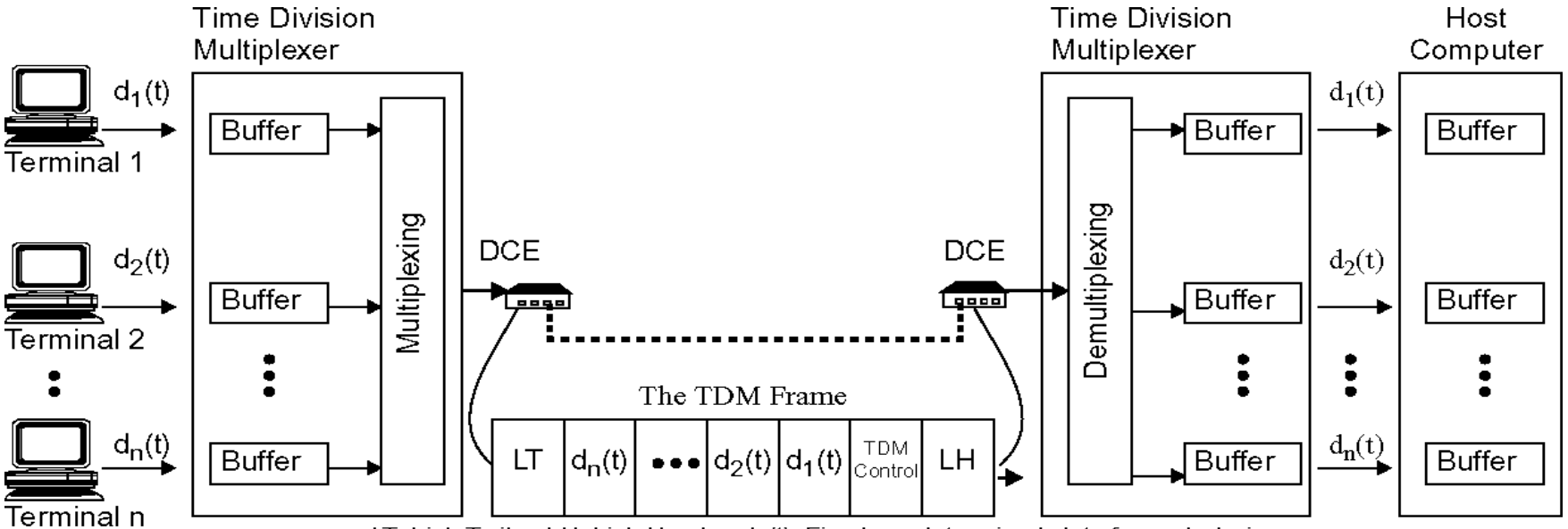
3.2 Time Division Multiplexing

Principle

- User receives a time slot
- During this time slot the user 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)

Multiplexer

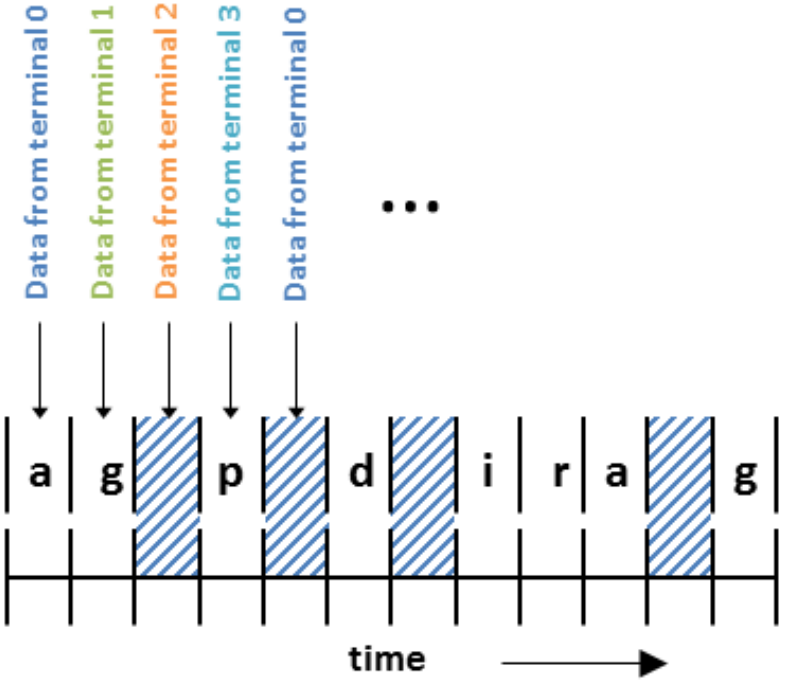
- INPUT from various links in predefined order
- OUTPUT at one single link in the same order
- Disadvantage: waste of timeslots if station is not sending

Concentrator

- INPUT from several links
- OUTPUT at one single link
- No fixed slot allocation,instead sending of [station addresses, data]
- PROBLEM: All stations use maximum speed for sending
- SOLUTION: internal buffers

Multiplexer and Concentrator

Multiplexer:



Concentrator: