Sample solution of the written examination in

Computer Networks

May 24th 2019

Last name: _____

First name: _____

Student number: _____

I confirm with my signature that I will process the written examination alone and that I feel healthy and capable to participate this examination.
I am aware, that from the moment, when I receive the written examination, I am a participant of this examination and I will be graded.

Signature: _____

- Use the provided sheets. Own paper must *not* be used.
- You are allowed to use a *self prepared*, *single sided DIN-A4 sheet* in the exam. Only *handwritten originals* are allowed, but no copies.
- You are allowed to use a non-programmable calculator.
- Do *not* use a red pen.
- The time limit ist *90 minutes*.
- Turn off your mobile phones!

Result:

Question:	1	2	3	4	5	6	7	8	9	10	**Σ**	Grade
Maximum points:	9	4	6	12	20	8	8	7	8	8	90	—
Achieved points:												

1.0: 90.0-85.5, **1.3**: 85.0-81.0, **1.7**: 80.5-76.5, **2.0**: 76.0-72.0, **2.3**: 71.5-67.5,
2.7: 67.0-63.0, **3.0**: 62.5-58.5, **3.3**: 58.0-54.0, **3.7**: 53.5-49.5, **4.0**: 49.0-45.0, **5.0**: <45

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Question 1)

Points: .....

Maximum points: 6+1+1+1=9

a) A scientific experiment produces 35 petabytes ($35 * 2^{50}$ Byte) of data per year, which need to be stored. What is the height of a stack of storage media, if for storing the data CDs (capacity: 650 MB = $650 * 10^6$ Byte, thickness: 1.2 mm) are used?

- Calculate the solution for 35 PB = $35 * 2^{50}$ Byte

  Number of CDs: $\frac{35*2^{50}\ \text{Byte}}{650*10^6\ \text{Byte}} \approx 60,625,379.60$

  Height of the CD stack: $60,625,380 * 1.2\ \text{mm} = 72,750,456\ \text{mm} \approx 72.75\ \text{km}$
- Calculate the solution for 35 PB = $35 * 10^{15}$ Byte

  Number of CDs: $\frac{35*10^{15}\ \text{Byte}}{650*10^6\ \text{Byte}} = \frac{35*10^9\ \text{Byte}}{650\ \text{Byte}} \approx 53,846,153.85$

  Height of the CD stack: $53,846,154 * 1.2\ \text{mm} \approx 64,615,384.62\ \text{mm} \approx 64.62\ \text{km}$

b) Do computer networks usually implement parallel or serial data transmission?

Serial data transmission.

c) What describes the physical topology of a computer network?

It describes the wiring.

d) What describes the logical topology of a computer network?

It describes the flow of data between the network devices.

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Question 2)

Points: .....

Maximum points: 4

A scientific experiment produces 30 petabytes ($30 * 2^{50}$ Byte) of data per year. How much time requires the transmission of the data via an Ethernet with a bandwidth of 1 gigabit per second?

Ethernet bandwidth:

$$1 \text{ Gbit/s} = 1,000,000,000 \text{ Bit/s}$$
$$= 125,000,000 \text{ Byte/s}$$

Transfer time:

$$\frac{30*2^{50} \text{ Byte}}{125{,}000{,}000 \text{ Byte/s}} \approx 270,215,977.65 \text{ s}$$

$$\approx 4,503,600 \text{ Minutes}$$
$$\approx 75,060 \text{ Hours}$$
$$\approx 3,127.5 \text{ Days}$$
$$\approx 8.56 \text{ Years}$$

(Each year has 365,25 days!)

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Question 3)

Points: .....

Maximum points: 6

A webcam at the surface of planet Mars sends pictures to Earth. Each image has a size of 30 MB (1 MB = 2^{20} Byte). How quickly, after a picture is taken, can it reach Mission Control on Earth?

(Note: The network connection is a point-to-point link.)

Data rate = 256 kbps (kilobit per second)
Signal propagation speed = 299.792.458 m/s
Waiting time = 0 s
Distance = 55.000.000.000 m

(Note: The distance between Earth and Mars fluctuates between approx. 55,000,000 km and approx. 400,000,000 km. For the further calculations, we use the 55,000,000 km, which is the distance from Earth to Mars, when they are closest together.)

Solution:

File size: 30 MB = 31,457,280 Bytes = 251,658,240 Bits

Data rate: 256,000 Bits/s

Latency = propagation delay + transmission delay + waiting time

Propagation delay = 55,000,000,000 m / 299,792,458 m/s ≈ 183.46 s

Transmission delay = 251,658,240 Bits / 256,000 Bits/s ≈ 983.04 s

Waiting time = 0 s

Latency = 183.46 s + 983.04 s + 0 s ≈ 1,166.5 s = 19 m 27 s

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Question 4)

Points: .....

Maximum points: 12

a) Fill out all enpty fields.

(Please fill in each empty cell only one correct answer!)

ISO/OSI Reference Model

	Layer	Protocol	Device	Sort of Data (data unit)	Addresses
7	Application Layer	SMTP, HTTP, POP3, SSH...		Message	
6	Presentation Layer				
5	Session Layer				
4	Transport Layer	TCP, UDP	(VPN-)Gateway	Segment	Port nummber
3	Network Layer	IP, ICMP	Router, L3-Switch	Packet	IP address
2	Data Link Layer	Ethernet, Wifi, Bluetooth, PPP...	Bridge, L2-Switch, Modem	Frame	MAC address
1	Presentation Layer	Ethernet, Wifi, Bluetooth...	Repeater, Hub	Signal	

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Question 5 – Part 1/2) Points: .....

Maximum points: 4.5+10+2+3.5=20

Figure 1: Network topology

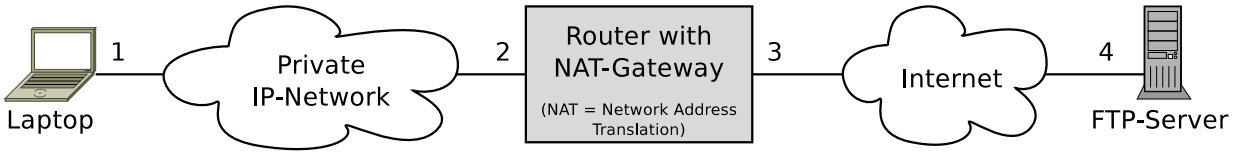

Figure 2: Wireshark output of a received transmission on interface 1

```
⊞ Ethernet II, Src: JuniperN_7a:d6:81 (50:c5:8d:7a:d6:81), Dst: ActionSt_0b:2a:ed (00:24:9b:0b:2a:ed)
⊟ Internet Protocol Version 4, Src: 217.160.233.106, Dst: 192.168.50.17
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  ⊞ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    Total Length: 75
    Identification: 0x1eb4 (7860)
  ⊞ Flags: 0x00
    Fragment offset: 0
    Time to live: 56
    Protocol: TCP (6)
  ⊞ Header checksum: 0xae34 [validation disabled]
    Source: 217.160.233.106
    Destination: 192.168.50.17
⊞ Transmission Control Protocol, Src Port: 21 (21), Dst Port: 4934 (4934), Seq: 24, Ack: 11, Len: 35
⊞ File Transfer Protocol (FTP)
```

Figure 3: Wireshark output of a received transmission on interface 3

```
⊞ Ethernet II, Src: 22:ac:11:45:e3:44 (22:ac:11:45:e3:44), Dst: JuniperN_bb:2e:fa (50:c5:8d:bb:2e:fa)
⊟ Internet Protocol Version 4, Src: 217.160.233.106, Dst: 194.94.80.16
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
  ⊞ Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    Total Length: 75
    Identification: 0x1eb4 (7860)
  ⊞ Flags: 0x00
    Fragment offset: 0
    Time to live: 56
    Protocol: TCP (6)
  ⊞ Header checksum: 0xae34 [validation disabled]
    Source: 217.160.233.106
    Destination: 194.94.80.16
⊞ Transmission Control Protocol, Src Port: 21 (21), Dst Port: 22345 (22345), Seq: 3306717526, Ack: 1149803236, Len: 35
⊞ File Transfer Protocol (FTP)
```

The transmissions in figure 2 and figure 3 correspond with each other because they are used to transport the same FTP data. They transport the reply from the FTP server, which is initiated by a request of the laptop.

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Question 5 – Part 2/2)

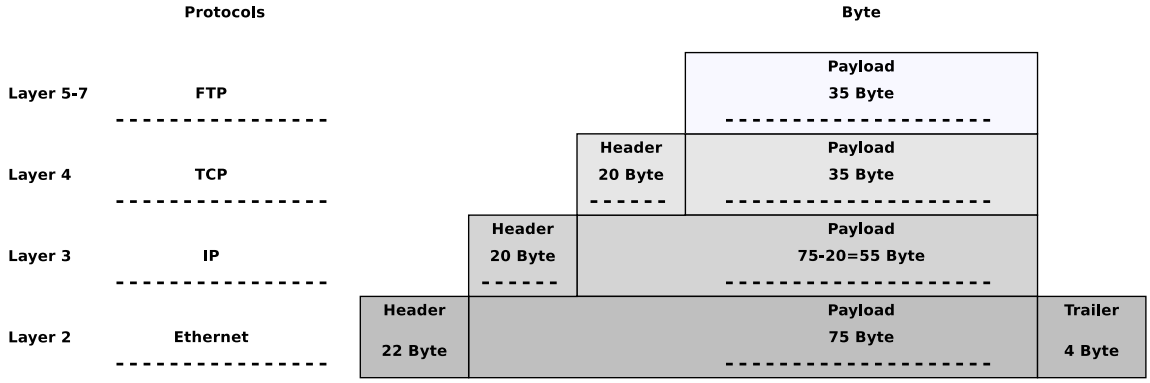
Points: .....

Maximum points: 4.5+10+2+3.5=20

a) Fill out all empty fields of the table.

Interface	1	2	3	4
MAC address	00:24:9b:0b:2a:ed	50:c5:8d:7a:d6:81	50:c5:8d:bb:2e:fa	
IP address	192.168.50.17		194.94.80.16	217.160.233.106
Port number	4934		22345	21

b) Show the protocol stack (starting with OSI layer 2) of the transmission in Figure 3. Fill in the correct number of Bytes of the headers, trailer and payloads. Also name the protocols used. Consider the FTP data as pure payload.



c) What is the amount of overhead in Bytes for the transmission of the FTP data (header and payload)?

$(22 + 4 + 20 + 20)\,\text{Byte} = 66\,\text{Byte}$

d) Calculate the overhead ratio in % (possible OSI layer 1 overhead is ignored).

Size of the transmission $= (75 + 22 + 4)\,\text{Byte} = 101\,\text{Byte}$

Overhead (headers and trailer) $= 66\,\text{Byte}$

$$\text{Overhead ratio} = \frac{66\,\text{Byte}}{101\,\text{Byte}} = 0.6534 * 100\% = 65.35\%$$

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Question 6)

Points: .....

Maximum points: 2+2+2+2=8

a) Simplify this IPv6 address:
`2001:0db8:0000:0001:0000:0000:0010:01ff`

Solution: `2001:db8:0:1::10:1ff`

b) Simplify this IPv6 address:
`2001:0db8:0000:000b:0000:0000:0000:001a`

Solution: `2001:db8:0:b::1a`

c) Provide all positions of this simplified IPv6 address:
`2001:db8:0:200::7`

Solution: `2001:0db8:0000:0200:0000:0000:0000:0007`

d) Provide all positions of this simplified IPv6 address:
`2001:14e0:50::10:0:1`

Solution: `2001:14e0:0050:0000:0000:0010:0000:0001`

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Question 7)

Points: .....

Maximum points: 3+5=8

a) Error Correction via simplified Hamming Distance (Hamming ECC method). Calculate the message, that will be transmitted (payload inclusive parity bits).

```
Payload: 10011010

              Position:  1  2  3  4  5  6  7  8  9 10 11 12
Data to be transmitted:  ?  ?  1  ?  0  0  1  ?  1  0  1  0

        0011 Position 3
        0111 Position 7
        1001 Position 9
    XOR 1011 Position 11
    --------------------
        0110 = parity bit values

              Position:  1  2  3  4  5  6  7  8  9 10 11 12
Data to be transmitted:  0  1  1  1  0  0  1  0  1  0  1  0
```

b) Error Correction via simplified Hamming Distance (Hamming ECC method). Verify, if the received message was transmitted correctly.

```
Received message: 0001101100101101

     Position: 1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16
Received data: 0  0  0  1  1  0  1  1  0  0  1  0  1  1  0  1

        00101 Position 5
        00111 Position 7
        01011 Position 11
        01101 Position 13
    XOR 01110 Position 14
    --------------------
        01010 Parity bits calculated
    XOR 00111 Parity bits received
    --------------------
        01101 => Bit 13 ist defective!
```

Last name: First name: Student number:

Question 8)

Points: .....

Maximum points: 1+1+1+1+1+1+1=7

a) What is the purpose of Bridges in computer networks?

For connecting different physical networks, Bridges are required because they forward frames from one physical network to another one.

Bridges and Switches check the correctness of the frames via checksums.

b) Why do Bridges try to avoid loops?

Loops can cause malfunctions and reduce the performance of the network or even lead to a network failure.

c) What protocol use Bridges to handle loops?

Spanning Tree Protocol (STP).

d) What is the selection criteria for determining, whether a Bridge becomes the Root Bridge?

First, the Bridges have to determine the Bridge with the lowest Bridge Priority in the Bridge ID. This Bridge is the Root Bridge of the spanning tree to be generated.

e) What is a Designated Bridge and what is its task?

For each physical network, a single one of the directly connected Bridges needs to be selected as responsible for forwarding the frames towards in the direction of the Root Bridge. This Bridge is called Designated Bridge for this network.

f) How many Designated Bridges does a computer network contain?

For each physical network, a single Designated Bridge exists.

g) What is the impact of Bridges and Layer-2-Switches on the collision domain?

If a physical network is subdivided via a Bridge or Switch, also the collision domain is divided and the number of collisions decreases.

Last name: First name: Student number:

Question 9)

Points: .....

Maximum points: 4+4=8

a) Error detection via CRC: Calculate the frame to be transferred.

```
Generator polynomial: 100101
Payload: 10110101
```

The generator polynomial has 6 digits. Therefore, five 0 bits are appended.

```
Frame with appended 0 bits: 1011010100000
```

```
1011010100000
100101|||||||
------vv|||||
  100001|||||
  100101|||||
  ------vv|||
     100000||
     100101||
     ------vv
        10100 (Remainder)
```

```
Frame to be transferred: 1011010110100
```

b) Error detection via CRC: Check, if the received frame was transmitted correctly.

```
Transferred frame: 1010010110100
Generator polynomial: 100101
```

```
1010010110100
100101|||||||
------vv|||||
  110001|||||
  100101|||||
  ------v||||
   101001||||
   100101||||
   ------||||
     110001||
     100101||
     ------||
      101000|
      100101|
      ------|
        11010 => Error
```

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Question 10)

Points: .....

Maximum points: 5+3=8

a) Split the class A network `16.0.0.0` for implementing 513 subnets. Calculate the subnet masks and answer the questions.

`Network ID:` `00010000.00000000.00000000.00000000` `16.0.0.0`

`Number of bits for subnet IDs?` $513 \Longrightarrow 1024 = 2^{10} \Longrightarrow 10$ bits for subnets

`Subnet mask:` `11111111.11111111.11000000.00000000` `255.255.192.0`

`Number of bits for host IDs?` 14

`Number of host IDs per subnet?` $2^{14} = 16384$
Two addresses cannot be assigned to network devices because they are the network address and the broadcast address!

b) The sender transmits an IP packet to a receiver. Calculate the subnet ID of sender and receiver and specify whether the IP packet leaves the subnet during transmission or not.

```
Sender:         10000100.10011000.01010011.11111110    132.152.83.254
Subnet mask:    11111111.11111111.11111100.00000000    255.255.252.0
                ----------------------------------
AND             11000100.10011000.01010000.00000000    20 => Subnetnumber


Receiver:       10000100.10011000.01010001.00000010    132.152.81.2
Subnet mask:    11111111.11111111.11111100.00000000    255.255.252.0
                ----------------------------------
AND             11000100.10011000.01010000.00000000    20 => Subnetnumber
```

`Subnet ID of sender? 20`

`Subnet ID of receiver? 20`

`Does the IP packet leave the subnet [yes/no]? no`