Sample solution of the written examination in

Computer Networks

March 3rd 2021

Last name: _____

First name: _____

Student number: _____

Mit dem Bearbeiten dieser schriftlichen Prüfung (Klausur) bestätigen Sie, dass Sie diese alleine bearbeiten und dass Sie sich gesund und prüfungsfähig fühlen. Mit dem Erhalt der Aufgabenstellung gilt die Klausur als angetreten und wird bewertet.

By attending this written exam, you confirm that you are working on it alone and feel healthy and capable to participate. Once you have received the examination paper, you are considered to have participated in the exam, and it will be graded.

- Use the provided sheets. Do *not* use own paper.
- 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.
- Time limit: *90 minutes*
- Turn off your mobile phones!

Result:

Question:	1	2	3	4	5	6	7	8	9	**Σ**	Grade
Maximum points:	8	6	8	8	7	14	14	11	14	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: 3+3+1+1=8

a) An image has a size of 4096x2160 pixels (Ultra HD 4K) with true color (3 Bytes per pixel are used for the color information). How long does it take to transmit the uncompressed image via a 50 Mbps ($= 50 * 10^6$ Bits per second) DSL connection?

Bytes per image: (1 point)

4096x2160 pixels = 8,847,360 pixels

*8,847,360 pixel * 3 Bytes per pixel = 26,542,080 Bytes per image*

Bits per image: (1 point)

*26,542,080 Bytes * 8 = 212,336,640 Bits per image*

Transfer time: (1 point)

$\frac{212{,}336{,}640 \text{ Bits}}{50{,}000{,}000 \text{ Bits/s}} = 4.2467328 \text{ s}$

b) Name the topology that is used by ...

modern Ethernet standards	*Star*
Thin Ethernet and Thick Ethernet	*Bus*
WLAN without an Access Point	*Mesh*
WLAN with an Access Point	*Cellular*
Powerline Communication (PowerLAN)	*Bus*
mobile phones (GSM standard)	*Cellular*

c) Name one topology...

where a cable failure causes the entire network to fail	*Ring, Bus*
that has no central component (device)	*Bus, Ring, Mesh*

d) Mark the label of Twisted Pair Cables that have no cable and no pair shielding.

☐ *ATP* ☐ *FTP* ☐ *STP* ☒ *UTP* ☐ *XTP* ☐ *ZTP*

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Question 2)

Points: .....

Maximum points: 6

A webcam at the surface of (dwarf) planet Pluto sends pictures to Earth. Each image has a size of 15 MB (1 MB = 2^{20} Byte). Calculate the time needed to transfer a picture to Mission Control on Earth.

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

Data rate = 1 kbps (kilobit per second) = $1 * 10^3$ bit per second
Signal propagation speed = 299,792,458 m/s
Waiting time = 0 s
Distance = 6,000,000,000,000 m = $6 * 10^{12}$ m

(Note: At its most distant, when Earth and Pluto are on the opposite sides of the sun from one another, Pluto lies 7.5 billion kilometers from Earth. At their closest, Pluto and Earth are only 4.28 billion km apart. For the further calculations – just to keep it simple – we use 6 billion km = 6,000,000,000 km.)

Conversion from Bytes to Bits: (1 point)

File size: 15 MB = 15,728,640 Bytes = 125,829,120 Bits

Understand what Latency means: (1 point)

Latency = propagation delay + transmission delay + waiting time

Calculate propagation delay: (1 point)

Propagation delay = 6,000,000,000,000 m / 299,792,458 m/s = 20013.845 s

Calculate transmission delay: (1 point)

Data rate: 1000 Bits/s

Transmission delay = 125,829,120 Bits / 1000 Bits/s = 125829.129 s

Calculate latency: (2 points)

Waiting time = 0 s

Latency = 20013.845 s + 125829.129 s + 0 s
= 145842.974 s = 2430 m 42.974 s
= 40 h 30 m 42.974 s

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Question 3)

Points: .....

Maximum points: 0.5+1+1+1+1+1+2.5=8

a) Data Link Layer protocols specify the format of...

☒ physical network addresses ☐ logical network addresses

b) Give the name (technical term) of Data Link Layer addresses.

MAC addresses (Media Access Control).

c) Name the protocol that is used by Ethernet for the address resolution.

Address Resolution Protocol (ARP).

d) Explain what MAC spoofing is.

MAC addresses can be modified via software. The method is called MAC spoofing.

e) One way to mark the frames' borders is via character count in the frame header. Name a potential issue that can arise from this method.

If the field, which contains the number of bytes payload inside the frame is modified during transmission, the receiver is unable to correctly detect the end of the frame.

f) Why do up-to-date Data Link Layer protocols, such as Ethernet and WLAN, work bit-oriented and not byte-oriented?

Because this allows using any character encoding.

g) Mark the information that an Ethernet frame contains.

☒ Sender and receiver MAC addresses
☐ Hostname of the sender and receiver
☐ Information about the Transport Layer protocol used
☒ Preamble to synchronize the receiver
☐ Port number of the receiver
☒ CRC checksum
☐ Information about the Application Layer protocol used
☐ Mojo level
☒ VLAN tag
☐ Sender and receiver IP addresses
☒ Information about the Network Layer protocol used
☐ Signals, which are transmitted via the transmission medium
☐ Port number of the sender

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Question 4)

Points: .....

Maximum points: 4+4=8

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

```
Generator polynomial: 100101
Payload: 101010
```

The generator polynomial has 6 digits $\Longrightarrow$ five 0 bits are appended

```
Frame with appended 0 bits: 10101000000

10101000000
100101|||||
------vv|||
  111100|||
  100101|||
  ------v||
   110010||
   100101||
   ------v|
    101110|
    100101|
    ------v
      10110 = Remainder

Remainder: 10110
Transferred frame: 10101010110
```

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

```
Transferred frame: 1101001110100
Generator polynomial: 100101

1101001110100
100101|||||||
------v||||||
 100011||||||
 100101||||||
 ------vvv|||
    110110|||
    100101|||
    ------v||
     100111||
     100101||
     ------vv
          1000 => Error
```

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Question 5)

Points: .....

Maximum points: 3+4=7

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

`Payload: 01001100`

Step 1: Determine parity bit positions:

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

Step 2: Calculate parity bit values:

```
        0101 Position 5
        1001 Position 9
    XOR 1010 Position 10
    --------------------
        0110 = parity bit values
```

Step 3: Insert parity bit values into the transmission:

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

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

`Received message: 001101100100`

```
Received data: 1  2  3  4  5  6  7  8  9 10 11 12
               0  0  1  1  0  1  1  0  0  1  0  0

        0011 Position 3
        0110 Position 6
        0111 Position 7
    XOR 1010 Position 10
    --------------------
        1000 Parity bits calculated
    XOR 0010 Parity bits received
    --------------------
        1010 => Bit 10 is defective!
```

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Question 6)

Points: .....

Maximum points: 2+1+1+5+5=14

a) Which devices subdivide (spilt) the collision domain (do not forward collisions)?

☐ Repeater	☒ Layer-3-Switch	☒ Router
☒ Layer-2-Switch	☐ Hub	☒ Bridge

b) Which devices subdivide (spilt) the broadcast domain (do not forward broadcasts)?

☒ Layer-3-Switch	☐ Layer-2-Switch	☐ Repeater
☐ Hub	☐ Bridge	☒ Router

c) Name <u>one</u> private IPv4 address space.

10.0.0.0/8 or *172.16.0.0/12* or *192.168.0.0/16*

d) Split the class B network `135.129.222.0` for implementing 10 subnets. Calculate the subnet masks and answer the questions.

`Network ID:` `10000111.10000001.11011110.00000000` `135.129.222.0`
`Number of bits for subnet IDs?` $10 => 16\ (= 2^4) => 4$ bits
`Subnet mask:` `11111111.11111111.11110000.00000000` `255.255.240.0`
`Number of bits for host IDs?` $16 - 4 = 12$ bits
`Number of host IDs per subnet?` $2^{12} - 2 = 4094$

e) Split the class C network `195.3.128.0` into subnets which contain 60 hosts each. Calculate the subnet masks and answer the questions.

`Network ID:` `11000011.00000011.10000000.00000000` `195.3.128.0`
`Number of bits for host IDs?` $60 => 64\ (= 2^6) => 6$ bits
`Number of bits for subnet IDs?` $8 - 6 = 2$ bits
`Number of possible subnets?` $2^2 = 4$
`Subnet mask:` `11111111.11111111.11111111.11000000` `255.255.255.192`

binary representation	decimal representation	binary representation	decimal representation
10000000	128	11111000	248
11000000	192	11111100	252
11100000	224	11111110	254
11110000	240	11111111	255

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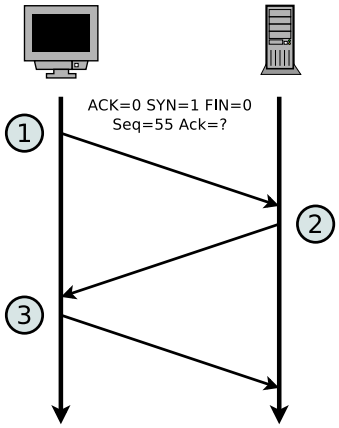
Question 7)

Points: .....

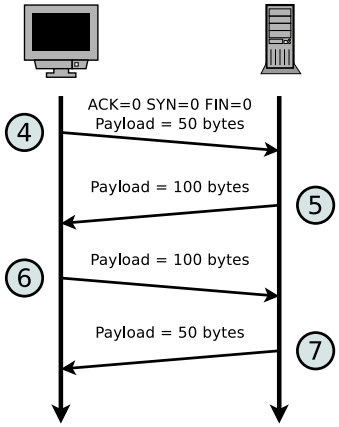
Maximum points: 4+5+5=14

a) The diagram shows the establishment of a TCP connection. Complete the table.



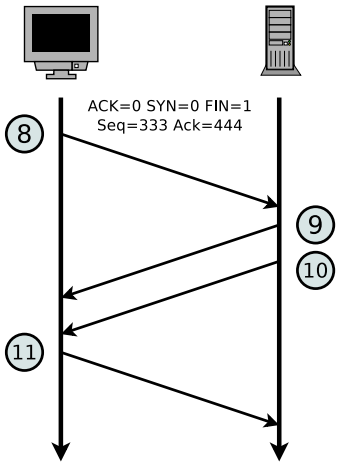
Message	ACK flag	SYN flag	FIN flag	Payload length	Seq number	Ack number
1	*0*	*1*	*0*	*0*	55	*?*
2	*1*	*1*	*0*	*0*	20	*56*
3	*1*	*0*	*0*	*0*	*56*	*21*

b) The diagram shows an excerpt of the transmission phase of a TCP connection. Complete the table.



Message	ACK flag	SYN flag	FIN flag	Payload length	Seq number	Ack number
4	*0*	*0*	*0*	50	100	200
5	*1*	*0*	*0*	100	*200*	*150*
6	*1*	*0*	*0*	*100*	*150*	*300*
7	*1*	*0*	*0*	*50*	*300*	*250*

c) The diagram shows the termination of a TCP connection. Complete the table.



Message	ACK flag	SYN flag	FIN flag	Payload length	Seq number	Ack number
8	*0*	*0*	1	0	333	444
9	*1*	*0*	*0*	*0*	*444*	*334*
10	*0*	*0*	*1*	*0*	*444*	*334*
11	*1*	*0*	*0*	*0*	*334*	*445*

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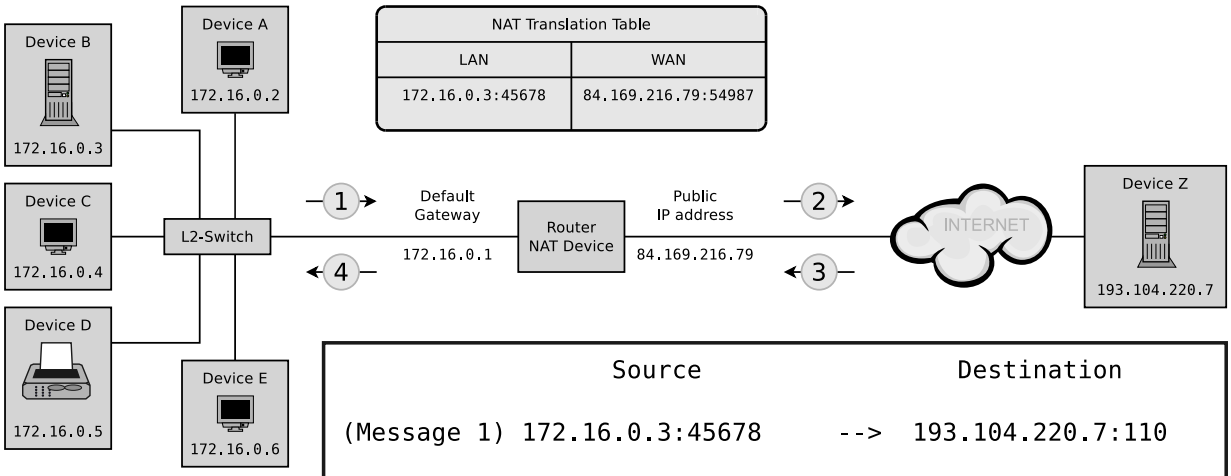
Question 8)

Points: .....

Maximum points: 8+3=11

a) Fill the missing IP addresses and port numbers into the figure that describes a NAT scenario where device B sends a request for an email to an email server process that runs on device Z and can be accessed on device Z via port number 110.



	Source		Destination
(Message 1)	172.16.0.3:45678	-->	193.104.220.7:110
(Message 2)	84.169.216.79:54987	-->	193.104.220.7:110
(Message 3)	193.104.220.7:110	-->	84.169.216.79:54987
(Message 4)	193.104.220.7:110	-->	172.16.0.3:45678

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
                                 ^^^^^^ => 010100 = subnet ID sender

Receiver:      10000100.10011000.01010001.00000010    132.152.81.2
Subnet mask:   11111111.11111111.11111100.00000000    255.255.252.0
                                 ^^^^^^ => 010100 = subnet ID receiver

        Subnet ID of sender? 010100 => 20
        Subnet ID of receiver? 010100 => 20
        Does the IP packet leave the subnet [yes/no]? no
```

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Question 9)

Points: .....

Maximum points: 14

For the network devices, protocols, transmission units, line codes and addressing schemes in the table, mark the corresponding layer of the hybrid reference model.

(1 stands for bottom layer and 5 for top layer in the hybrid reference model. If more than just a single layer are a correct answer, it is sufficient to select at least one correct layer.)

	Hybrid reference model layer				
	1	2	3	4	5
Congestion control				X	
CSMA/CA, CSMA/CD		X			
Distance vector routing protocol			X		
Dynamic Host Configuration Protocol (DHCP)					X
Flow control				X	
Frame		X			
Hub	X				
Hypertext Transfer Protocol (HTTP)					X
ICMP			X		
Internet Protocol (IP)			X		
Link state routing protocol			X		
Logical address			X		
Manchester-Code	X				
Media access control		X			
Network Time Protocol (NTP)					X
Non-Return to Zero (NRZ)	X				
Open Shortest Path First (OSPF)			X		
Packet			X		
Physical address		X			
Port number				X	
Reliable end-to-end (process-to-process) connection				X	
Repeater	X				
Signal	X				
Spanning Tree Protocol (STP)		X			
Transmission Control Protocol (TCP)				X	
Transmission Media	X				
Non-Return to Zero Invert (NRZI)	X				
User Datagram Protocol (UDP)				X	