Physical Network Layer

Properties of communication networks

Constraining factors:

- **Transfer rate, (capacity, bandwidth)**
- **Propagation latency**

Transfer rates:

Morse-telegraph: < 100Bit/sec
Telegraphy: < 150 Bit/sec
Phone: ~ 50Kbit /sec
Serial RS232: ~ 100Kbit/sec
Field bus: few Kbit/sec ... ~ 1Mbit/sec
Ethernet: 10-1000Mbit/sec
High speed networks: >> Gbit/sec

Latency: **Satellite connection (2 x 35700 km): ~ 240 ms,**
cabel (trans-atlantic) (~ 6.000 km): ~ 20 ms

Topology: point-to-point, star, bus, tree, grid, multi-level....

The Physical Layer Issues

- Asynchronous serial transmission (character oriented)
- Synchronous serial transmission (bitsynchronization)

- Bit coding:
  - NRZ (Non-Return-to-Zero
  - Manchester Code
  - MFM (Modified-Frequency-Modulation)

- Modulation and data transmission:
  - Base band — Example: Morsetel. / Ethernet
  - Broad band — Example: Radio, TV, Cabel-TV, Modem
    Modulation: AM, FM

- Transmissionmedia:
  - Fiber (Multi-Mode, Single-Mode)
  - Copper (Twisted Pair, Coaxial)
  - Radio (Frequency band)
  - Satellite (Geostationary, orbiting)

How much information can be transfered over a line?

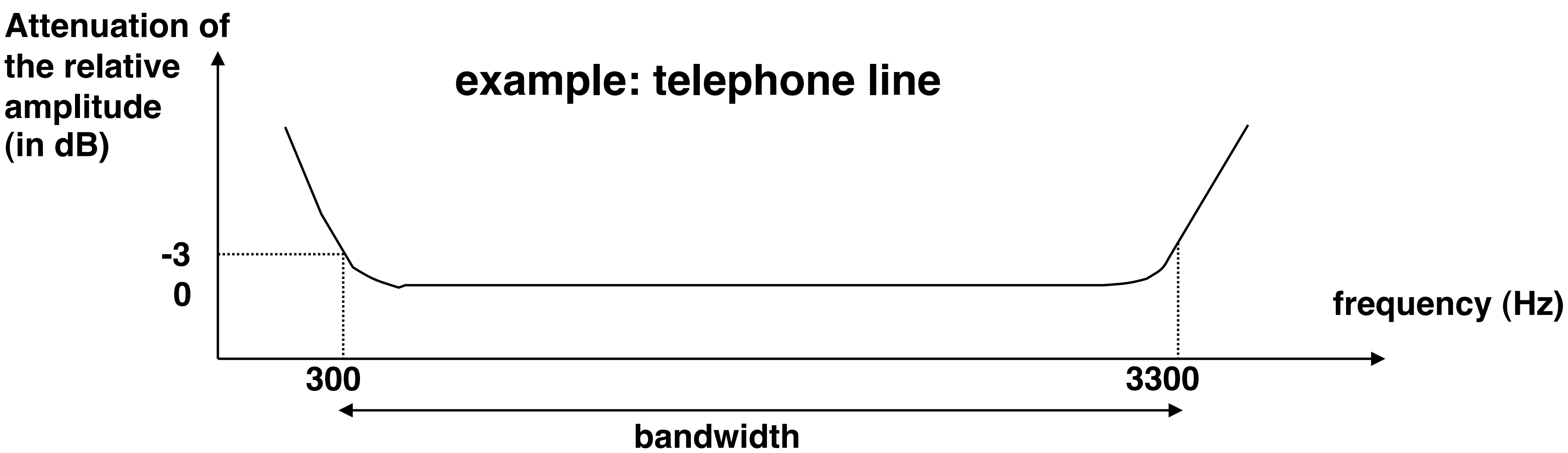
limiting factors:

→ **bandwidth of the channel**

→ **noise**

→ **The bandwidth limits the number of transitions, i.e. the frequency of switching from one signal level to the other**

→ **Noise (informally) limits the ability to distinguish between multiple signal levels**



Capacity of a channel (Shannon):

$$C = B \cdot ld\,(P_s + P_n) / P_n = B \cdot ld\,(1 + P_s / P_n)$$

C : capacity of a channel (measured in Bit/sec (bps))
P_s : signal strength (measured in μW, mW, W)
P_n : noise (measured in μW, mW, W)
B: bandwidth
P_s / P_n : signal-to-noise ratio

Example:
Telephone: bandwidth 3000Hz, signal-to-noise ratio 1000/1

$$C = 3000 \cdot ld\,(1+1000) = 3000 \cdot 9{,}97 = 29900 \text{ Bit/sec (bps)}$$

Bps and BAUD

Bps (Bit/sec) defines a Bit rate

BAUD defines the number of level transitions

Bit/sec is contraint by the channel capacity !

BAUD is constraint by the channel bandwidth !

Basic methods to increase the bps-Rate at a given BAUD rate of the channel:

- **distinguish multiple levels**
- **Coding with the smallest number level transitions**

Coding options (base band)

- level
- pulse width
- transitions

Bit coding:

NRZ	(Non-Return-To-Zero)
Manchester	
MFM	(Modified-Frequency-Modulation)

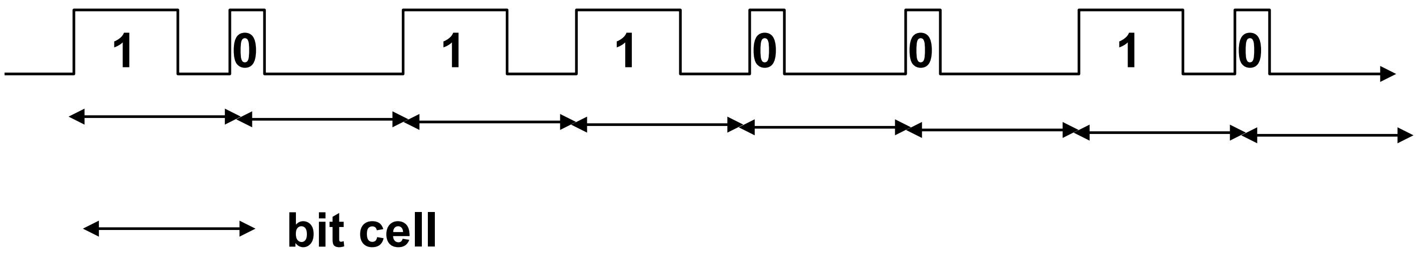
Problems:

- synchronization
- number of transitions
- constant/variable frame length

A (bad) example

RZ: (Always) Return to Zero (PWM)

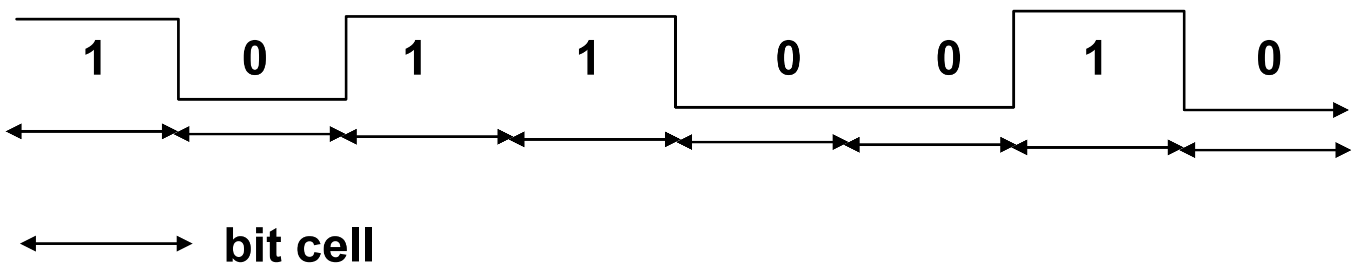
Example: 1011 0010



NRZ Codes

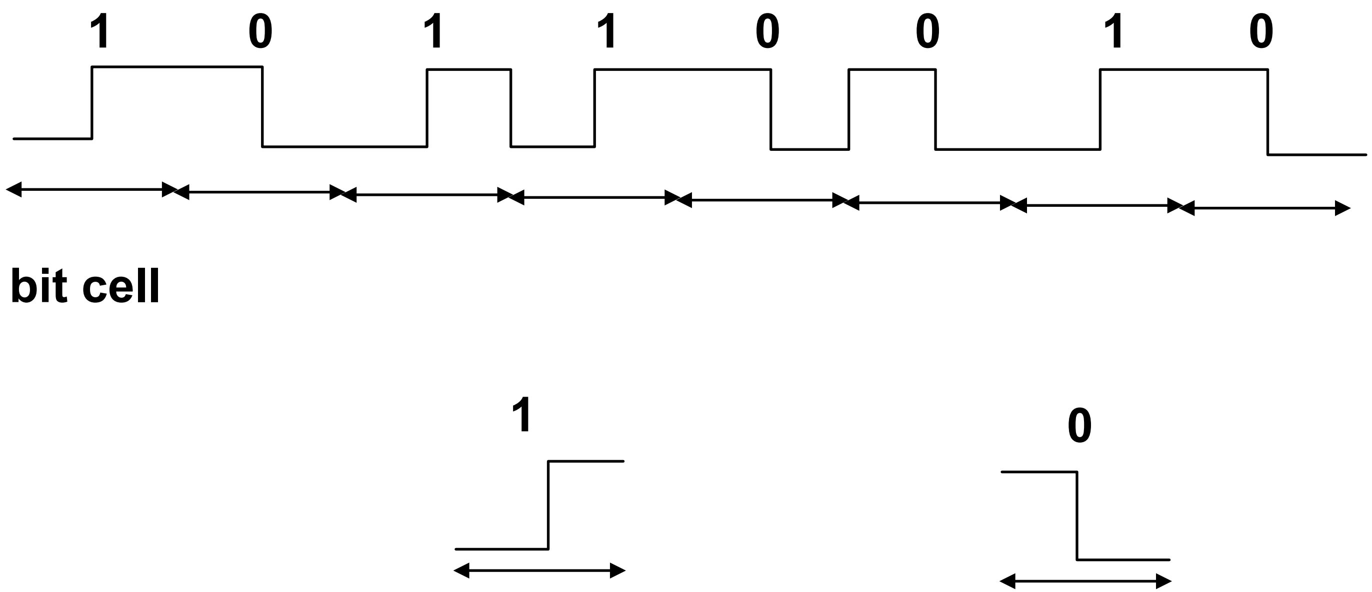
NRZ: Non Return to Zero

Example: 1011 0010



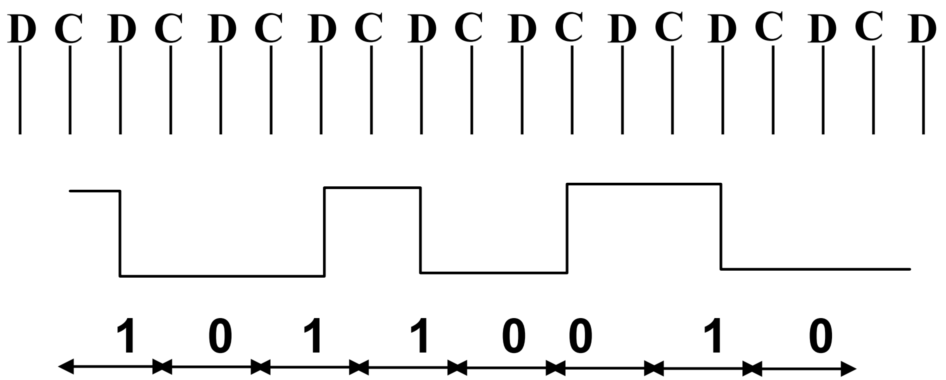
Manchester Coding

Example: 1011 0010



MFM (Modified Frequency Modulation)

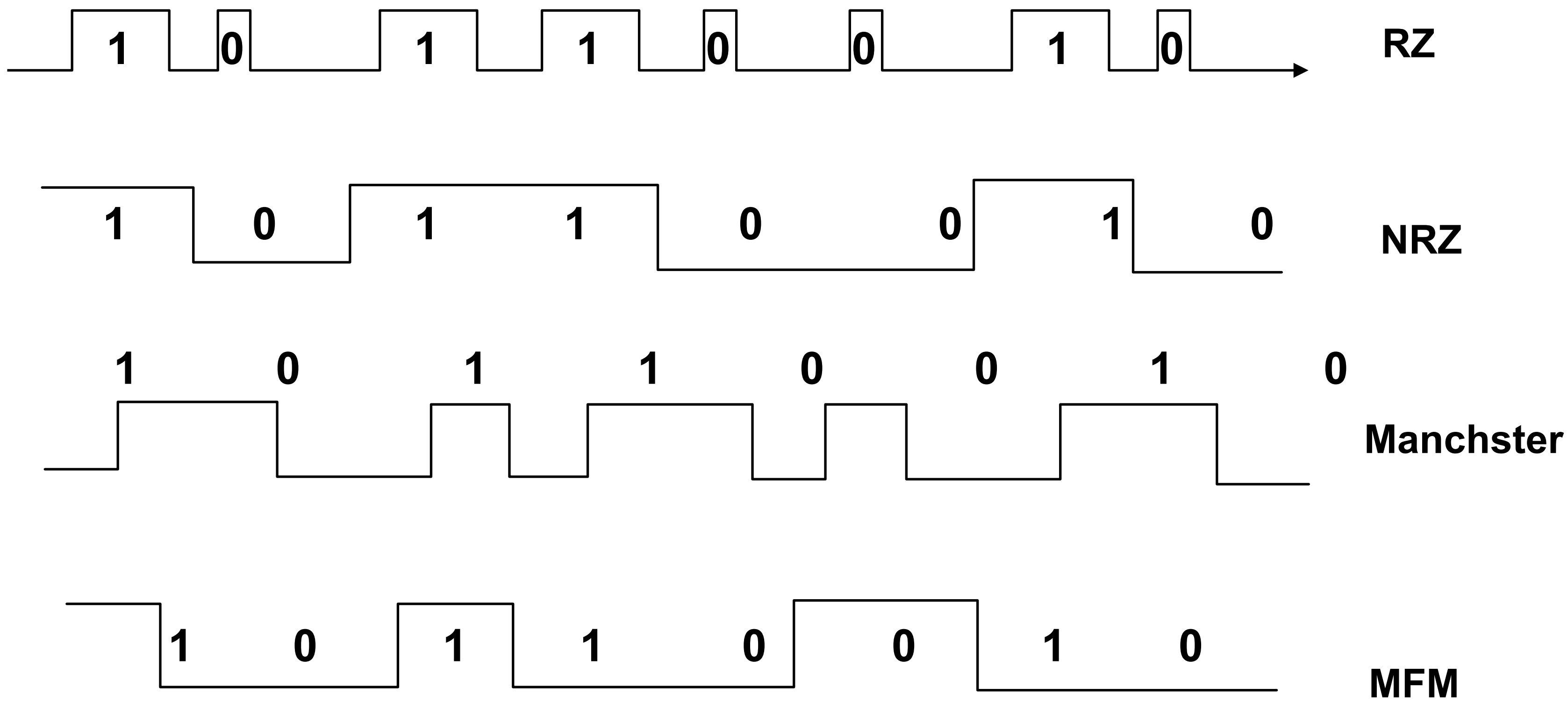
Example: 1011 0010



1: always transition at a data point (D)
0: no transition at a data point (D)

multiple consecutive "0" : transistion at a clock point (C)

Comparison of Codes



Comparison of Codes

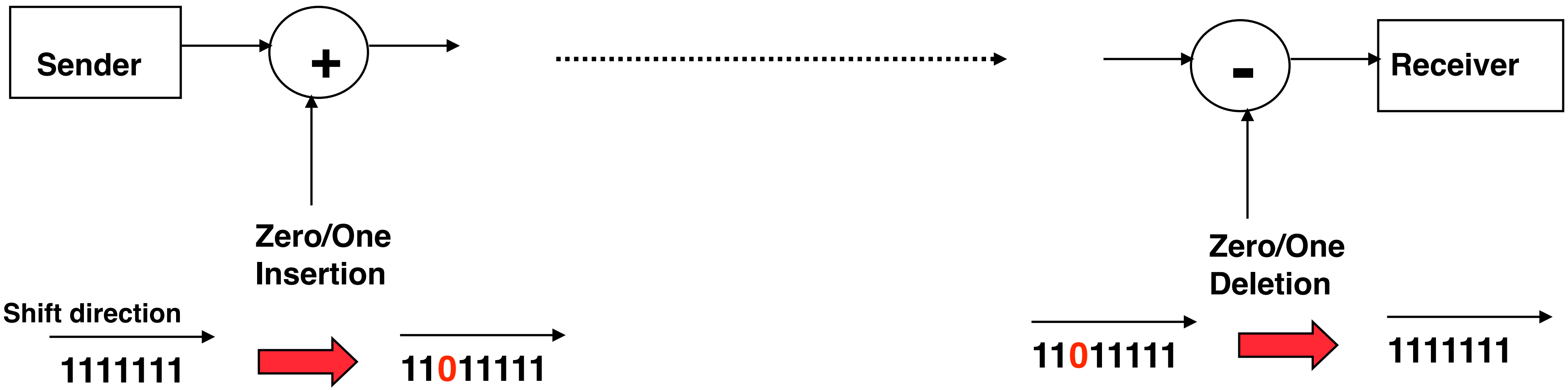
Type	Synchronization	transitions/Bit average/max		fixed length
RZ	Y	2	2	Y
NRZ	N	>0,5	1	Y
NRZ*	Y	>0,5	1	N
Manchester	Y	1,5	2	Y
MFM	Y	>0,5	1	Y

NRZ*: NRZ mit Bit Stuffing

Bit-Stuffing

When a long sequence of identical values "0" or "1" occurs, bit stuffing inserts a complemetary signal level after a fixed specified number of equal signal levels.

Sender transparently inserts stuff bits. The receiver re-establishes the original message by removing the respective stuff bits.



Bit-Stuffing and framing

Motivating examples:

- character-oriented protocols
  e.g. IBM BiSync

- binary protocols
  e.g. IBM HDLC

BiSync-Protokoll (IBM)

Byte-orientiert
Character-orientiert

SYN	SYN	Header	STX	.... Text	ETX	BCC

SOH	Adresse	Block Sequence #	Control	ACK

ASCII-Code

SYN :	**16_{16}**	
STX :	**2_{16}**	**Start of Text**
ETX:	**3**	**End of Text**
BCC:		**Error Correcting Code**
SOH:	**1_{16}**	**Start of Header**
ACK:	**6_{16}**	**Acknowledge**
NAK:	**15_{16}**	**Negative Ack.**
ENQ:	**5_{16}**	**Enquire Request.**

Bit stuffing to identify message boundaries

Example: HDLC (High Level Data Link Control)

Problem:
In character-oriented protocols, control and seperation characters (STX, ETX, etc.) can be identified easily..
In bit-oriented protocols any combination of bits as data is possible!

➡ **How to identify control information?**

HDLC-Frame

Flag	address	control	info		flag
0111 1110	8	8	optional	FCS	0111 1110

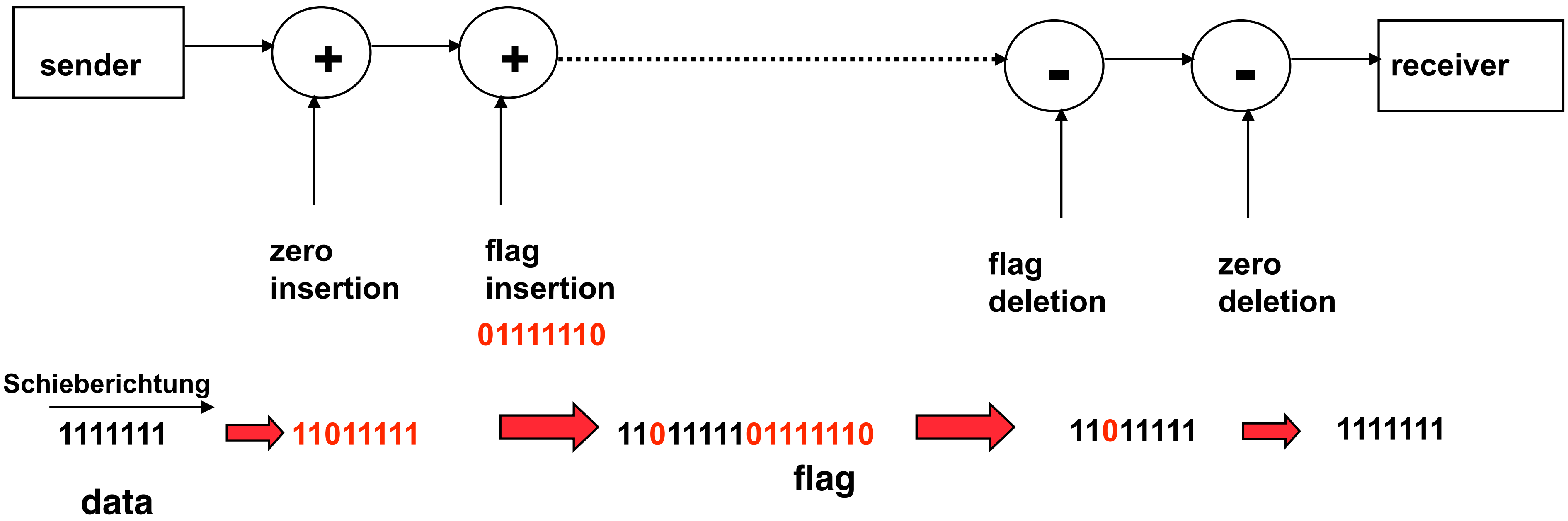
I-Frame - Information Frame: data transport
S-Frame - Supervisor Frame: flow control, e.g. ACK, re-transmission
U-Frame - Un-numbered Frame: additional control info e.g. connect, disconnect

How to distinguish the control info 01111110 from data ?

Bit stuffing to identify message boundaries

goal: recognizing the flag "01111110".

method: The sender normally inserts a stuff bit "0" after 5 consecutive "1". Therefore there is a max. number of five consecutive "1". The flag is inserted AFTER the bist stuffing stage in the sender and detected and removed before the receiver stuffing stage.



Bit stuffing

- ensures synchronization

- needed for framing in binary protocols

- exploited for special signals