

Sample solution of the written examination in Computer Networks

February 25th 2025

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 | Σ |
| Maximum Points: | 15 | 9 | 8 | 12 | 12 | 8 | 10 | 9 | 7 | 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: of 15

4 Points

- (1) An image has a size of 3200x2400 pixels (Quad UXGA) with true color (3 Bytes per pixel are used for the color information). Calculate how long it takes to transmit the uncompressed image via a 50 Mbps (= $50 \cdot 10^6$ Bits per second) DSL connection.

Bytes per image: (1 point)

$$3200 \times 2400 \text{ pixels} = 7,680,000 \text{ pixels}$$

$$7,680,000 \text{ pixels} \cdot 3 \text{ Bytes per pixel} = 23,040,000 \text{ Bytes per image}$$

Bits per image: (1 point)

$$23,040,000 \text{ Bytes} \cdot 8 = 184,320,000 \text{ Bits per image}$$

Transfer time: (2 points)

$$\frac{184,320,000 \text{ Bits}}{50,000,000 \text{ Bits/s}} = 3.6864 \text{ s} \approx 3.7 \text{ s}$$

11 Points

- (2) Fill out all empty fields.
(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 number |
| 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 | Physical Layer | Ethernet, Wifi, Bluetooth... | Repeater, Hub | Signal | |

Question 2)

Points: of 9

1 Point

- (1) Explain the difference between serial 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.
Several data lines exist, when parallel data transmission is used.

1/2 Point

- (2) Computer networks usually implement. . .
 Serial data transmission *Parallel data transmission*

1/2 Point

- (3) Data Link Layer protocols specify the format of. . .
 physical network addresses *logical network addresses*

1 Point

- (4) Explain what the physical topology of a computer network describes.
It describes the wiring.

1 Point

- (5) Explain what the logical topology of a computer network describes
It describes the flow of data between the network devices.

1/2 Point

- (6) Name the topology that is used by modern Ethernet standards.
Star

1/2 Point

- (7) Name the topology that is used by Thin and Thick Ethernet.
Bus

1/2 Point

- (8) Name the topology that is used by Token Ring (physical).
Star

1/2 Point

- (9) Name the topology that is used by Token Ring (logical).
Ring

1/2 Point

- (10) Name the topology that is used by WLAN without an Access Point.
Mesh

1/2 Point

- (11) Name the topology that is used by WLAN with an Access Point.
Cellular

1/2 Point

- (12) Name one topology that contains a single point of failure.
Bus (the medium!), Ring (the medium!), Star, Cellular

1/2 Point

- (13) Name the topology that is used by mobile phones (GSM standard).
Cellular

1/2 Point

- (14) Name one topology where a cable failure causes the entire network to fail.
Ring, Bus

1/2 Point

- (15) Name one topology that has no central component.
Bus, Ring, Mesh

Question 3)

Points: of 8

4 Points

- (1) Error Detection via CRC: Check, if the received frame was transmitted correctly.

```

Received frame: 1010010110100      Generator polynomial: 100101
1010010110100
100101|||||
-----v|||||
 110001|||||
 100101|||||
-----v|||||
 101001|||||
 100101|||||
-----vv|||
 110001|||
 100101|||
-----v|
 101000|
 100101|
-----v
 11010 => Error
    
```

4 Points

- (2) Transmission errors can be detected via CRC checksums. If it is important to not only recognize errors, but also to be correct them, then the data to be transmitted must be encoded in a way, that error-correction is possible. Error correction can be realized e.g. via the Simplified Hamming Code we discussed in the computer networks course.

Verify, if the following message was transmitted correctly: 0001101100101101

```

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

Question 4)

Points: of 12

5000 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 < 5000 bytes.



| | LAN A | LAN B | LAN C |
|-------------------------------------|-------|-------|----------|
| Network technology | WLAN | PPPoE | Ethernet |
| MTU [bytes] | 2312 | 1492 | 1500 |
| IP header [bytes] | 20 | 24 | 28 |
| maximum payload [bytes] in theory | 2292 | 1468 | 1472 |
| Multiple of 8 [yes/no] | no | no | yes |
| maximum payload [bytes] in practice | 2288 | 1464 | 1472 |

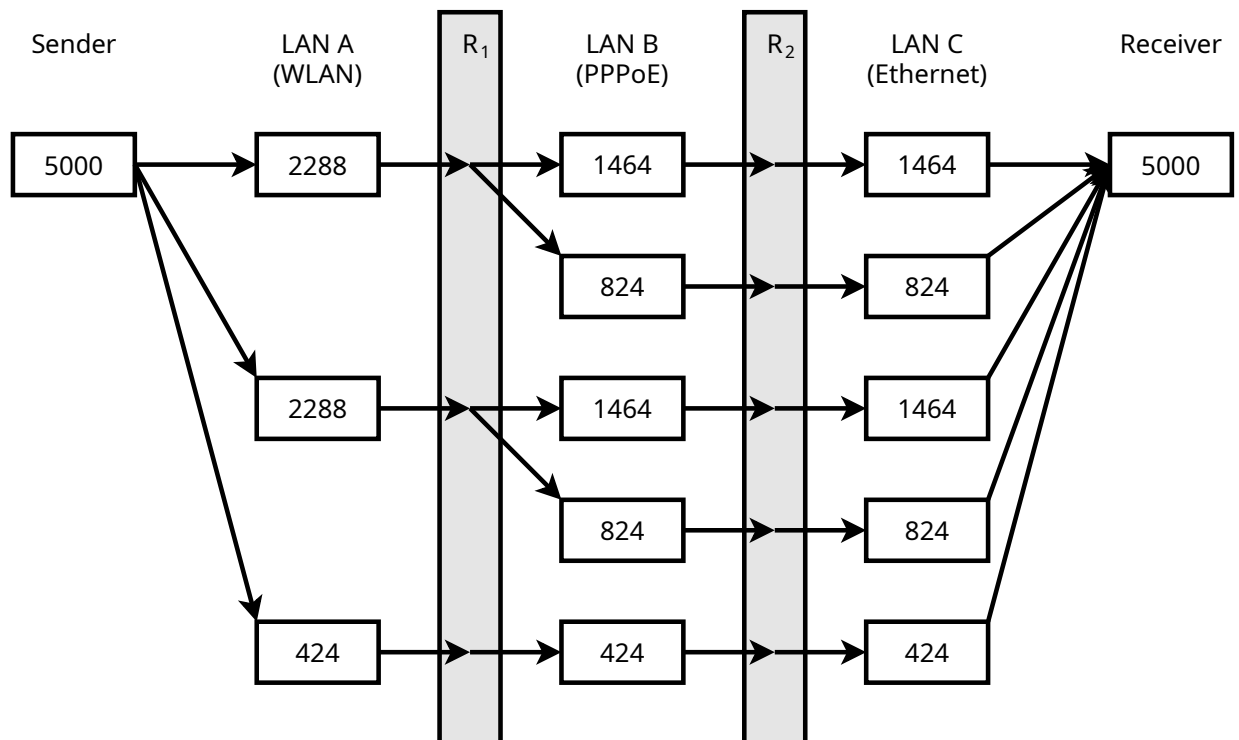
Hint: In practice, the fragment offset is counted in 8-byte increments; therefore, the payload in a fragment must be a multiple of 8.

4½ Points

(1) Calculate the max. payload [bytes] per network and fill the values into the table.

7½ Points

(2) Display graphically the way, the payload is fragmented, and how many bytes of payload each fragment contains.

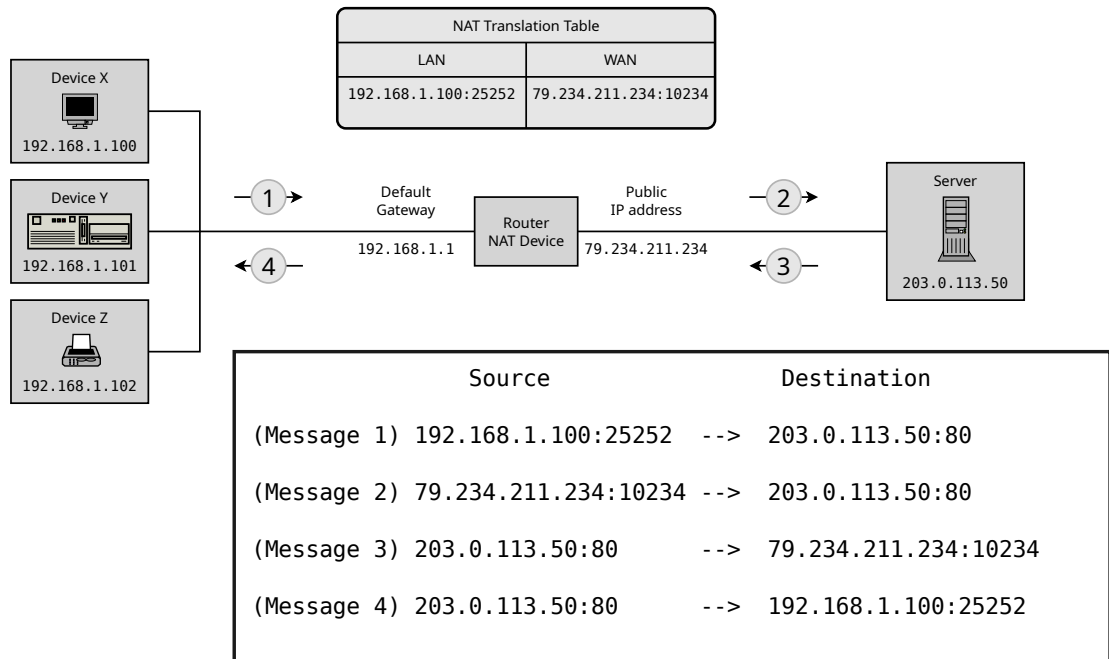


Question 5)

Points: of 12

8 Points

- (1) Fill the missing IP addresses and port numbers into the figure that describes a NAT scenario where device X sends a request for a web page to a web server process that runs on the server and can be accessed via port number 80.



1 Point

- (2) Simplify this IPv6 address:
 2001:0db8:0001:0000:0000:0000:0000:0001
Solution: 2001:db8:1::1

1 Point

- (3) Simplify this IPv6 address:
 fe80:0000:0000:0000:0204:61ff:fe9d:f156
Solution: fe80::204:61ff:fe9d:f156

1 Point

- (4) Provide all positions of this simplified IPv6 address:
 2001:db8::ff00:42:8329
Solution: 2001:0db8:0000:0000:0000:ff00:0042:8329

1 Point

- (5) Provide all positions of this simplified IPv6 address:
 2001:db8::abcd:0:0:1234
Solution: 2001:0db8:0000:0000:abcd:0000:0000:1234

Question 6)

Points: of 8

4 Points

- (1) Split the class B network 189.23.0.0 for implementing 20 subnets. Calculate the subnet mask and fill in the missing numbers.

Network ID: 10111101.00010111.00000000.00000000 189.23.0.0
 Number of bits for subnet IDs: 20 => 32 ($= 2^5$) => 5 bits (1 point)
 Subnet mask: 11111111.11111111.11111000.00000000 255.255.248.0 (1 point)
 Number of bits for host IDs: 11 (1 point)
 Number of host IDs per subnet: $2^{11} - 2 = 2046$ (1 point)

4 Points

- (2) Split the class C network 195.3.128.0 into subnets which contain 60 hosts each. Calculate the subnet masks and fill in the missing numbers.

Network ID: 11000011.00000011.10000000.00000000 195.3.128.0
 Number of bits for host IDs: 60 => 64 ($= 2^6$) => 6 bits (1 point)
 Number of bits for subnet IDs: $8 - 6 = 2$ bits (1 point)
 Number of possible subnets: $2^2 = 4$ (1 point)
 Subnet mask: 11111111.11111111.11111111.11000000 255.255.255.192 (1 point)

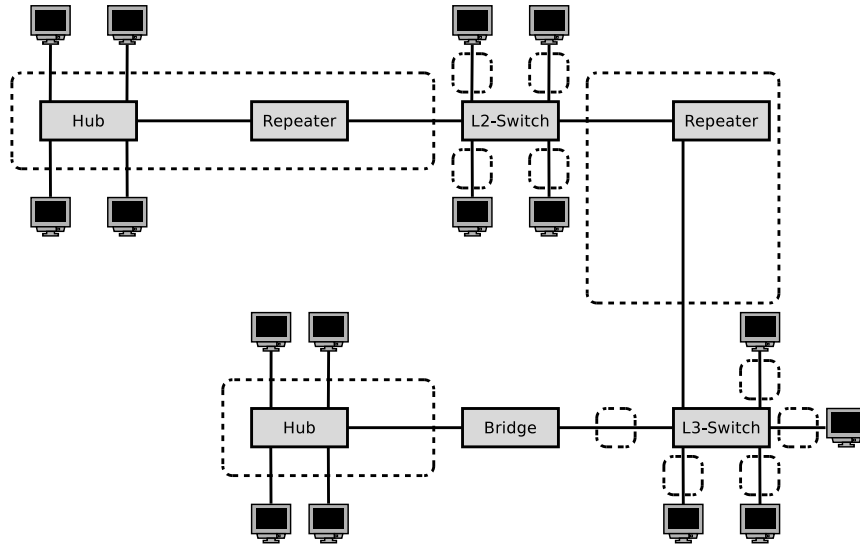
| binary representation | decimal representation |
|-----------------------|------------------------|
| 10000000 | 128 |
| 11000000 | 192 |
| 11100000 | 224 |
| 11110000 | 240 |
| 11111000 | 248 |
| 11111100 | 252 |
| 11111110 | 254 |
| 11111111 | 255 |

Question 7)

Points: of 10

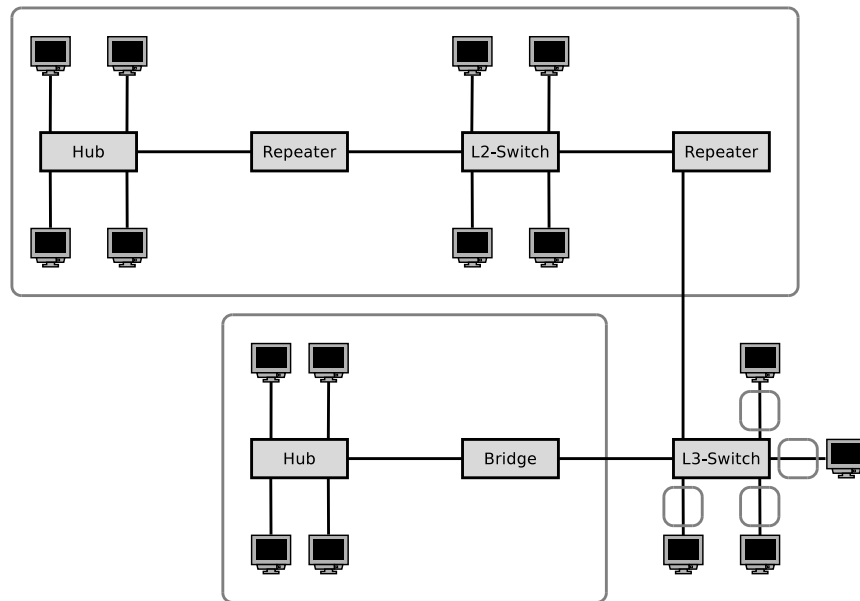
6 Points

(1) Sketch in the diagram all collision domains.



3 Points

(2) Sketch in the diagram all broadcast domains.



1 Point

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

Question 8)

Points: of 9

1 Point

- (1) Mark the label of Twisted Pair Cables that have no cable and no pair shielding.
 ATP FTP STP UTP XTP ZTP

2 Points

- (2) Explain the meaning of the information 24AWG, 26AWG, and 28AWG on cables and explain the effect on the attenuation and installation.

American wire gauge (AWG) is a standardized wire gauge system, which is used mainly in the United States and Canada for the diameters of electrically conducting wires.

24AWG = 0.51054 mm, 26AWG = 0.405 mm, 28AWG = 0.321 mm

Larger wire diameter \implies less electrical resistance for the electronic signals \implies lower attenuation.

24AWG cables have lower attenuation than 26AWG or 28AWG cables.

28AWG cables are thinner than 24AWG or 26AWG.

Thinner cables block airflow in server racks less and simplify the installation.

2 Points

- (3) Explain the meaning of the information SOLID and STRANDED on cables and explain the effect on the installation.

Solid cables use solid copper wires. Such cables are well suited for permanent infrastructure installation. They have a lower attenuation and cost less compared to stranded cables.

Stranded cables consist of multiple strands of wires wrapped around each other. They are typically used to create patch cables because they are very flexible. Attenuation of stranded cables is higher compared to solid cables. Thus, they are used for shorter distances.

4 Points

- (4) A scientific experiment produces 50 PB ($50 * 10^{15}$ Byte) of data per year, which need to be stored. Calculate the height of the stack of storage media, if for storing the data SSDs with 2 TB ($2 * 10^{12}$ Byte) capacity and 0.7 cm thickness are used?

$$\text{Number of SSDs:} \quad \frac{50 * 10^{15} \text{ Byte}}{2 * 10^{12} \text{ Byte}} = \frac{50 * 10^3 \text{ Byte}}{2 \text{ Byte}} = 25,000$$

$$\text{Height of the SSD stack:} \quad 25,000 * 0.7 \text{ cm} = 17500 \text{ cm} = 175 \text{ m}$$

Question 9)

Points: of 7

2 Points

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

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

- (2) 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.

1 Point

- (3) Explain what the function of the Address Resolution Protocol (ARP) is.

The Address Resolution Protocol (ARP) is used to convert IP address of the Network Layer to MAC address of the Data Link Layer.

1 Point

- (4) Explain what the ARP cache is and why it is used in practice.

The ARP cache is a table, which contains IP addresses and MAC addresses, that belong together. It is used to speed up the address resolution.

1 Point

- (5) Explain why loops on Data Link Layer can cause malfunctions in the network.

Computer networks should always provide only a single path to each possible destination on the Data Link Layer. That is to avoid that frames are duplicated and arrive multiple times at the destination. Loops can reduce the performance of the network or even lead to a network failure.