Computer Networks

Exercise Session 04

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General Schedule

All exercises will follow this general schedule

- Identify potential understanding problems
  → Ask your questions
  → Recap of the lecture
- Address the understanding problems
  → Answer your questions
  → Repeat certain topics
- Walk through the exercises/solutions → Some hints and guidance
  → Work time or presentation of results

Data Encoding

You have seen ...

- what a baseband transmission is
- which requirements exist for a good encoding (robustness, efficiency, and clock recovery)
- several line codes and how they relate to these requirements
- what the problems of baseline wander and clock recovery are and how to tackle them
- how an encoding of group of bits in combination of another encoding can be used to address all requirements → e.g., 4B/5B

Modulation

You have seen . . .

- how data can be modulated onto a carrier frequency in broadband
- what amplitude, frequency, and phase modulation are
- which advantages and drawbacks these methods have

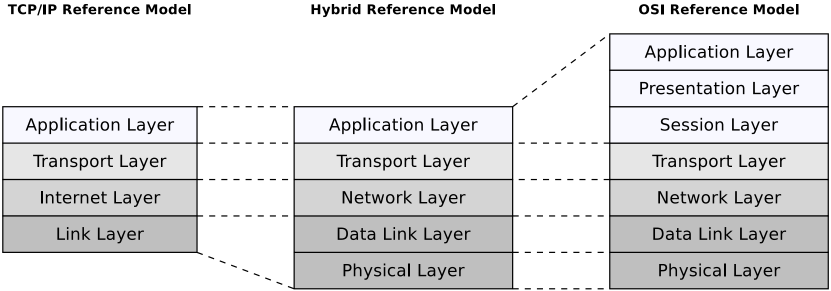
Physical Layer: Transmission Media

You have seen . . .

- which categories of transmission media exist
- common types of guided transmission media (coaxial, twisted pair, and fiber optic)

Any other questions left?

Exercise 1.1 and 1.2: Layers of Reference Model



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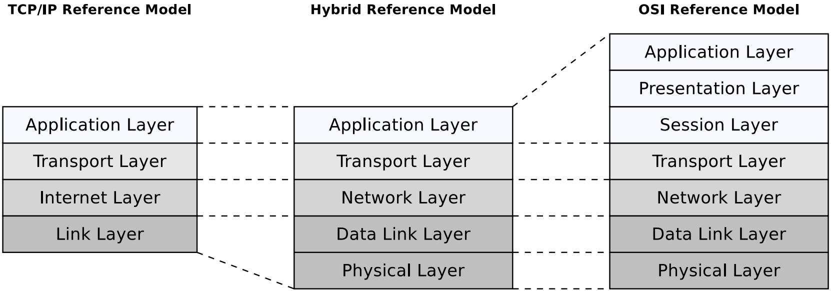

Signals $\Longrightarrow$ Physical Layer
Frames $\Longrightarrow$ Data Link Layer
Packets $\Longrightarrow$ Network Layer
Segments $\Longrightarrow$ Transport Layer

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- Why are the Presentation Layer and the Session Layer not intensively used?
  The functionalities, which are intended for the Session Layer and Presentation Layer, are often part of protocols in the Transport or Application Layer.
- Why is the hybrid reference model closer to reality, compared with the TCP/IP reference model?
  The hybrid reference model illustrates the functioning of computer networks in a realistic way because it distinguishes between the Physical Layer and Data Link Layer and it does not subdivide the Application Layer. It combines the advantages of the TCP/IP reference model and the OSI reference model, without taking over their drawbacks.

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Hartley's law (1924) [1]

maximum data rate[bit/s] $= 2 * H * log_2(V)$

- V: number of different symbol values
- H: the channel bandwidth in *Hertz (Hz)*

→ Not realistic - there is no completely noiseless channel.

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- Why can a symbol not carry an arbitrary amount of bits?
  Because of the noise $\rightarrow$ upper bound given by the *Shannon-Hartley theorem*.

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  Broadband transmission is more robust against noise.

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  $S/N = \frac{P_{signal}}{P_{noise}} = 1830$

  $\Leftrightarrow P_{signal} = 1830 * P_{noise}$

  $\Rightarrow P_{signal} = 1830 * 0.1\ kW = \mathbf{183\ kW}$

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3. Explain the way Non-Return-To-Zero (NRZ) works.
   It represents logical 0s and 1s by using different voltage levels.

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   Clock Recovery when using NRZ. Even if the processes for encoding and decoding run on different computers, they need to be controlled by the same clock. In each clock cycle, the sender transmits a bit and the receiver receives a bit. If the clocks of sender and receiver drift apart, the receiver may lose count during a long sequence of logic 0 bits or 1 bits.

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6. Explain how the problems from subtask 5 can be avoided.

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6 Explain how the problems from subtask 5 can be avoided.
In order to prevent Baseline Wander, when using a line code with 2 physical signal levels, the usage of both signal levels must be equally distributed. One way to avoid the clock recovery problem is by using a separate line, which transmits just the clock. In computer networks, a separate signal line just for the clock is not practical because of the cabling effort. Instead, it is recommended to increase the number of guaranteed signal level changes to enable the clock recovery from the data stream.

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    Lack of efficiency.

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    A scrambler is a device, which modifies a data stream according to a simple algorithm in a way that it is easy to reverse.
15. Why are scramblers used?
    When the AMI line code is used, clock recovery is impossible for the receiver, when series of logical 0 bits are transmitted. In AMI case, scramblers are used, to interrupt long series of logic 0 bits. This makes the clock recovery for the receiver possible.

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Variants with positive or negative inequality alternate to prevent Baseline Wander.

Exercise 5: Line Codes

16 All line codes have drawbacks. What can be done to avoid the problems, that can result from these drawbacks?
Modern network technologies encode the bit stream first with a line code that works efficient on the one hand, but also ensures clock recovery and avoids baseline wander. These encodings improve the bit stream in a way, that a further encoding with the line codes NRZ, NRZI and MLT-3 does not result in any problems. An example of a line code, which improve the bit stream first, is 4B5B. This line code encode fixed-size input blocks into fixed-size output blocks.

17 Which line code maps groups of **4** payload bits onto groups of **5** code bits?
4B5B

18 Which line code maps groups of **5** payload bits onto groups of **6** code bits?
5B6B

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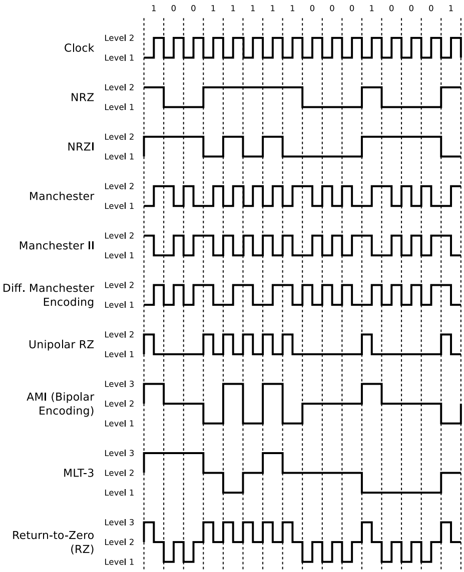
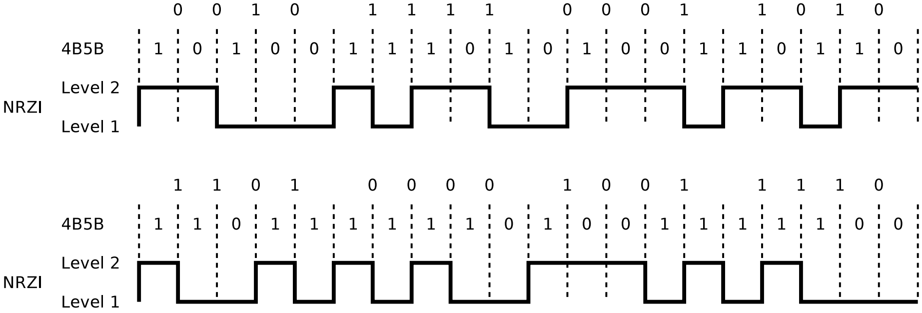
20 How is the efficiency of a line code calculated? Efficiency = ratio of bit rate (payload in bits per time) and baud rate (signal changes per second).

Exercise 6.1: Encoding Data with Line Codes



Exercise 6.2: Encoding Data with Line Codes

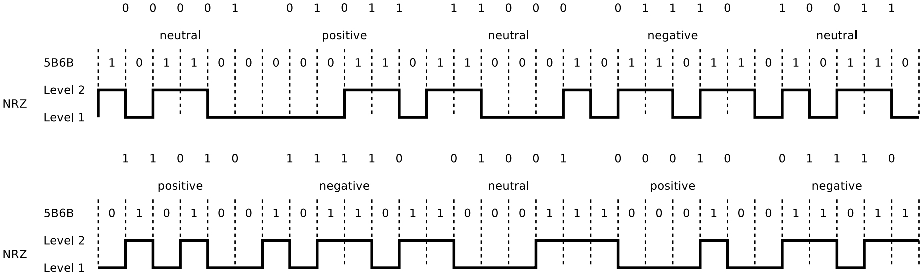
2. Encode the bit sequences with 4B5B and NRZI and draw the signal curve.
   - 0010 1111 0001 1010
   - 1101 0000 1001 1110



Exercise 6.3: Encoding Data with Line Codes

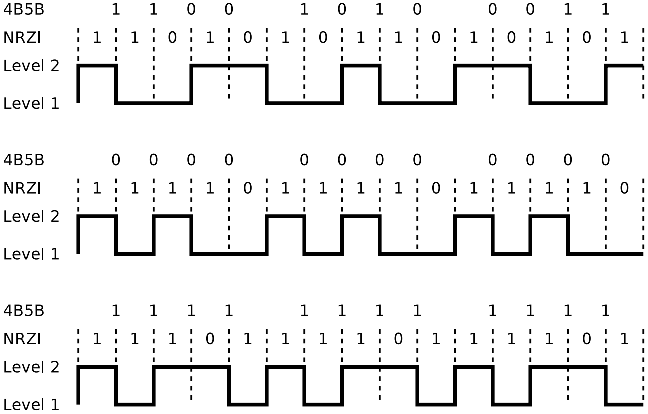
3 Encode the bit sequences with 5B6B and NRZ and draw the signal curve.

- 00001 01011 11000 01110 10011
- 11010 11110 01001 00010 01110



Exercise 6.4: Encoding Data with Line Codes

4 These signal curves are encoded with NRZI and 4B5B. Decode the data.



Exercise 7.1 and 7.2: Do some research

7.1 In the late 1980s modems typically achieved a data rate of 9.6 kbit/s (2400 baud). Which modulation scheme was used and how many bits could be employed per symbol?

7.2 Find out which (historical) data storage used Differential Manchester Encoding.

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Early floppy disks.

Exercise 7.3 and 7.4: Do some research

7.3 An Internet access over ISDN (Integrated Services Digital Network) offers a data rate of 64 kbit/s (single B channel). Why did it still provide a much more significant advantage over, for instance, 56k modem connections?

7.4 The (in)famous *hacker* John Thomas Draper is widely known as **Captain Crunch**. Explain the origin of this nickname and how it related to the principles of the physical layer.

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Cap'n Crunch was a cereal product. For a marketing campaign, they were packaged with a toy whistle that emitted a tone at 2600 Hz which was used in AT&T networks as a control sound.

https://www.youtube.com/watch?v=ugTKmveF2G4