

## 5. Link Layer Theory

### Exercise 1 . Distributed Systems Basics

Consider the following distributed systems: (i) the Amazon store, (ii) Wikipedia, and (iii) Carsharing Südtirol - Alto Adige.

Compare these distributed systems according to their fulfilment of the distributed systems requirements (a) resource sharing, (b) transparency, (c) openness and (d) scalability.

### Exercise 2 . Framing

The following character encoding is used in a data link protocol: A: 01000111; B: 11100011; FLAG: 01111110; ESC: 11100000.

Show the byte sequence transmitted for the frames A B FLAG ESC and FLAG ESC B ESC ESC A, when each of the following framing methods are used:

1. Character count
2. Flag bytes with byte stuffing

Bonus: Why could it be important to end each frame with a flag byte and start the next one with a second flag byte, instead of just using one flag byte?

### Exercise 3 . Error Codes and Hamming Distance

A link layer protocol divides a bit stream into chunks of four bits, each of which is then sent twice. For instance, 0000 1111 becomes 0000 0000 1111 1111.

1. How many errors can this protocol detect and how many can it correct?
2. If additionally we add one parity bit for the whole message, how many errors can the protocol detect and how many correct?
3. What if we add a parity bit only for the four bits of the original message?

#### **Exercise 4 . Hamming Code**

The following message consists of four ASCII characters, encoded with the Hamming code presented in the lecture. Encode it. Where did errors occur?

```
0100110 1000101
0100110 0101111
0100110 1100011
1101101 0000000
```

#### **Exercise 5 . Round-trip Times and Sliding Window Protocol**

Consider connections between Bozen and New York using (a) a satellite network with satellites in 40000 km altitude (signal transmission at the speed of light), and (b) a fiber cable (signal transmission at 2/3rd of light speed).

1. What is the best-case round-trip time (RTT) for the reply to a message using each connection?
2. What is the best-case bandwidth of a sliding window protocol that sends frames containing 100 Bytes of data, and uses a window size of 10 frames?