# Sample Solution for Exercise Communication Networks I

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| **Published at:** | 24.04.2015 |
| **Tutorial date:** | 30.04.2015 |

## General Remarks

Welcome to the exercise for Communication Networks I. Please adhere to the following general remarks regarding the organization of the exercise during this summer term.

- One week before the tutorial, a new exercise will be published at the Exercise area of the KN1 Moodle (`https://moodle.tu-darmstadt.de/course/view.php?id=5268`)
- The exercise serves as your hands-on experience in addition to the lecture and as a preparation for the exam
- The questions in the exercise can be discussed at the tutorial date
- The sample solution for the exercise is available at the Exercise area of KN1 Moodle in addition to the corresponding tutorial. Nevertheless, we encourage students to try to solve the exercise themselves before the tutorial date without looking into the solution as a good practice to understand the subject of the lecture

## Problem 1 - Multiple Choice

### a) Why does the Data Link Layer append a trailer to frames?

A) This is due to the router configuration.
B) The Data Link Layer runs always in reverse mode.
C) Defined by IP.
D) The Data Link Layer only appends a header, but never a trailer.
E) This way the checksum for error correction can be done “on the fly”.

**Solution:** Answer E

### b) Which layer does IP belong to?

A) Physical Layer
B) Data Link Layer
C) Network Layer
D) Transport Layer
E) Application Layer

**Solution:** Answer C

### c) Which is not a layer in the ISO-OSI model?

A) Security Layer
B) Physical Layer
C) Data Link Layer
D) Network Layer
E) Transport Layer

**Solution:** Answer A

### d) Which of the following statements is true?

I) In a well designed system, the higher layer does not have to worry about the implementation details of lower layers
II) A layer offers a service to the next higher layer
III) Two entities of the same layer handle a protocol

Select the correct option:

A) Only I
B) I and II
C) I, II and III
D) Only II
E) II and III

**Solution:** Answer C

### e) Which of these encoding mechanisms are not “self-clocking”?

I) Manchester encoding
II) Differential Manchester encoding
III) Binary encoding
IV) Nonreturn to zero

V) Return to zero

Select the correct option:

A) I, II and III
B) I, II and V
C) II, IV and V
D) III and IV
E) IV and V

**Solution:** Answer D

### f) What is the technique of merging inputs of many links onto one link called?

A) Digitalizing
B) Multiplexing
C) Transmitting
D) Tunneling
E) Routing

**Solution:** Answer B

## Problem 2 - Terminology

a) Explain the terms service and protocol in the context of the layer model.

**Solution:** The instance of a layer provides a service which is used from the layer above. Two instances of the same layer handle a protocol.

b) Explain the terms connection-oriented service and connectionless service with examples.

**Solution:** A connection oriented service consists of three phases:

1) connect
2) data transfer
3) disconnect

Example: Telephone
A connectionless service, each message carries the full destination address and is routed through the system independently.
Example: Postal system

c) Consider the following illustration of a packet. What do you notice?

| H4 | H3 | H5 | Data |
|---|---|---|---|

**H: Header-Data**

**Solution:**

It is unusual that the header data of a layer is stored behind the header data of the layer above. However, it is possible that protocol data is attached at the end of the data packet (Calculation "on the fly")

d) The president of a company designing cellular phones wants to start a joint venture with a company designing microchips. He tells his legal department to look into it who in turn asks engineering for help. As a result, the chief engineer calls his counterpart of the other company to discuss the technical details of the project. The engineers then report back to the legal department, which then confer by telephone to arrange the legal aspects. Finally, the two presidents discuss the finances of the deal. Is this an example of a multilayer protocol in the sense of the OSI model?

**Solution:** No, in the ISO model, physical communication only takes place in the lowest layer, not in every layer.

e) A system has a n-layer protocol hierachy. Applications generate messages of length M bytes. What fraction of the network bandwidth is filled with headers, if at each of the layers a h-byte header is added?

**Solution:** The total number of header bytes per message is $hn$, therefore, the fraction is $hn/(hn+M)$

f) What is the Interplanetary Internet Special Interest Group?

**Solution:** The objective of the Interplanetary Internet project is to define the architecture and protocols necessary to permit interoperation of the Internet resident on Earth with other remotely located internets resident on other planets or spacecraft in transit.

## Problem 3 - Layer Model

### a) Describe the Layers of the ISO-OSI Model and their function.

**Solution:**

| Layer | Function |
|---|---|
| 1<br>Physical | sending bit 1 is also received as bit 1<br>(and not as bit 0): |
| 2<br>Data Link | reliable data transfer between adjacent stations with frames |
| 3<br>Network | connection endsystem to endsystem |
| 4<br>Transport | connection end/source (application/process) to end/destination (application/process) |
| 5<br>Session | support a “session” over a longer period |
| 6<br>Presentation | data presentation independent from the end system |
| 7<br>Application | application related services |

### b) What are the differences of the ISO-OSI Model to the TCP/IP Model?

**Solution:** ISO - OSI:

- “A first step towards international standardization of protocols”
- devised before protocols were invented

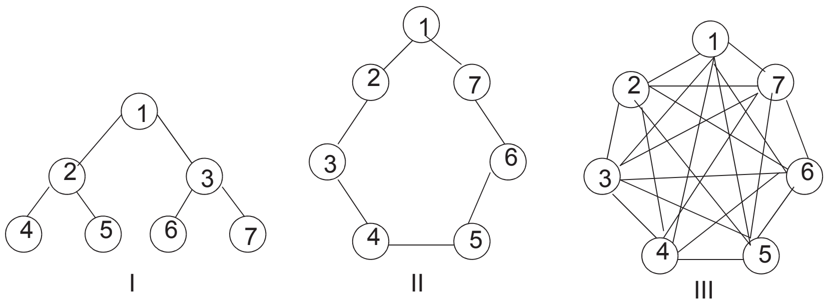
TCP/IP:

- developed with the ARPANET, connect multiple networks
- main idea: robust network (connectionless internetwork layer)

(→ Tanenbaum)

### Problem 4 - Topology

In topology I), 7 routers are interconnected by a binary tree. In topology II) they are interconnected in a ring, and in topology III) there is link between any two routers.




**a)** A message is sent via the shortest path. For each topology, what is the average number of hops, assuming that all router pairs are equally likely? The router-host and router-router links are counted as one hop each.

**Solution:**

| I/II/III | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| 1 | 1/1/1 | 1/2/1 | 2/3/1 | 2/3/1 | 2/2/1 | 2/1/1 |
| 2 | | 2/1/1 | 1/2/1 | 1/3/1 | 3/3/1 | 3/2/1 |
| 3 | | | 3/1/1 | 3/2/1 | 1/3/1 | 1/3/1 |
| 4 | | | | 2/1/1 | 4/2/1 | 4/3/1 |
| 5 | | | | | 4/1/1 | 4/2/1 |
| 6 | | | | | | 2/1/1 |

Total number router pairs: $6+5+4+3+2+1=21$

I) cumulated # hops: 48 $\rightarrow$ $n_I = 48/21 = 2,3$

II) cumulated # hops: 42 $\rightarrow$ $n_{II} = 42/21 = 2$

III) 1

**b)** The probability for a router being down is p. What is the probability that the path from router 4 to router 7 exists, assuming that neither 4 nor 7 are down.

**Solution:** Probabiliy for a router being up: $(1-p)$

I) $P_I = (1-p)^3$

II) $P_{II} = 1-(1-(1-p)^2)(1-(1-p)^3)$

III) 1

**c)** Discuss the advantages and disadvantages of each topology.

**Solution:** Topology I) is very cheap to build. However, due to lack of redundancy, the failure of a router can cause problems.

Topology III) is the most expensive and highly redundant. Two routers can still communicate even if all others are down.

Topology II) is somewhere in between. Some redundancy; not cost optimal.

**Problem 5 - Physical Layer**

a) Transmission of data can be amazing high by using magnetic tapes. However, why is this way of data transmission unsuitable for a lot of applications?

**Solution:** The delay of the end-to-end transmission is too high.
(transmission rate vs. latency)

b) For data transmission a three-tier signal is used to transmit the values 0, 1, and 2. Per second 2000 signal alternations can be realized.

I) How high is the bit rate?
II) How high is the baud rate?

**Solution:**

I) bit rate:
number of bits per time interval: $ld$(number of signal tiers)
$2000 \times ld(3) \approx 2000 \times 1.5849625 \approx 3170$ bps

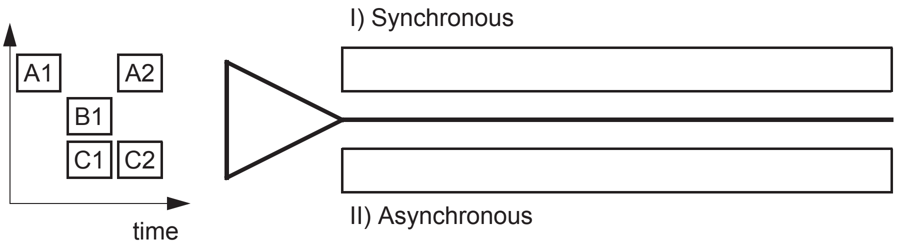
II) baud rate:
2000 (is given: "Per second 2000 signal alternations $\cdots$")

c) We want to implement data transmission with 1 kbit/s between two systems using Differential Manchester Encoding. What baud rate do we need?

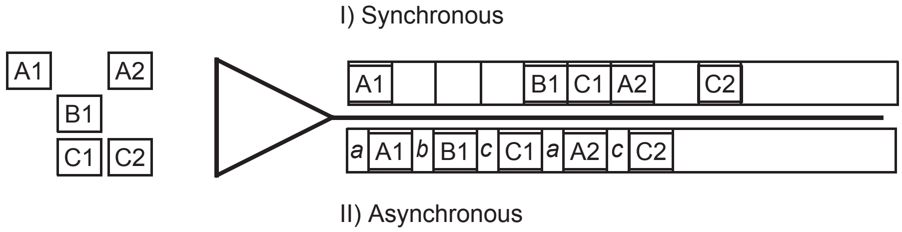
**Solution:** 2000
With Differential Manchester Encoding we can transmit only $0,5$ bit per baud, so for 1000 bit/s we need 2000 baud (= 2000 signals per second).

d) In the following figure, the differences between synchronous and asynchronous time multiplexing have to be shown. Therefore, all the required information have to be depicted. If necessary, a legend should be given. Three stations A, B and C want to send some data in the order you see at the left. Please draw in the figure what will be on the line using $\cdots$

I) synchronous time multiplexing.
II) asynchronous time multiplexing.




**Solution:**




legend:
a: Header A
b: Header B
c: Header C

e) Why was the packet transmission technique not chosen for traditional telephone service?

**Solution:**

- same data characteristic for all connections
- constant data rate
- accounting

## Problem 6 - Data link layer

a) Which are the services of the data link layer?

**Solution:** reliable, efficient data transfer between adjacent stations

b) Which are the functions of the data link layer?

**Solution:**

- data transmission as frames
- error control and correction
- flow control of the frames
- configuration management

c) A data link layer protocol defines 01111110 as a block delimiter and uses the bit-stuffing procedure. How is the following bit stream modified and handed over to the physical layer?

00110111110000111111011111111110

**Solution:** **01111110** 0011011111**0**000011111**0**1011111**0**11111**0**10 **01111110**

d) A character oriented data link layer protocol uses the character string "**ex**" to indicate the beginning of a frame and "**er**" to indicate the end of a frame. "**e**" is the DLE. How is the following character stream modified and handed over to the physical layer?

Fritz Brause is an extremely great singer

**Solution:** **ex**Fritz Braus**e**e is an **e**extr**e**em**e**ely gr**e**eat sing**e**er**er**

Bit stuffing and byte stuffing realize lightly different principles: by bit stuffing the occurrence of the delimiter pattern is avoided by inserting zeros into the data stream; by byte stuffing the inserted DLE (e in our case) denotes that the next DLE is not a control field.

e) The following code is given:

A) 000000
B) 000111
C) 111000
D) 111111

I) What is the hamming distance of this code?
II) Which errors can be detected?
III) Which errors can be corrected?

**Solution:**

- hamming distance: 3
- error detection of 2-bit-errors
- error correction of 1-bit-errors

IV) Which data has been transmitted by the following stream?
101000 000000 010101 000001 111000 111101

**Solution:** C A (B) A C D

In the $3rd$ block is a 2-bit-error. In general, this code does not support reliable correction of 2-bit errors. However, in this case $B$ is the most probable option, since all other words have higher distances to the received block 010101.

f) The bit stream 0011001111001 is coded by the Cyclic Redundancy Code (CRC) method. The generator polynomial $x^4 + x + 1$ is used. What is the transmitted frame?

In addition to the examples of the polynomial division in the lecture slides (see Chapter **Data Link Layer** Section 3.4) there are numerous examples on the Internet (in case you are not familiar with the polynomial division). You can find example in the link below:

- `http://www.lammertbies.nl/comm/info/crc-calculation.html`

**Solution:** Transmitted Frame: 0011001111001**0100**

The degree of $G(X)$ is 4. So we add 4 0-bits to the end of the source frame. Let's call the result $A(X)$: $A(X) =$ 0011001111001**0000**

Now, we divide $A(X)$ by $G(X)$ using modulo 2 division and determine the remainder:

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | | |
| | 0 | 1 | 1 | 0 | 0 | | | | | | | | | | | |
| | 0 | 0 | 0 | 0 | 0 | | | | | | | | | | | |
| | | 1 | 1 | 0 | 0 | 1 | | | | | | | | | | |
| | | 1 | 0 | 0 | 1 | 1 | | | | | | | | | | |
| | | | 1 | 0 | 1 | 0 | 1 | | | | | | | | | |
| | | | 1 | 0 | 0 | 1 | 1 | | | | | | | | | |
| | | | | 0 | 1 | 1 | 0 | 1 | | | | | | | | |
| | | | | 0 | 0 | 0 | 0 | 0 | | | | | | | | |
| | | | | | 1 | 1 | 0 | 1 | 1 | | | | | | | |
| | | | | | 1 | 0 | 0 | 1 | 1 | | | | | | | |
| | | | | | | 1 | 0 | 0 | 0 | 0 | | | | | | |
| | | | | | | 1 | 0 | 0 | 1 | 1 | | | | | | |
| | | | | | | | 0 | 0 | 1 | 1 | 0 | | | | | |
| | | | | | | | 0 | 0 | 0 | 0 | 0 | | | | | |
| | | | | | | | | 0 | 1 | 1 | 0 | 1 | | | | |
| | | | | | | | | 0 | 0 | 0 | 0 | 0 | | | | |
| | | | | | | | | | 1 | 1 | 0 | 1 | 0 | | | |
| | | | | | | | | | 1 | 0 | 0 | 1 | 1 | | | |
| | | | | | | | | | | 1 | 0 | 0 | 1 | 0 | | |
| | | | | | | | | | | 1 | 0 | 0 | 1 | 1 | | |
| | | | | | | | | | | | 0 | 0 | 0 | 1 | 0 | |
| | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | |
| | | | | | | | | | | | | 0 | 0 | 1 | 0 | 0 |
| | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | 0 | 1 | 0 | 0 |

g) If we use "Cyclic Redundancy Code"(CRC) with generator polynomial $G(X) = x^4 + x^2 + 1$ to add an error correction to the frame 1010110101, what will be transmitted?

**Solution:** 10101101010000
The degree of $G(X)$ is 4. So we add 4 0-bits to the end of the source frame.
Let's call the result $A(X)$: $A(X) = 1010110101\mathbf{0000}$
Now, we divide $A(X)$ by $G(X)$ using modulo 2 division:

```
 10101101010000 / 10101 = 1000010000
-10101|||||||||
======v||||||||
  00001||||||||
 -00000||||||||
 ======v|||||||
   00010|||||||
  -00000|||||||
  ======v||||||
    00101||||||
   -00000||||||
   ======v|||||
     01010|||||
    -00000|||||
    ======v||||
      10101||||
     -10101||||
     ======v|||
       00000|||
      -00000|||
      ======v||
        00000||
       -00000||
       ======v|
         00000|
        -00000|
        ======v
          00000
         -00000
         ======
              0  (<- remainder)
```

In the final step we subtract the remainder (zero) from $A(X)$ using modulo 2 subtraction: $A(X) - 0 = 10101101010000$
So the transmitted frame is 10101101010000.