Sample solution of the written examination in

Computer Networks

June 24th 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 *hand-written 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!

Grade: _____

Questions:	1	2	3	4	5	6	7	8	9	10	**Σ**
Maximum points:	8	10	13	6	7	8	9	9	15	5	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

Question 1)

Points: .....

1 Point (1) Explain the difference between serial data transmission and parallel data transmission.

A single data line exists when serial data transmission is used. The bits are transmitted one after another via the bus.

Separate data lines exist when parallel data transmission is used.

1 Point (2) Name an advantage of serial data transmission compared with parallel data transmission.

Fewer wires are required.

1 Point (3) Name an advantage of parallel data transmission compared with serial data transmission.

Higher throughput.

½ Point (4) Computer networks usually implement...

☐ parallel data transmission ☒ serial data transmission

½ Point (5) Explain your answer of question 4.

Computer networks usually implement serial data transmission because parallel data transmission is cost-intensive for long distances.

2 Points (6) 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: $\frac{35*2^{50}\ \text{Byte}}{650*10^6\ \text{Byte}} \approx 60,625,379.60$

CD stack height: $60,625,380 * 1.2\ \text{mm} = 72,750,456\ \text{mm} \approx 72.75\ \text{km}$

2 Points (7) Calculate the solution of question 6 for 35 PB = $35 * 10^{15}$ Byte

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

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

Question 2)

Points: .....

1 Point (1) Name <u>two</u> systems, that operate according to the simplex principle.

Radio, TV, pager, satellite, GPS, radio clock signal.

1 Point (2) Name <u>two</u> systems, that operate according to the full-duplex principle.

Ethernet via twisted pair cables, telephone.

1 Point (3) Name <u>two</u> systems, that operate according to the half-duplex principle.

Networks with fiber-optic cables or coaxial cables, Wireless networks with just a single channel.

5 Points (4) A file with a size of $15 * 10^7$ bits must be transferred from terminal device A to terminal device B. The signal propagation speed is 200,000 km/s. A and B are directly connected by a link with a length of 20,000 km. The file is transferred as a single message, that has a size of $15 * 10^7$ bits. No network protocol headers or trailers exist.

Calculate the transfer time (latency) of the file, when the data rate of the computer network between both terminal devices is 50 Mbps.

```
File size: 150,000,000 Bits
Data rate:  50,000,000 Bits/s
Propagation delay = 20,000,000 m / 200,000,000 m/s = 0.1 s
Transmission delay = 150,000,000 Bits / 50,000,000 Bits/s = 3 s
Waiting time = 0 s
Latency = propagation delay + transmission delay + waiting time
        = 0.1 s + 3 s = 3.1 s.
```

2 Points (5) Calculate the volume of the network connection. In other words: What is the maximum number of bits that can reside inside the line between the sender and receiver?

Hint: Transmission delay = 0 s, Waiting time = 0 s.

Propagation delay = 0.1 s

```
50,000,000 Bits/s * 0.1 s = 5.000.000 Bits
```

Question 3)

Points: .....

11 Points

(1) Fill out all empty fields.

(Please fill in each empty cell only <u>one</u> correct answer!)

ISO/OSI Reference Model

	Layer	Protocol	Device	Sort of Data (data unit)	Addresses
7	Application Layer	SMTP		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	

1 Point

(2) Explain why computer networks require line codes.

Computers are digital machines. Transmision mediums work analogous. Line codes specify the conversion of binary data ($\Longrightarrow$ binary numbers) into signals (encoding).

1 Point

(3) Many different line codes exist. Explain why it is impossible to use one single line code for every network technology.

Different transmission mediums are used for computer networks. Therefore, different numbers of signal levels are used.

Question 4)

Points: .....

1 Point (1) Explain the way Non-Return-To-Zero (NRZ) works.

It represents logical 0 and 1 is by using different voltage levels.

1 Point (2) Name the two problems that can occur when NRZ is used to encode data.

Baseline Wander and Clock Recovery.

2 Points (3) Explain both problems from subtask 2 in detail.

Baseline Wander = shift of the average when using NRZ. The receiver distinguishes the physical signal levels by using the average of a certain number of received signals. Signals far below the average, interprets the receiver as logical 0 bit. Signals significantly above the average, interprets the receiver as logical 1 bit. When transmitting a long series of logical 0 bits or 1 bits, the average can shift so much, making it difficult to detect a significant change in the physical signal.

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.

2 Points (4) Explain how the problems from subtask 2 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.

Question 5)

Points: .....

1 Point (1) Name <u>two</u> examples of Bridge implementations.

WLAN Bridges and Laser Bridges.

1 Point (2) Explain what a spanning tree is.

It is a subgraph of the graph, which covers all nodes, but it is cycle-free, because edges have been removed.

1 Point (3) Explain what a BPDU message is and for what purpose it is used.

Bridges exchange information about Bridge IDs and path costs via special data frames, called Bridge Protocol Data Unit (BPDU). These messages are used by the Spanning Tree Protocol (STP).

1 Point (4) Explain what a switched network is.

In a switched network, each port of the switches is connected with just a single network device.

1 Point (5) Explain the benefit of a switched network compared to a non-switched network.

Such a network cannot have collisions.

1 Point (6) Explain why it is important that the transmission of a frame is not completed when a collision occurs in an Ethernet network.

Otherwise, the network device might already be finished with the transmission and believes the transmission was successful.

1 Point (7) Explain what is done to ensure that the transmission of a frame is not completed when a collision occurs in an Ethernet network.

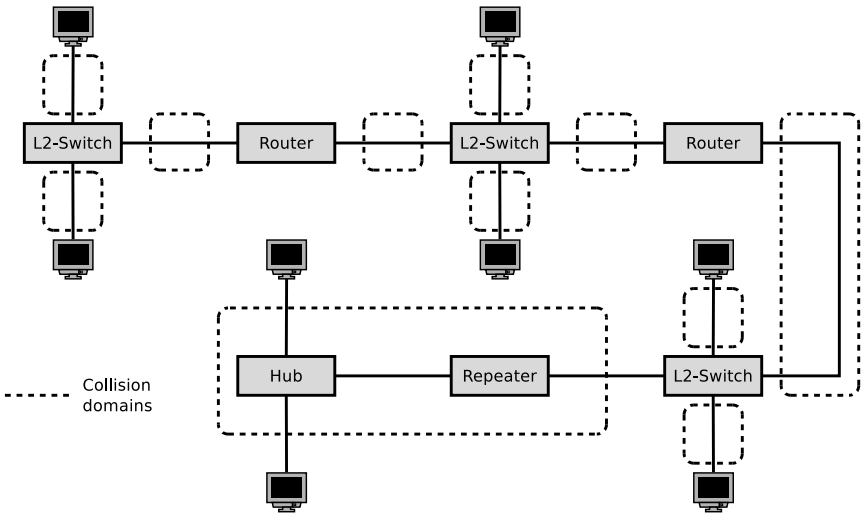
Each frame has a certain minimum length. It is dimensioned in a way, that the transmission duration for a frame of minimum length does not fall below the maximum Round Trip Time. This ensures that a collision reaches the sender before its transmission is finished. If a sender detects a collision, it understands that its frame has not arrived correctly at the receiver, and the sender may try to transmit the frame again later.

Question 6)

Points: .....

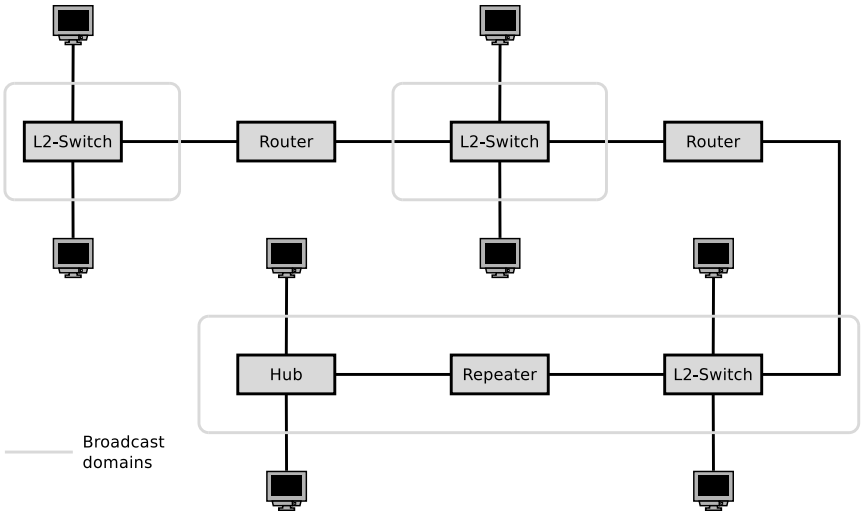
5½ Points

(1) Sketch in the diagram all collision domains.



1½ Points

(2) Sketch in the diagram all broadcast domains.



1 Point

(3) Give the number of logical subnets required for the given network topology.
Three logical subnets are required.

Question 7)

Points: .....

1 Point (1) Name the two special characteristics of the transmission medium in wireless networks that cause undetected collisions at the receiver.

Hidden terminal problem and Fading.

2 Points (2) Describe both special characteristics of subtask 1.

Hidden terminal problem (problem caused by invisible or hidden terminal device). Because of obstacles, not all stations can detect all transmissions, although they interfere each other at the Access Point.

Fading (decreasing signal strength). The electromagnetic waves of the wireless network are weakened by obstacles and in free space. Caused by the positions of stations to each other, their signals are so weak, that the stations cannot detect each others transmissions.

2 Points (3) Explain what the Network Allocation Vector (NAV) is and for what purpose it is used.

The NAV is a counter variable which is maintained by each node itself. It contains the expected time when the transmission medium will be occupied. It reduces the number of collisions when CSMA/CA is used.

2 Points (4) Explain what the Contention Window (CW) is and for what purpose it is used.

If the NAV and another DIFS with an idle transmission medium has expired, a backoff time is created from the CW. The backoff time is calculated by using a random value between the minimum CW and maximum CW and multiplying this random value with the slot time. After the backoff time has expired, the frame is transmitted. The CW prevents that all stations which wait for a free transmission medium, start their transmissions at the same time.

2 Points (5) Name a benefit and a drawback of using the control frames Request To Send (RTS) and Clear To Send (CTS)?

Advantage: It reduces collisions because it solves the problem of hidden terminals.

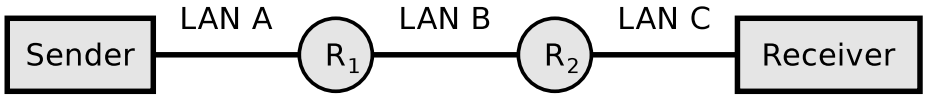
Drawbacks: Delays occur, which are caused by the reservation of the transmission medium. The RTS and CTS frames, which are used to reserve the transmission medium, are overhead.

Question 8)

Points: .....

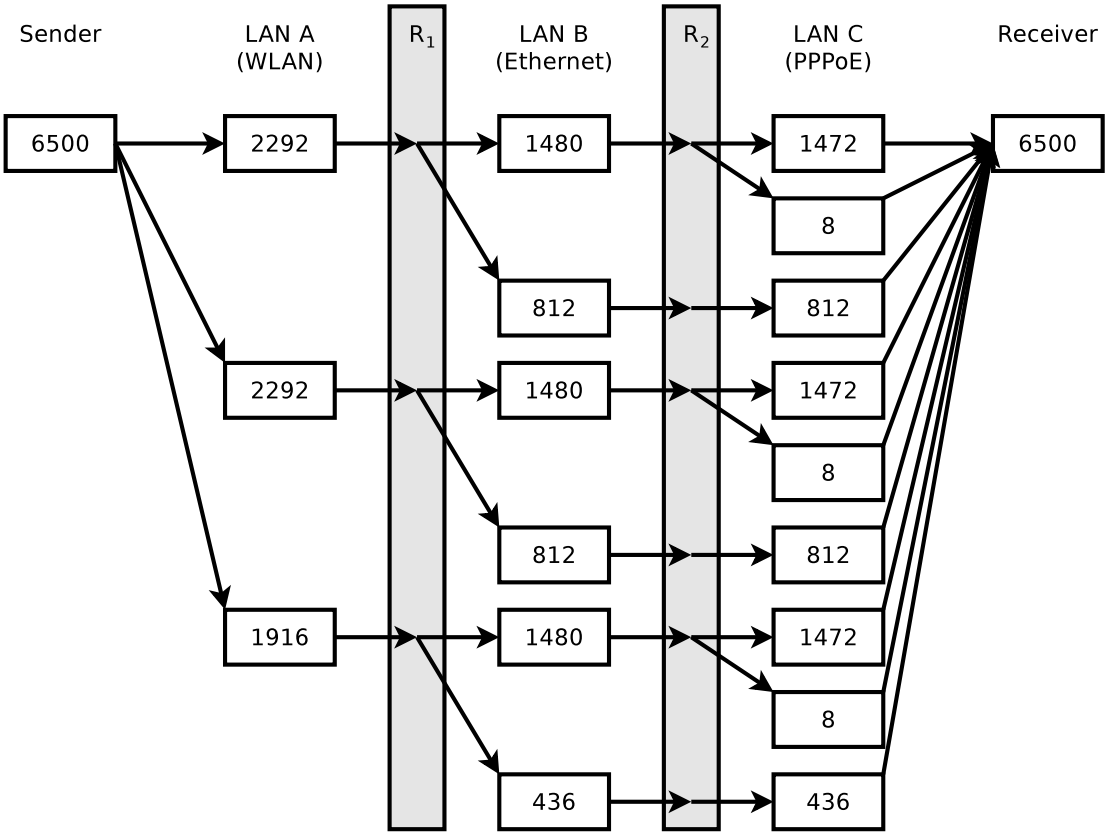
9 Points

(1) 6500 bytes payload need to be transmitted via the IP protocol. The payload must be fragmented, because it is transmitted over multiple physical networks, whose MTU is < 6500 bytes. Display graphically the way, the payload is fragmented, and how many bytes of payload each fragment contains.



	LAN A	LAN B	LAN C
Network technology	WLAN	Ethernet	PPPoE
MTU [bytes]	2312	1500	1492
IP header [bytes]	20	20	20
max. payload [bytes]	2292	1480	1472

Hint: In practice, the fragment offset is counted in 8-byte increments; therefore, the payload in a fragment must be a multiple of 8. However, for the sake of simplicity, you can also create fragments that are not multiples of 8 in this task.



Question 9)

Points: .....

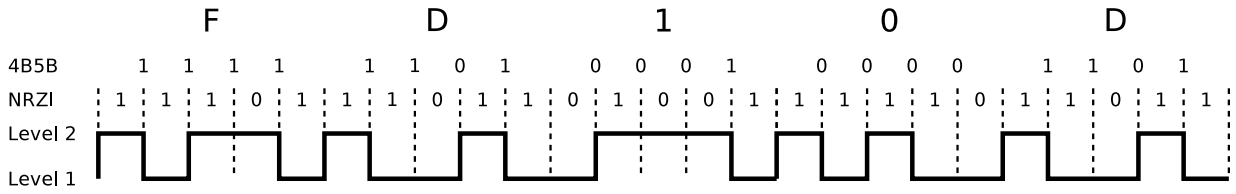
2 Points (1) Simplify this IPv6 address:
`21da:00d3:0000:0000:02aa:00ff:fe28:9c5a`
Solution: `21da:d3::2aa:ff:fe28:9c5a`

2 Points (2) Simplify this IPv6 address:
`2001:0db8:0000:0000:5a6b:0000:0001:678a`
Solution: `2001:db8::5a6b:0:1:678a`

2 Points (3) Provide all positions of this simplified IPv6 address:
`2001:db8:84a2::8a2e:70:4`
Solution: `2001:0db8:84a2:0000:0000:8a2e:0070:0004`

2 Points (4) Provide all positions of this simplified IPv6 address:
`2001:cdba::18:2`
Solution: `2001:cdba:0000:0000:0000:0000:0018:0002`

5 Points (5) This signal curve is encoded with NRZI and 4B5B. Decode the data.



Label	4B	5B	Function
0	0000	11110	0 hexadecimal
1	0001	01001	1 hexadecimal
2	0010	10100	2 hexadecimal
3	0011	10101	3 hexadecimal
4	0100	01010	4 hexadecimal
5	0101	01011	5 hexadecimal
6	0110	01110	6 hexadecimal
7	0111	01111	7 hexadecimal

Label	4B	5B	Function
8	1000	10010	8 hexadecimal
9	1001	10011	9 hexadecimal
A	1010	10110	A hexadecimal
B	1011	10111	B hexadecimal
C	1100	11010	C hexadecimal
D	1101	11011	D hexadecimal
E	1110	11100	E hexadecimal
F	1111	11101	F hexadecimal

1 Point (6) Explain the purpose of the Internet Control Message Protocol (ICMP).
It is used for the exchange of diagnostic and control messages, as well as error messages.

1 Point (7) Give <u>two</u> examples for command line tools, which use ICMP.
ping, tranceroute

Question 10)

Points: .....

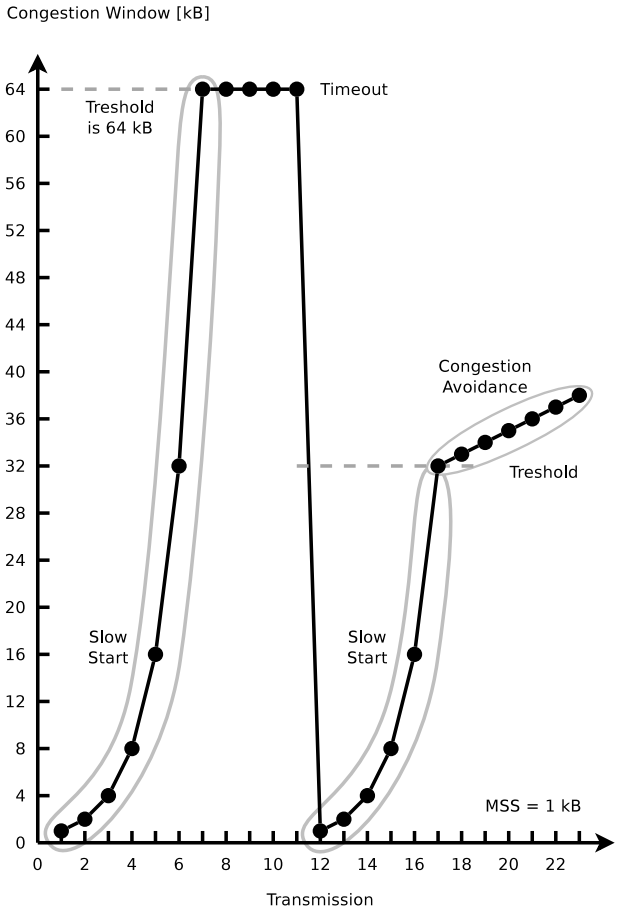
1 Point (1) Describe what the Seq number in an TCP segment specifies.

The sequence number of a segment is the position of the segments first byte in the data stream.

1 Point (2) Describe what the Ack number in an TCP segment specifies.

The sequence number of the next expected indicates.

1 Point (3) Mark in the figure both the slow-start phase and the congestion avoidance phase.



1 Point (4) Describe what fast retransmit is.

After three duplicate ACKs arrived, the lost segment is sent again.

1 Point (5) Describe what fast recovery is.

The slow-start phase after three duplicate ACKs arrived is avoided. If three duplicate ACKs arrive, the congestion window is set directly on the threshold value.