Sample solution of the written examination in

Computer Networks

June 9th 2017

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: _____

- Provide on all sheets (including the cover sheet) your *last name*, *first name* and *student number*.
- Use the provided sheets. Own paper must *not* be used.
- Place your *ID card* and your *student ID card* on your table.
- 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.
- Answers, written with pencil or red pen are *not* accepted.
- Time limit: *90 minutes*
- Turn off your mobile phones!

Result:

Question:	1	2	3	4	5	6	7	8	9	10	11	12	13	**Σ**	Grade
Maximum points:	7	4	6	14	7	5	7	7	8	8	8	5	4	90	—
Achieved points:															

Last name: First name: Student number:

Question 1)

Points: .....

Maximum points: 4+0,5+0,5+1+0,5+0,5=7

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) Name an advantage of serial data transmission compared with parallel data transmission.

Fewer wires are required.

c) Name an advantage of parallel data transmission compared with serial data transmission.

Higher throughput.

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

Serial data transmission.

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

It describes the wiring.

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

It describes the flow of data between the network devices.

Last name: First name: Student number:

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+1+1=14

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	Physical Layer	Ethernet, Wifi, Bluetooth...	Repeater, Hub	Signal	

b) Mark the IP address of the Default Gateway in the output of `route -n`.

```
# route -n
Kernel IP routing table
Destination   Gateway       Genmask         Flags Metric Ref Use Iface
0.0.0.0       192.168.0.1   0.0.0.0         UG    1024   0     0 eth0
192.168.0.0   0.0.0.0       255.255.255.0   U     0      0     0 eth0
```

c) Mark the MAC address of the Default Gateway in the output of `arp -n`.

```
# arp -n
192.168.0.191        ether      00:11:32:1c:03:f3      C        eth0
192.168.0.21         ether      1c:b0:94:c4:a2:74      C        eth0
192.168.0.1          ether      08:96:d7:2a:c6:06      C        eth0
```

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Question 5)

Points: .....

Maximum points: 1+2+2+2=7

a) Why is it impossible to connect different buildings with shielded cables?

Shields must be electrically grounded on both sides of the cable. If only one end of a shielded cable is grounded, an antenna effect occurs, which results in a compensation current.

b) Name a benefit and a drawback of mono-mode (single-mode) fibers compared with multi-mode fibers.

Advantage: Can be used for long distances (up to about 70 km).
Drawback: Only a single propagation mode.

c) Name a benefit and a drawback of multi-mode fibers compared mono-mode (single-mode) fibers.

Advantage: Several thousand propagation modes.
Drawback: Can only be used for short distances (up to about 500 m).

d) The following information come from existing twisted pair network cables. What information is provided about the shielding of these cables?

- `E138922 RU AWM 2835 24 AWG 60°C CSA LL81295 FT2 ETL VERIFIED EIA/TIA-568A CAT.5 UTP EVERNEW G3C511`
  UTP = Unshielded Twisted Pair
- `E188601 (UL) TYPE CM 75°C LL84201 CSA TYPE CMG FT4 CAT.5E PATCH CABLE TO TIA/EIA 568A STP 26AWG STRANDED`
  STP = Shielded Twisted Pair
- `SSTP ENHANCED CAT.5 350MHZ 26AWG X 4P PATCH TYPE CM (UL) C(UL) E200579 CMG CSA LL81924 3P VERIFIED`
  SSTP = Screened Shielded Twisted Pair
- `EC-net 7.5 m 11184406 13/03 PremiumNet 4 PAIR 26AWG S-FTP HF IEC 332-1 ENHANCED CATEGORY 5 PATCH CORD EN0173+ISO/IEC`
  SFTP = Screened Foiled Twisted Pair

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Question 6)

Points: .....

Maximum points: 1+1+1+1+1=5

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

A Repeater retransmits all received signals at a higher level or higher power, so that the signal can cover longer distances.

b) What is the major difference between Repeaters and Hubs?

Hubs are Repeaters with > 2 interfaces.

c) Why do Repeaters and Hubs not require physical or logical addresses?

Repeaters and Hubs have no physical or logical network addresses because they just forward the received signals.

d) What network topologies do Hubs implement?

Physical topology: Star network because of the cabling.
Logical topology: Bus network, because equal to a long cable, were all network devices are connected with, a Hub forwards incoming signals to all other interfaces.

e) What is a collision domain?

The collision domain is a network or a section of a network where multiple network devices use a shared transmission medium. It includes all network devices which compete for accessing a shared transmission medium.

Last name: First name: Student number:

Question 7)

Points: .....

Maximum points: 1+2+2+1+1=7

a) Describe the functioning of the line code Non-Return-To-Zero (NRZ)?

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

b) What two problems can occur, when NRZ is used to encode data?

Baseline Wander and Clock Recovery.

c) How can the problems from subtask b) 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.

d) Why is it important for the receiver of signals, which are encoded according to the Differential Manchester Encoding, to know the initial signal level?

Depending on the initial signal level, two signal sequences, inverse to each other, are possible.

e) Why do some line codes, that map groups of payload bits onto groups of code bits, implement variants with neutral inequality, positive inequality and negative inequality?

Variants with positive or negative inequality alternate to prevent Baseline Wander.

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.

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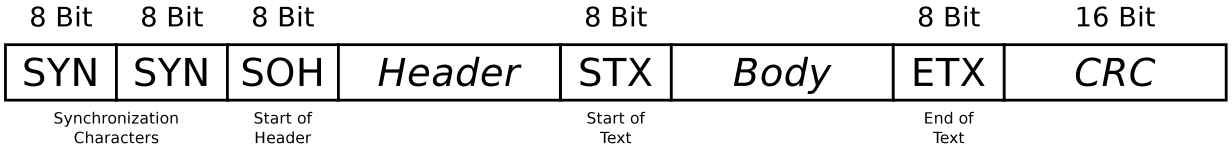
Question 9)

Points: .....

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

The character-oriented protocol BISYNC uses control characters to mark the structure of the frames. The start of a frame highlights the character `SYN`. The start of the header highlights the character `SOH` (*Start of header*). The payload is located between `STX` (*Start of text*) and `ETX` (*End of text*).



If the payload (body) contains the control characters `ETX` and `DLE` (*Data Link Escape*), they are protected (*escaped*) by the Data Link Layer protocol with a stuffed `DLE` caracter. A single `ETX` in the payload area is represented by the sequence `DLE ETX`. The `DLE` character itsef is represented by the sequence `DLE DLE`.

Control character	SOH	STX	ETX	DLE	SYN
Hexadecimal notation	01	02	03	10	16

Mark the payload inside the following BISYNC frames?

a) `16 16 01 99 98 97 96 95 02 C1 12 34 56 78 90 C2 03 A0 B7`

The payload is:

`C1 12 34 56 78 90 C2`

b) `16 16 01 99 98 97 96 95 02 B1 10 10 10 10 10 10 10 10 10 10 B3 03 76 35`

The payload is:

`B1 10 10 10 10 10 B3`

c) `16 16 01 99 98 97 96 95 02 10 03 10 10 10 03 10 10 10 03 10 10 03 92 55`

The payload is:

`03 10 03 10 03 10`

d) `16 16 01 99 98 97 96 95 02 10 10 A1 10 10 B1 10 03 C1 01 C2 A1 03 99 B2`

The payload is:

`10 A1 10 B1 03 C1 01 C2 A1`

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Question 10)

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)
```

```
Zu übertragender Rahmen: 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 11)

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 => Subnetznummer


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 => Subnetznummer
```

Subnet ID of sender? 20

Subnet ID of receiver? 20

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

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Question 12)

Points: .....

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

a) Describe one example, where using the Transport Layer protocol TCP makes sense.

TCP is used for Email transmission, file transmission and web page transmission because no part of the information is allowed to get lost.

b) Describe one example, where using the Transport Layer protocol UDP makes sense.

If UDP is used for video transmission or video telephony, the only consequence of losing a segment is losing an image.

c) Which two possible reasons for the occurrence of congestion in computer networks exist?

Receiver capacity. The receiver can not process the received data fast enough and therefore its receive buffer becomes full.

Network capacity. Congestion of the network occurs.

d) Why does the sender maintain two windows when using TCP and not just a single one?

The Advertised Receive Window avoids congestion of the receiver.

The Congestion Window avoids congestion of the network.

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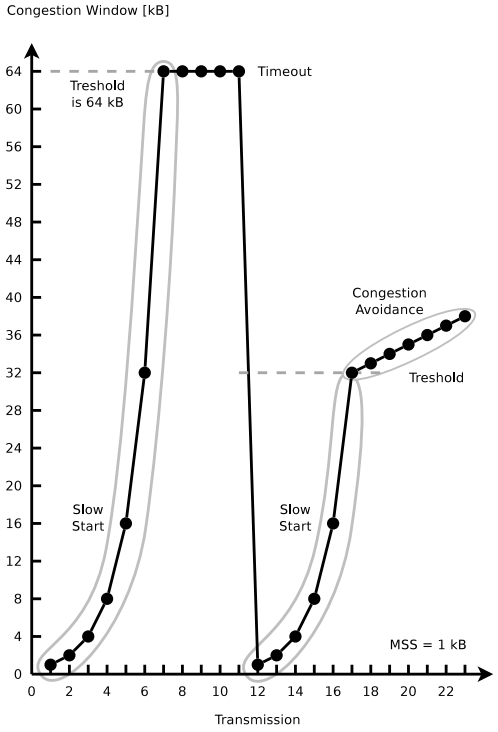
Question 13)

Points: .....

Maximum points: 2+1+1=4

a) Mark in the figure the slow-start phase and the congestion avoidance phase both.



b) Describe what fast retransmit is?

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

c) 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.