Sample solution of the written examination in

Computer Networks

February 23th 2018

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.
- The time limit ist *90 minutes*.
- Turn off your mobile phones!

Result:

Question:	1	2	3	4	5	6	7	8	9	10	11	12	**Σ**	Grade
Maximum points:	4	7	6	8	8	8	6	5	6	8	8	16	90	—
Achieved points:														

Last name: First name: Student number:

Question 1)

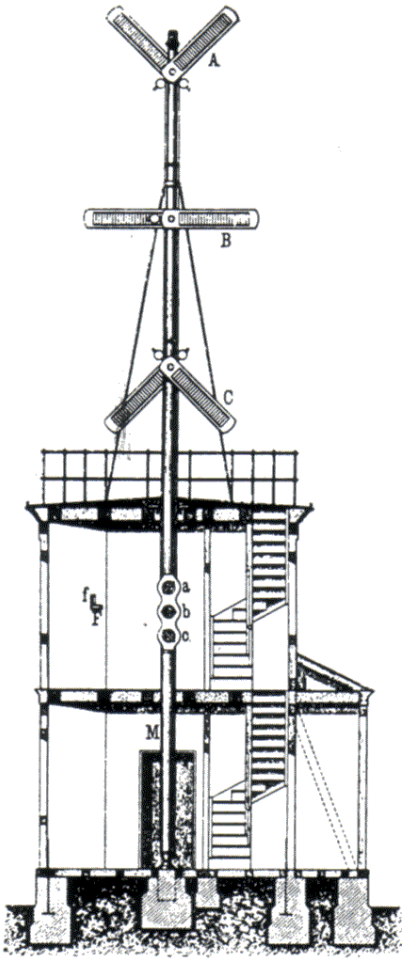
Points: .....

Maximum points: 2+2=4

The Prussian semaphore system (dt. *Preußischer optischer Telegraf*) was a telegraphic communications system used from 1832 until 1849 between Berlin and Koblenz.

Messages were transmitted using optical signals over a distance of nearly 550 km via 62 telegraph stations.

Each station was equipped with 6 telegraph arms. Each arm had 4 positions for encoding.



a) Data rate: How many bits can be transmitted per second when a new adjustment of the telegraph arms can be performed every 6 seconds?

Each station of the telegraphic communications system has 6 telegraph arms with 4 positions each.
$\Longrightarrow$ *This means* $4^6 = 4096$ *telegraph arm positions (= states) are possible.*
$\Longrightarrow$ *With 4096 states per adjustment, 12 Bits can be encoded per adjustment.*
Explanation: With 2 states, 1 bit can be encoded. With 4 states, 2 Bits can be encoded. With 8 states, 3 Bits can be encoded. . . and with 4096 states, 12 Bits can be encoded.
A new adjustment of the telegraph arms can be performed every 6 seconds.

$$\text{Data rate} = \frac{12 \text{ Bits}}{6 \text{ s}} = 2 \text{ Bits/s}$$

b) Latency: If each station requires 2 minutes for the forwarding, what is the end-to-end delay?

62 stations exist $\Longrightarrow$ *just 61 stations need to forward the message because the last station does not need to forward the message* $\Longrightarrow$ *122 minutes.*

Last name: First name: Student number:

Question 2)

Points: .....

Maximum points: 7

A true color image has a size of 1366x768 pixels. True color means that 3 Bytes per pixel are used for the color information. How long does it take to transmit the image via a...

Bits per Image:

1366x768 pixels = 1,049,088 pixels * 3 bytes/pixel = 3,147,264 bytes * 8 = 25,178,112 bits

a) 64 kbps ISDN connection?

$\frac{25{,}178{,}112 \text{ Bits}}{64{,}000 \text{ Bits/s}} = 393.408 \text{ s}$

b) 16 Mbps DSL connection?

$\frac{25{,}178{,}112 \text{ Bits}}{16{,}000{,}000 \text{ Bits/s}} = 1.573632 \text{ s}$

c) 1 Gbps Ethernet connection?

$\frac{25{,}178{,}112 \text{ Bits}}{1{,}000{,}000{,}000 \text{ Bits/s}} = 0.025178112 \text{ s}$

Last name: First name: Student number:

Question 3)

Points: .....

Maximum points: 3+1+1+1=6

a) What information contains an Ethernet frame?

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

b) Describe the function of the Address Resolution Protocol (ARP).

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

c) Describe what the ARP cache is.

The ARP cache is a table, which contains IP addresses and MAC addresses, that belong together.

d) Name one benefit of the ARP cache.

It is used to speed up the address resolution.

Last name: First name: Student number:

Question 4)

Points: .....

Maximum points: 4+4=8

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

```
Generator polynomial: 100101
Payload: 10101010
```

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

```
Frame with appended 0 bits: 1010101000000

1010101000000
100101|||||||
------vv|||||
  111110|||||
  100101|||||
  ------v||||
   110110||||
   100101||||
    -----v|||
    100110|||
    100101|||
    ------vvv                    Remainder: 11000
        11000 = Remainder        Transferred frame: 1010101011000
```

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

```
Transferred frame: 1011010110110        1011010110110
Generator polynomial: 100101            100101|||||||
                                        ------vv|||||
                                          100001|||||
                                          100101|||||
                                          ------vvv||
                                             100101||
                                             100101||
                                             ------vv
                                                   10 => Error
```

Last name: First name: Student number:

Question 5)

Points: .....

Maximum points: 1+1+1+1+2+1+1=8

a) Describe Unicast in the network layer.

An IP address is assigned to a single receiver.

b) Describe Broadcast in the network layer.

An IP address is assigned to all receivers in the subnet.

c) Describe Anycast in the network layer.

An IP address is used to reach a single device of a group of devices.

d) Describe Multicast in the network layer.

An IP address is assigned to a group of receivers.

e) Describe the purpose of Routers in computer networks.
(*Also explain the difference to Layer-3-Switches.*)

They forward packets between networks with different logical address ranges and provide a WAN interface. Layer-3-Switches do not provide a WAN interface.

f) Describe the purpose of Gateways in computer networks.

They enable communication between networks, which base on different protocols.

g) Describe why Gateways in the network layer are seldom required nowadays.

Modern computer networks operate almost exclusively with the Internet Protocol (IP). For this reason, a protocol conversion at the Network Layer is mostly not required.

Last name: First name: Student number:

Question 6)

Points: .....

Maximum points: 5+1+1+1=8

a) Split the class A network `16.0.0.0` for implementing 2500 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? 2500 => 4096 = 2^12 => 12 bits

Subnet mask:    11111111.11111111.11110000.00000000    255.255.240.0

Number of bits for host IDs? 12

Number of host IDs per subnet? 2^12 = 4096 => 4096 -2 = 4094 (because the
network address and the broadcast address cannot be used as host IDs)
```

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

b) Name one private IPv4 address space.

10.0.0.0/8 or 172.16.0.0/12 or 192.168.0.0/16

c) Describe the function of the Internet Control Message Protocol (ICMP).

It is used for the exchange of diagnostic and control messages, as well as error messages.

d) Give two examples for command line tools, which use the ICMP.

ping, tranceroute

Last name: First name: Student number:

Question 7)

Points: .....

Maximum points: 6

Calculate for each network configuration whether an IP packet, which is send from the given IP address to the destination address, leaves the subnet during transmission or not.

IP address	Subnet mask	Destination address	Leaves the subnet
15.200.99.23	255.192.0.0	15.239.1.1	☐ **yes** ☒ **no** <=== !!!

```
    00001111.11001000.01100011.00010111    15.200.99.23
AND 11111111.11000000.00000000.00000000    255.192.0.0
-------------------------------------
    00001111.11000000.00000000.00000000
             ^^                            => 3 = subnet ID sender

    00001111.11101111.00000001.00000001    15.239.1.1
AND 11111111.11000000.00000000.00000000    255.192.0.0
-------------------------------------
    00001111.11000000.00000000.00000000
             ^^                            => 3 = subnet ID sender
```

Sender and receiver have equal subnet IDs $\Longrightarrow$ the subnet is not left.

IP address	Subnet mask	Destination address	Leaves the subnet
201.20.222.13	255.255.255.240	201.20.222.17	☒ **yes** ☐ **no** <=== !!!

```
    11001001.00010100.11011110.00001101    201.20.222.13
AND 11111111.11111111.11111111.11110000    255.255.255.240
-------------------------------------
    11001001.00010100.11011110.00000000
                              ^^^^         => 0 = subnet ID sender

    11001001.00010100.11011110.00010001    201.20.222.17
AND 11111111.11111111.11111111.11110000    255.255.255.240
-------------------------------------
    11001001.00010100.11011110.00010000
                              ^^^^         => 1 = subnet ID sender
```

Sender and receiver have different subnet IDs $\Longrightarrow$ the subnet is left.

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

Last name: First name: Student number:

Question 8)

Points: .....

Maximum points: 1+1+0.5+0.5+0.5+0.5+0.5+0.5=5

a) Name the two major classes of routing protocols.

Distance Vector Routing Protocols and Link State Routing Protocols.

b) Describe what an autonomous system is.

Each AS consists of a group of logical networks, which use the Internet Protocol, are operated and managed by the same organization (e.g. an Internet Service Provider, a corporation or university) and use the same routing protocol.

c) The Routing Information Protocol (RIP) is a protocol for...

☒ Intra-AS routing ☐ Inter-AS routing

d) Which routing protocol class from subtask a) implements the RIP?

Distance vector routing.

e) The Border Gateway Protocol (BGP) is a protocol for...

☐ Intra-AS routing ☒ Inter-AS routing

f) Which routing protocol class from subtask a) implements the BGP?

None. It implements path-vector routing, which has some similarities with distance-vector-routing.

g) Open Shortest Path First (OSPF) is a protocol for...

☒ Intra-AS routing ☐ Inter-AS routing

h) Which routing protocol class from subtask a) implements OSPF?

Link state routing.

Last name: First name: Student number:

Question 9)

Points: .....

Maximum points: 2+2+1+1=6

a) The concept of TCP congestion control is called AIMD (= Additive Increase / Multiplicative Decrease). Describe the reason for the aggressive reduction and conservative increase of the congestion window.

The consequences of a congestion window which is too large in size are worse than for a window which is too small.

If the window is too small in size, available bandwidth remains unused. If the window is too large in size, segments will get lost and must be transmitted again This increases the congestion of the network even more!

The congestion state of must be left as quick as possible. Therefore, the size of the congestion window is reduced significantly.

b) Describe the steps of a Denial-of-Service attack via SYN flood.

*A client sends many connection requests (*SYN*), but does not respond to the acknowledgments (*SYN ACK*) of the server via* ACK*. The server waits some time for the acknowledgment of the clients because the delay of the confirmation could be caused by a network issue. During this period, the address of the client and the status of incomplete connection are stored in the memory of the network stack.*

By flooding the server with connection requests, the table which stores the TCP connections in the network stack is completely filled. This causes the server to become unable to establish new connections. The memory consumption at the server may become this large that the main memory gets completely filled and the server crashes.

c) Describe what the congestion avoidance phase of TCP is.

The linear growth phase.

d) Describe what the slow-start phase of TCP is.

The exponential growth phase.

Last name: First name: Student number:

Question 10)

Points: .....

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

a) Simplify this IPv6 address:
`1080:0000:0000:0000:0007:0700:0003:316b`

Solution: `1080::7:700:3:316b`

b) Simplify this IPv6 address:
`2001:0db8:0000:0000:f065:00ff:0000:03ec`

Solution: `2001:db8::f065:ff:0:3ec`

c) Provide all positions of this simplified IPv6 address:
`2001:db8:0:c::1c`

Solution: `2001:0db8:0000:000c:0000:0000:0000:001c`

d) Provide all positions of this simplified IPv6 address:
`1080::9956:0:0:234`

Solution: `1080:0000:0000:0000:9956:0000:0000:0234`

Last name: First name: Student number:

Question 11)

Points: .....

Maximum points: 8

```
# WAN Interface
auto eth0
iface eth0 inet dhcp

# LAN 1
auto eth1
iface eth1 inet static
  address 192.168.100.1
  netmask 255.255.255.0
  broadcast 192.168.100.255

# LAN 2
auto eth2
iface eth2 inet static
  address 10.20.0.1
  netmask 255.255.0.0
  broadcast 10.20.255.255
```

Listing 1: `/etc/network/interfaces` of **Router**

Diagram 1 presents the setup of a network. Listing 1 contains the content of the file `/etc/network/interfaces` of the **Router** machine.

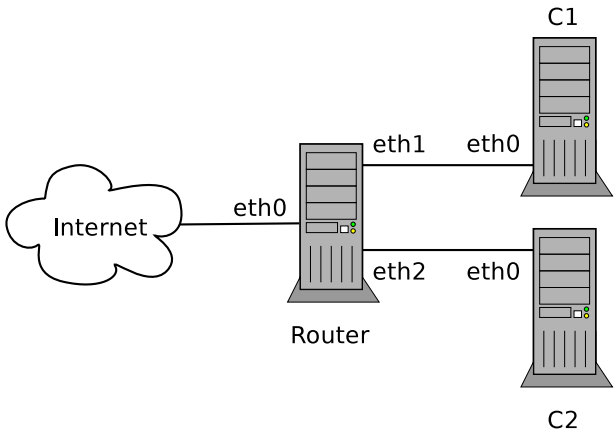


Diagram 1: Example network

a) Assign valid network configurations for the Computers **C1** and **C2**. Make your configurations in a way, that a connection between the **Router** and the computers **C1** and **C2** is established. The IP addresses **have to be** assigned statically!

```
auto eth0
iface eth0 inet static
  address 192.168.100.10
  netmask 255.255.255.0
  gateway 192.168.100.1
```

Listing 2: `/etc/network/interfaces` of **C1**

```
auto eth0
iface eth0 inet static
  address 10.20.30.40
  netmask 255.255.0.0
  gateway 10.20.0.1
```

Listing 3: `/etc/network/interfaces` of **C2**

Last name: First name: Student number:

Question 12)

Points: .....

Maximum points: 10+1+1+1+2+1=16

a) Use the configuration details from question 11 to fill in the missing parts of the three commands below, that need to be executed on the **Router** machine to implement NAT forwarding.

```
# NAT forwarding

# Configure the forwarding for the interface
iptables -A FORWARD -o eth0 -s 0.0.0.0/0 -m conntrack --ctstate NEW -j ACCEPT

# Configure the NAT masquerading for the interface
iptables -t nat -A POSTROUTING -o eth0 -j MASQUERADE

# Activate IP forwarding
sysctl -w net.ipv4.ip_forward=1
```

Listing 4: `iptables` of **Router**

b) Name a command that can be used in Linux to stop the network interfaces.

`ifdown eth0` or `ifdown -a` or `ip link set eth0 down` or
`sudo systemctl stop networking.service`

c) Name a command that can be used in Linux to start the network interfaces.

`ifup eth0` or `ifup -a` or `ip link set eth0 up` or
`sudo systemctl start networking.service`

d) Name a command that can be used in Linux to check the network configuration of the local machine.

`ifconfig` or `cat /etc/network/interfaces` or `ip addr show` or `ip link show`

e) Describe the functionality of the command `dnsmasq`.

It is a lightweight DHCP and caching DNS server. With `dnsmasq` *it is possible to resolve machines inside a network via their FQDN istead of their IP address.*

f) Explain the content of the file `/etc/hosts`.

It contains the hostnames and the corresponding IP addresses of the machines inside a local network.