
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 transferred over a line?

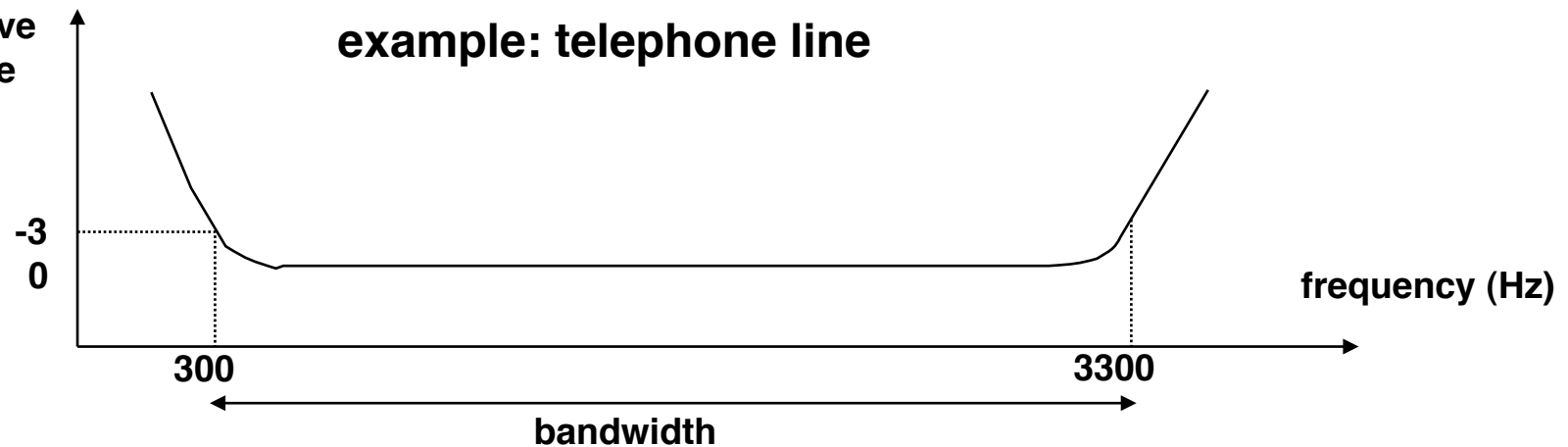
limiting factors:

→ 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

Attenuation of the relative amplitude (in dB)



Capacity of a channel (Shannon):

$$C = B \cdot \log_2 (P_s + P_n) / P_n = B \cdot \log_2 (1 + P_s / P_n)$$

C : capacity of a channel (measured in Bit/sec (bps))

P_s : signal strength (measured in μ W, mW, W)

P_n : noise (measured in μ W, mW, W)

B: bandwidth

P_s / P_n : signal-to-noise ratio (dB) = $20 \cdot \log_{10} (P_s / P_n)$

Example:

Telephone: bandwidth 3000Hz, signal-to-noise ratio 60 dB
(corresponds to a relation 1000/1)

$$C = 3000 \cdot \log_2 (1+1000) = 3000 \cdot 9,97 = 29900 \text{ Bit/sec (bps)}$$



U_1/U_0	dB	comment
1000	60	amplification
100	40	amplification
10	20	amplification
3,16	10	amplification
2	6	amplification
1,414	3	amplification
1	0	(1:1) transmission
0,7071	-3	attenuation
0,5	-6	attenuation
0,316	-10	attenuation
0,1	-20	attenuation
0,01	-40	attenuation
0,001	-60	attenuation

$$L = 20 \cdot \lg \frac{U_1}{U_0}$$

http://de.wikipedia.org/wiki/Dezibel_%28Spannungspegel%29



Bps and BAUD

Bps (Bit/sec) defines a Bit rate

BAUD defines the number of level transitions

Bit/sec is constraint by the channel capacity !

BAUD is constraint by the 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:

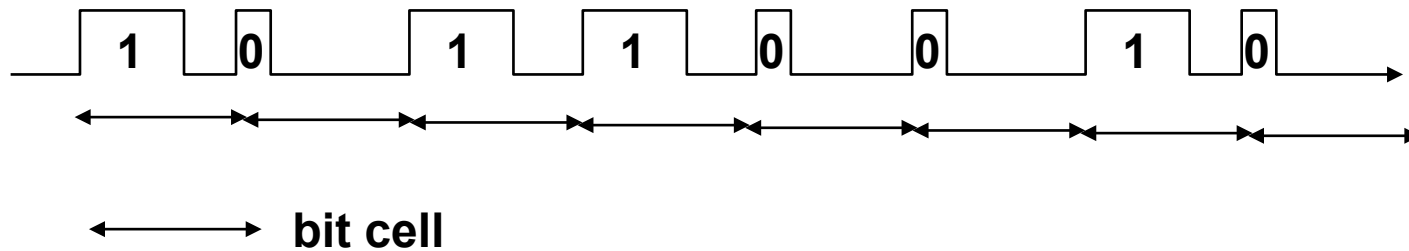
**synchronization
number of transitions
constant/variable frame length**



A (bad) example

RZ: (Always) Return to Zero (PWM)

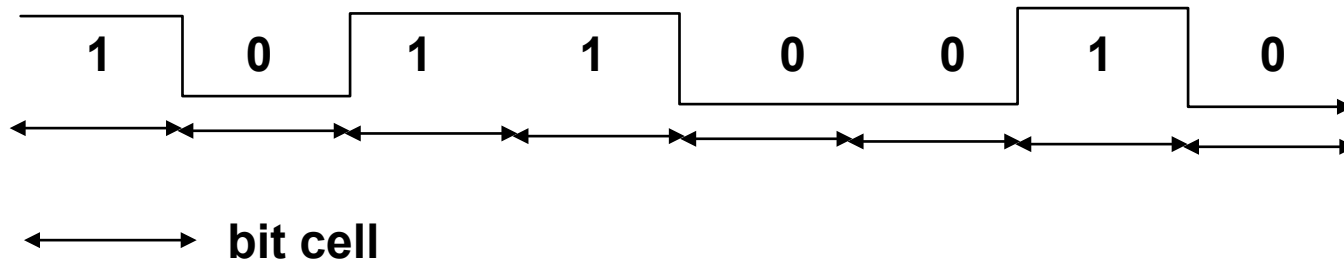
Example: 1011 0010



NRZ Codes

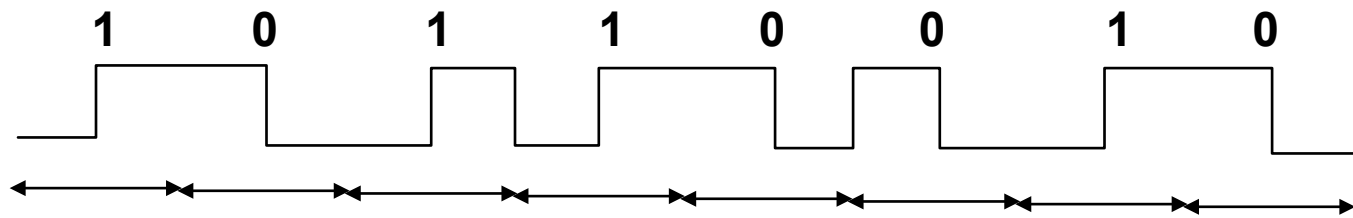
NRZ: Non Return to Zero

Example: 1011 0010



Manchester Coding

Example: 1011 0010

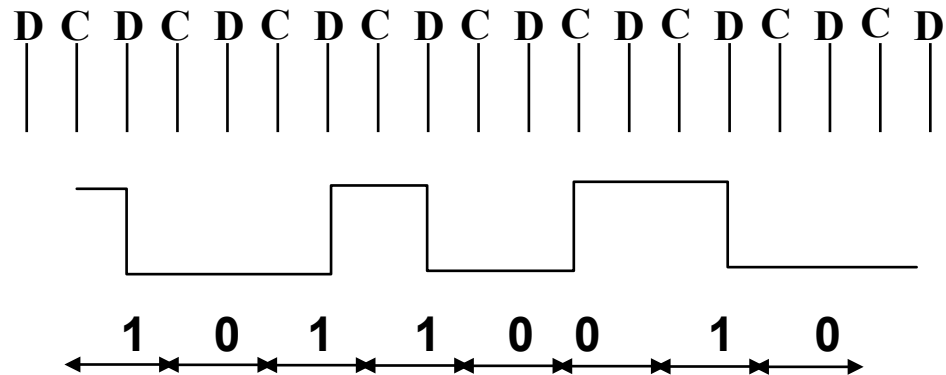


bit cell



MFM (Modified Frequency Modulation)

Example: 1011 0010



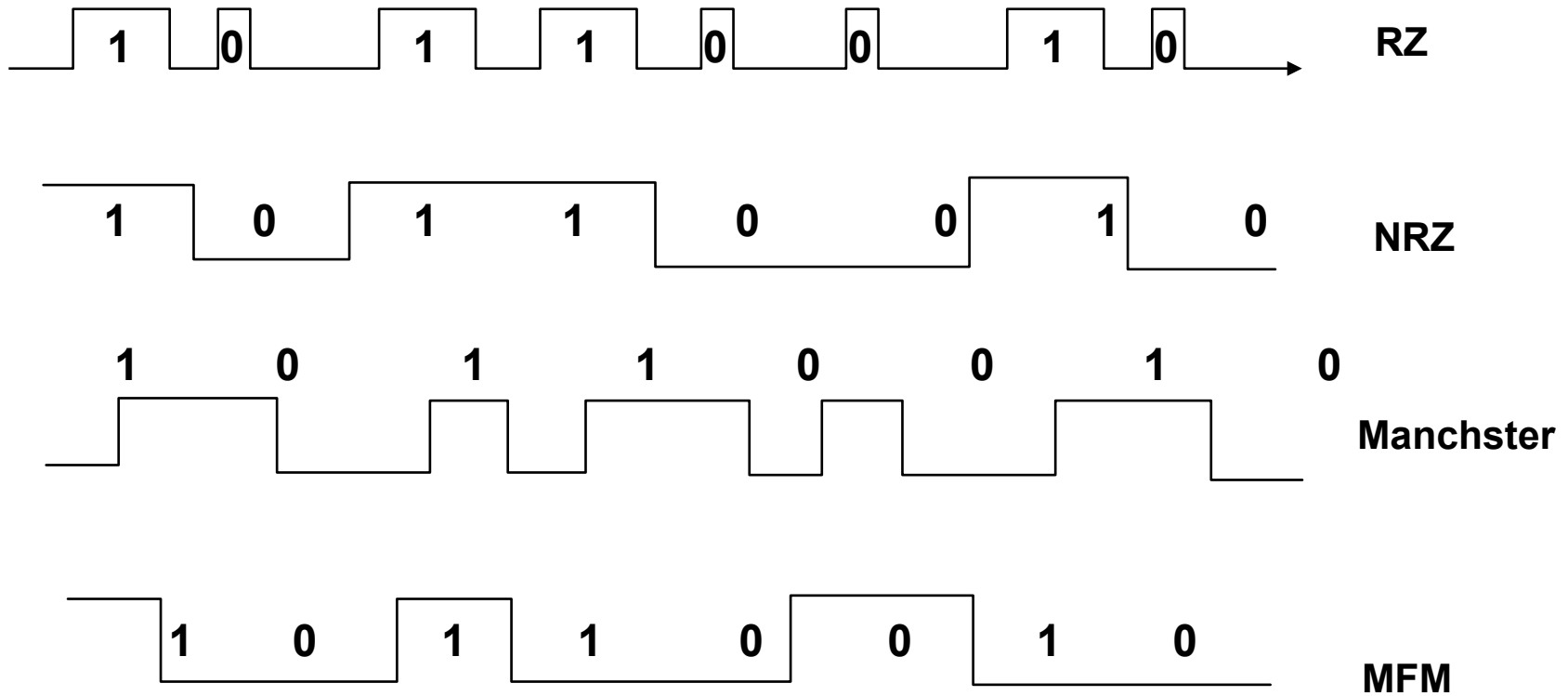
1: always transition at a data point (D)

0: no transition at a data point (D)

multiple consecutive "0" : transition 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

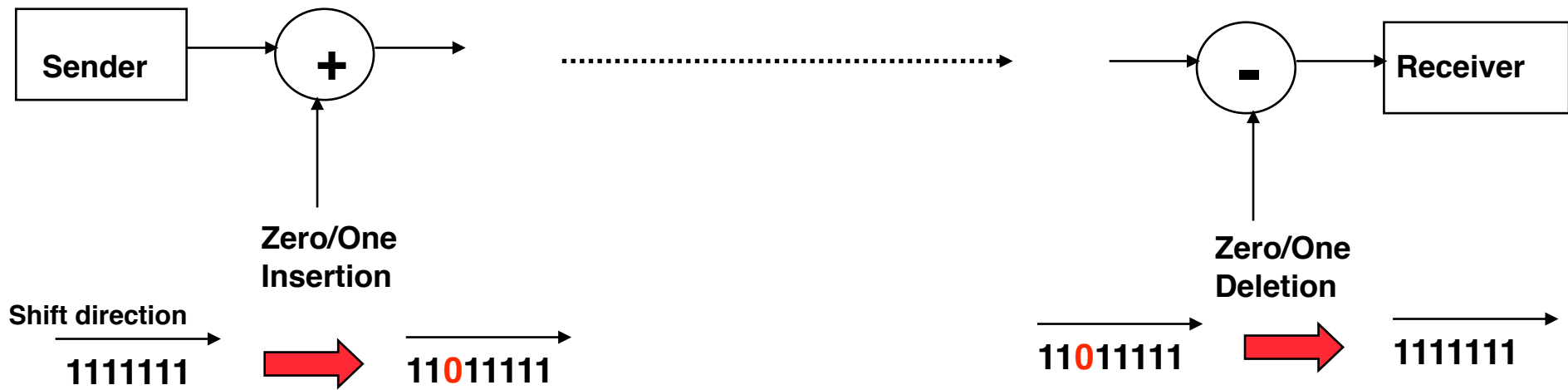
NRZ*: NRZ mit Bit Stuffing



Bit-Stuffing

When a long sequence of identical values "0" or "1" occurs, bit stuffing inserts a complementary 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 to identify message boundaries

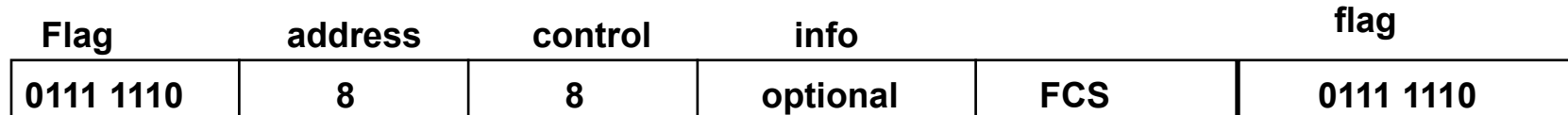
Example: HDLC (High Level Data Link Control)

Problem:

In character-oriented protocols, control and separation 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



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 bit stuffing stage in the sender and detected and removed before the receiver stuffing stage.

