Solution of Exercise Sheet 4

Exercise 1 (Routers, Layer-3-Switches, Gateways)

1. Explain 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.

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

   They are Routers too, which means they forward packets between networks with different logical address ranges, but they do not provide a WAN interface.

3. Explain the purpose of **Gateways** in computer networks.

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

4. Explain why **Gateways** in the Network Layer of computer networks 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.

Exercise 2 (Collision Domain, Broadcast Domain)

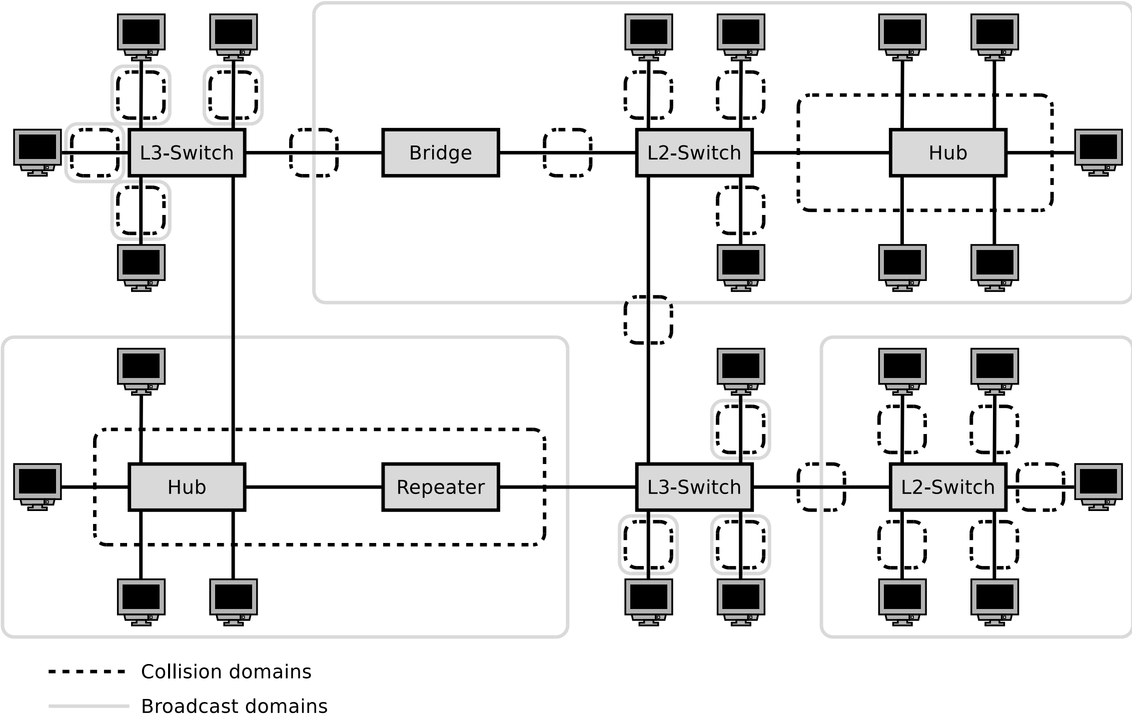
1. Mark the devices that **divide the collision domain**.

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

2. Mark the devices that **divide the broadcast domain**.

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

3. Sketch in the diagram all **collision domains** and all **broadcast domains**.



Exercise 3 (Addressing in the Network Layer)

1. Explain the meaning of **Unicast** in the Network Layer of computer networks.

   An IP address is assigned to a single receiver.

2. Explain the meaning of **Broadcast** in the Network Layer of computer networks.

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

3. Explain the meaning of **Anycast** in the Network Layer of computer networks.

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

4. Explain the meaning of **Multicast** in the Network Layer of computer networks.

   An IP address is assigned to a group of receivers.

5. Explain why the IPv4 **address space** does contain only 4,294,967,296 addresses.

   IPv4 addresses have a length of 32 bits (4 bytes). Thus, the address space contains $2^{32} = 4,294,967,296$ *possible addresses.*

6. Explain why **Classless Interdomain Routing (CIDR)** was introduced.

Because with address classes, many addresses are wasted and it is impossible to dynamically adjust address classes.

7. Describe in simple words the **functioning of CIDR**.
   Focus on the way, how IP addresses are treated and subnets are created.

   Since the introduction of CIDR, the address class of an IPv4 address is no longer important. All hosts in a network have a subnet mask assigned, which has a length of 32 bits (4 bytes) and is used to specify the number of subnets and hosts. The network mask splits the host ID of an IP address into subnet ID and host ID. 1-bits in the subnet mask indicate, which part of the address space is used for subnet IDs and 0-bits indicate, which part of the address space is used for host IDs.

Exercise 4 (Addressing in the Network Layer)

Calculate for each subtask of this exercise the **first and last host addresses**, the **network address** and the **broadcast address** of the subnet.

```
IP Address:          151.175.31.100   10010111.10101111.00011111.01100100
Subnet mask:         255.255.254.0    11111111.11111111.11111110.00000000
Part for host IDs:                                           x xxxxxxxx
Network address?     151.175.30.0     10010111.10101111.00011110.00000000
First host address?  151.175.30.1     10010111.10101111.00011110.00000001
Last host address?   151.175.31.254   10010111.10101111.00011111.11111110
Broadcast address?   151.175.31.255   10010111.10101111.00011111.11111111
```

```
IP Address:          151.175.31.100   10010111.10101111.00011111.01100100
Subnet mask:         255.255.255.240  11111111.11111111.11111111.11110000
Part for host IDs:                                                 xxxx
Network address?     151.175.31.96    10010111.10101111.00011111.01100000
First host address?  151.175.31.97    10010111.10101111.00011111.01100001
Last host address?   151.175.31.110   10010111.10101111.00011111.01101110
Broadcast address?   151.175.31.111   10010111.10101111.00011111.01101111
```

```
IP Address:          151.175.31.100   10010111.10101111.00011111.01100100
Subnet mask:         255.255.255.128  11111111.11111111.11111111.10000000
Part for host IDs:                                              xxxxxxx
Network address?     151.175.31.0     10010111.10101111.00011111.00000000
First host address?  151.175.31.1     10010111.10101111.00011111.00000001
Last host address?   151.175.31.126   10010111.10101111.00011111.01111110
Broadcast address?   151.175.31.127   10010111.10101111.00011111.01111111
```

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

Exercise 5 (Addressing in the Network Layer)

In each subtask of this exercise, a sender transmits an IP packet to a receiver. Calculate for each subtask the **subnet ID of sender and receiver** and specify whether the IP packet **leaves the subnet during transmission** or not.

```
Sender:      11001001.00010100.11011110.00001101    201.20.222.13
Subnet mask: 11111111.11111111.11111111.11110000    255.255.255.240
         AND -----------------------------------
             11001001.00010100.11011110.00000000
                                        ^^^^        => Subnet ID = 0

Receiver:    11001001.00010100.11011110.00010001    201.20.222.17
Subnet mask: 11111111.11111111.11111111.11110000    255.255.255.240
         AND -----------------------------------
             11001001.00010100.11011110.00010000
                                        ^^^^        => Subnet ID = 1

       Subnet ID of sender? 0
       Subnet ID of receiver? 1
       Does the IP packet leave the subnet [yes/no]? yes

Sender:      10000100.10011000.01010011.11111110    132.152.83.254
Subnet mask: 11111111.11111111.11111100.00000000    255.255.252.0
         AND -----------------------------------
             11000100.10011000.01010000.00000000
                               ^^^^^^               => Subnet ID = 20

Receiver:    10000100.10011000.01010001.00000010    132.152.81.2
Subnet mask: 11111111.11111111.11111100.00000000    255.255.252.0
         AND -----------------------------------
             11000100.10011000.01010000.00000000
                               ^^^^^^               => Subnet ID = 20

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

Sender:      00001111.11001000.01100011.00010111    15.200.99.23
Subnet mask: 11111111.11000000.00000000.00000000    255.192.0.0
         AND -----------------------------------
             00001111.11000000.00000000.00000000
                      ^^                            => Subnet ID = 3

Receiver:    00001111.11101111.00000001.00000001    15.239.1.1
Subnet mask: 11111111.11000000.00000000.00000000    255.192.0.0
         AND -----------------------------------
             00001111.11000000.00000000.00000000
                      ^^                            => Subnet ID = 3

       Subnet ID of sender? 3
       Subnet ID of receiver? 3
       Does the IP packet leave the subnet [yes/no]? no
```

Exercise 6 (Addressing in the Network Layer)

Calculate for each subtask of this exercise the **subnet masks** and answer the **questions**.

1. Split the class C network `195.1.31.0` for implementing 30 subnets.

Network ID: `11000011.00000001.00011111.00000000` `195.1.31.0`
Number of bits for subnet IDs? 30 => 32 $(= 2^5)$ => 5 bits
Subnet mask: `11111111.11111111.11111111.11111000` `255.255.255.248`
Number of bits for host IDs? 3
Number of host IDs per subnet? $2^3 - 2 = 6$

2. Split the class A network `15.0.0.0` for implementing 333 subnets.

Network ID: `00001111.00000000.00000000.00000000` `15.0.0.0`
Number of bits for subnet IDs? 333 => 512 $(= 2^9)$ => 9 bits
Subnet mask: `11111111.11111111.10000000.00000000` `255.255.128.0`
Number of bits for host IDs? 15
Number of host IDs per subnet? $2^{15} - 2 = 32766$

3. Split the class B network `189.23.0.0` for implementing 20 subnets.

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

4. Split the class C network `195.3.128.0` into subnets, which contain 17 hosts each.

Network ID: `11000011.00000011.10000000.00000000` `195.3.128.0`
Number of bits for host IDs? 17 => 32 $(= 2^5)$ => 5 bits
Number of bits for subnet IDs? $8 - 5 = 3$ bit
Number of possible subnets? $2^3 = 8$
Subnet mask: `11111111.11111111.11111111.11100000` `255.255.255.224`

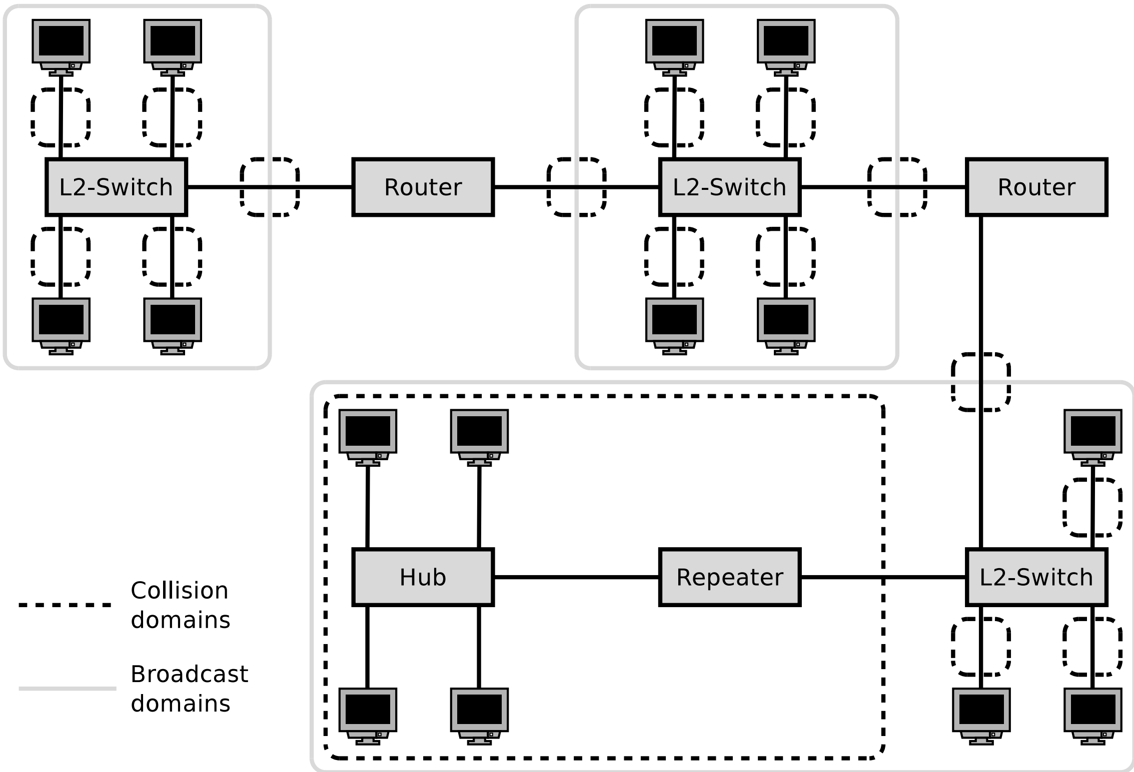
5. Split the class B network `129.15.0.0` into subnets, which contain 10 hosts each.

Network ID: `10000001.00001111.00000000.00000000` `129.15.0.0`
Number of bits for host IDs? 10 => 16 $(= 2^4)$ => 4 bits
Number of bits for subnet IDs? $16 - 4 = 12$ bit
Number of possible subnets? $2^{12} = 4096$
Subnet mask: `11111111.11111111.11111111.11110000` `255.255.255.240`

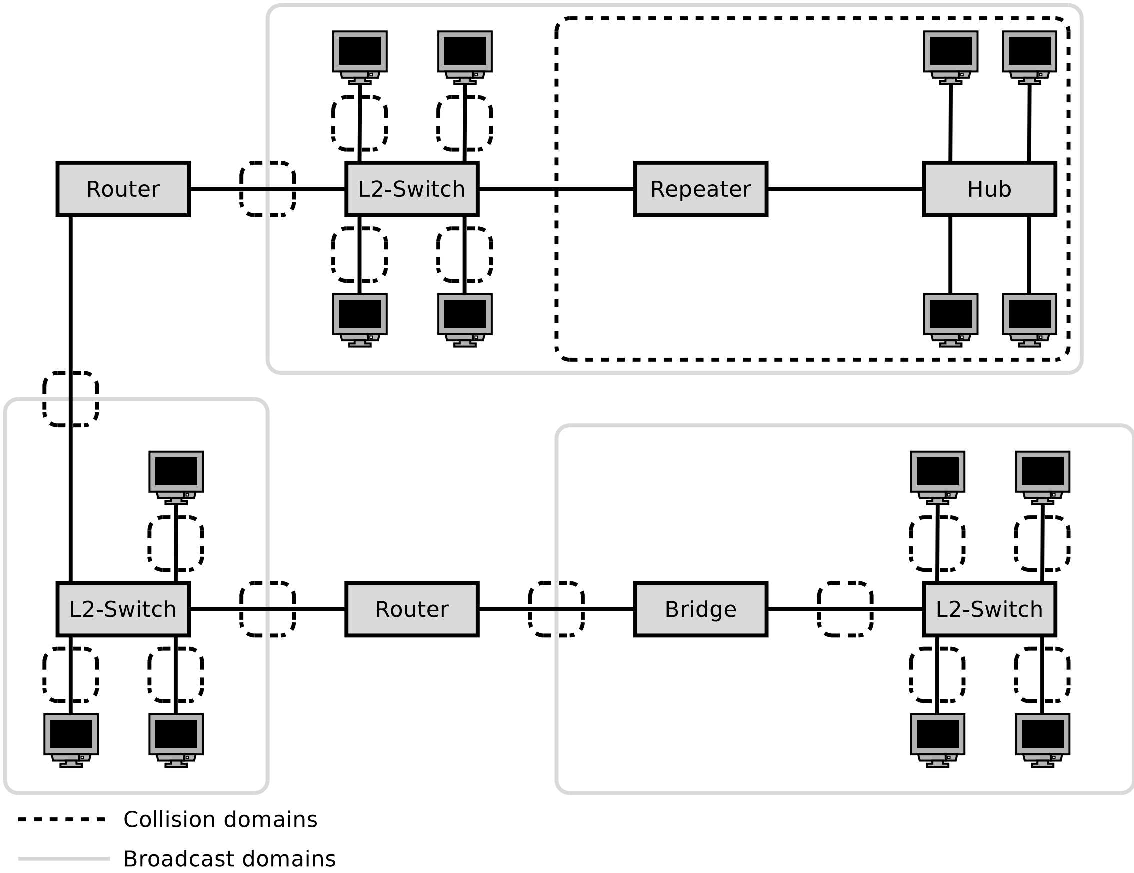
binary representation	decimal representation	binary representation	decimal representation
10000000	128	11111000	248
11000000	192	11111100	252
11100000	224	11111110	254
11110000	240	11111111	255

Exercise 7 (Collision Domain, Broadcast Domain)

1. Sketch in the diagram of the network topology all **collision domains** and all **broadcast domains**.

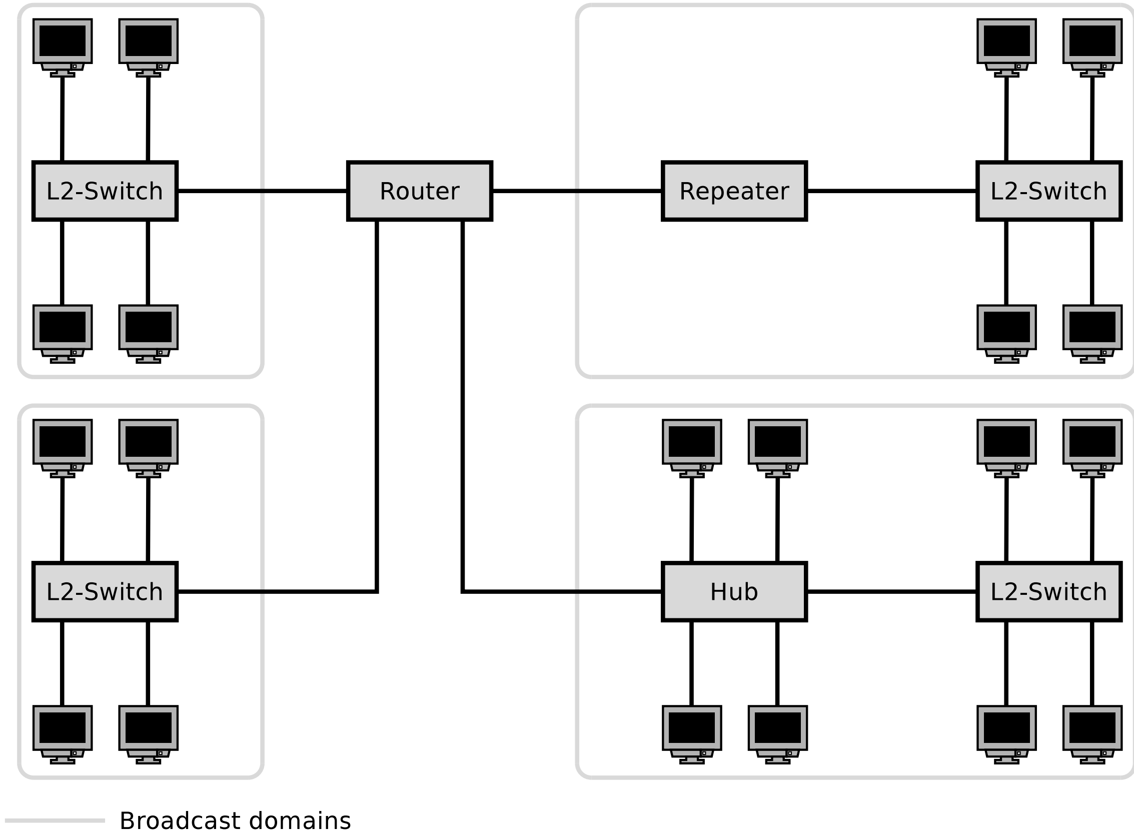


2. Sketch in the diagram of the network topology all **collision domains** and all **broadcast domains**.



Exercise 8 (Broadcast Domain)

1. Sketch in the diagram of the network topology all **broadcast domains**.
2. What is the **required number of subnets** for this network topology?



4 subnets are required because each port of a Router is connected to a different IP network. It is impossible to operate an IP subnet on multiple ports of a Router.

Exercise 9 (Private IP Address Spaces)

Name the three private IPv4 address spaces.

- 10.0.0.0/8
- 172.16.0.0/12
- 192.168.0.0/16

Exercise 10 (Addressing in the Network Layer)

Calculate for each network configuration in the table whether an IP packet, which is sent 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 [yes/no]
201.20.222.13	255.255.255.240	201.20.222.17	*yes*
15.200.99.23	255.192.0.0	15.239.1.1	*no*
172.21.23.14	255.255.255.0	172.21.24.14	*Private IPs are not routed*
210.5.16.198	255.255.255.252	210.5.16.197	*no*
210.5.16.198	255.255.255.252	210.5.16.201	*yes*
5.5.5.5	255.254.0.0	5.6.6.6	*yes*

(A part of the solution is the calculations performed. Where no calculation is required, you need to give a reason for your answer. Answering the question with just "yes" or "no" is not sufficient!)

Source: Jörg Roth. Prüfungstrainer Rechnernetze. Vieweg (2010)

```
    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 receiver
```

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

```
    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 receiver
```

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

172.21.23.14 and 172.21.24.14 are private IP addresses $\Longrightarrow$ they are not forwarded by Routers.

```
    11010010.00000101.00010000.11000110    210.5.16.198
AND 11111111.11111111.11111111.11111100    255.255.255.252
---------------------------------------
    11010010.00000101.00010000.11000100
                               ^^^^^^      => 49 = subnet ID sender

    11010010.00000101.00010000.11000101    210.5.16.197
AND 11111111.11111111.11111111.11111100    255.255.255.252
---------------------------------------
    11010010.00000101.00010000.11000101
                               ^^^^^^      => 49 = subnet ID receiver
```

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

```
    11010010.00000101.00010000.11000110    210.5.16.198
AND 11111111.11111111.11111111.11111100    255.255.255.252
---------------------------------------
    11010010.00000101.00010000.11000100
                               ^^^^^^      => 49 = subnet ID sender

    11010010.00000101.00010000.11001001    210.5.16.201
AND 11111111.11111111.11111111.11111100    255.255.255.252
---------------------------------------
    11010010.00000101.00010000.11001000
                               ^^^^^^      => 50 = subnet ID receiver
```

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

```
    00000101.00000101.00000101.00000101    5.5.5.5
AND 11111111.11111110.00000000.00000000    255.254.0.0
---------------------------------------
    00000101.00000100.00000000.00000000
             ^^^^^^^                       => 2 = subnet ID sender

    00000101.00000110.00000110.00000110    5.6.6.6
AND 11111111.11111110.00000000.00000000    255.254.0.0
---------------------------------------
    00000101.00000110.00000000.00000000
             ^^^^^^^                       => 3 = subnet ID receiver
```

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

Exercise 11 (Addressing in the Network Layer)

Specify for each subtask of this exercise the correct **subnet mask**.

1. A maximum number of subnets with 5 hosts each in a class B network.

   5 hosts $\Longrightarrow$ 3 bit are required.
   `11111111 11111111 11111111 11111000` *255.255.255.248*

2. 50 subnets with 999 hosts each in a class B network.

   999 hosts $\Longrightarrow$ 10 bit are required.
   `11111111 11111111 11111100 00000000` *255.255.252.0*

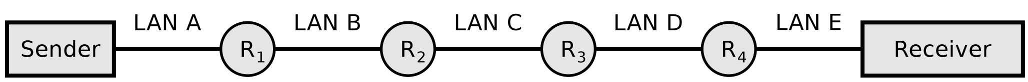
3. 12 subnets with 12 hosts each in a class C network.

   12 hosts $\Longrightarrow$ 4 bit are required.
   `11111111 11111111 11111111 11110000` *255.255.255.240*

Source: Jörg Roth. Prüfungstrainer Rechnernetze. Vieweg (2010)

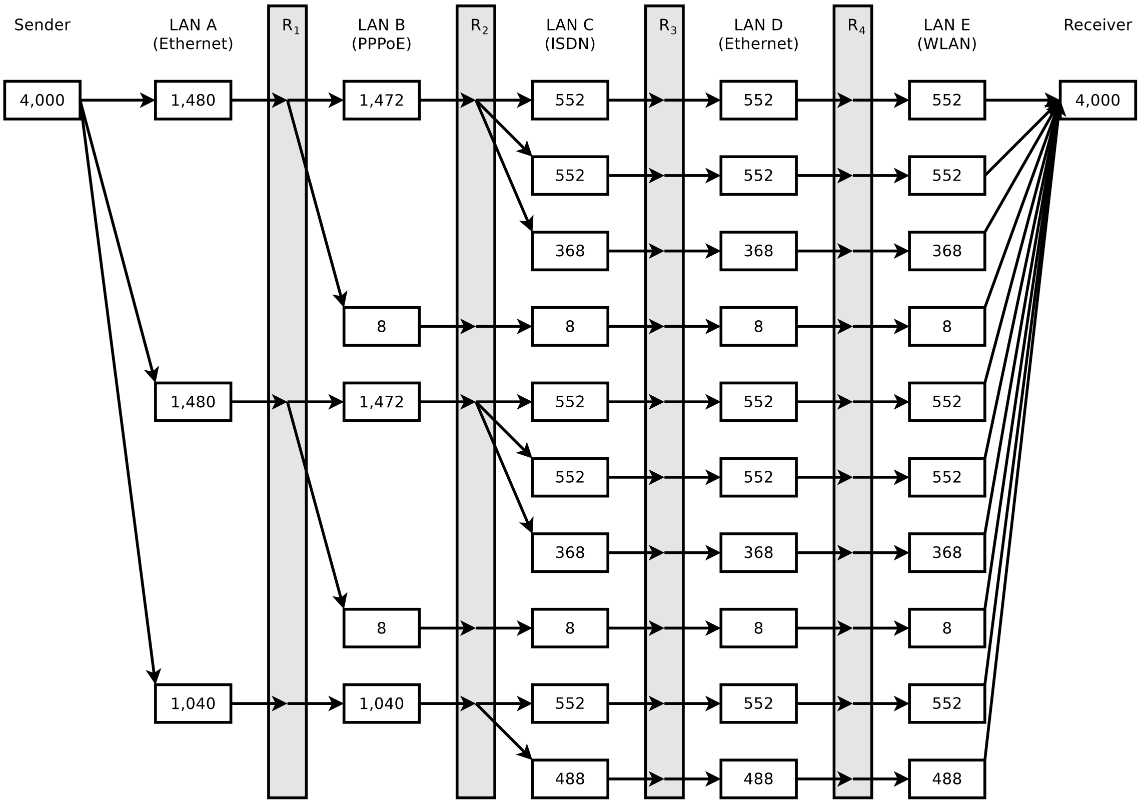
Exercise 12 (Fragmenting IP Packets)

4,000 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 $< 4,000$ bytes.



	LAN A	**LAN B**	**LAN C**	**LAN D**	**LAN E**
Network technology	Ethernet	PPPoE	ISDN	Ethernet	WLAN
MTU [bytes]	1,500	1,492	576	1,400	2,312
IP-Header [bytes]	20	20	20	20	20
max. payload [bytes] in theory	1,480	1,472	556	1,380	2,292
Multiple of 8	yes	yes	no	no	no
max. payload [Bytes] in practice	1,480	1,472	552	1,376	2,288

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



Exercise 13 (Forwarding and Path Calculation)

1. Name the two major classes of **routing protocols**.

   Distance Vector Routing Protocols and Link State Routing Protocols.

2. Name the **algorithms for best path calculation**, the routing protocol classes from subtask 1 do implement.

   Distance Vector Routing Protocols implement the Bellman-Ford algorithm.

   Link State Routing Protocols implement the Dijkstra algorithm.

3. Explain 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.

4. The **Border Gateway Protocol** (BGP) is a protocol for…

   ☐ Intra-AS routing ☒ Inter-AS routing

5. Name the **routing protocol class** from subtask 1 that does the BGP implement.

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

6. **Open Shortest Path First** (OSPF) is a protocol for…

   ☒ Intra-AS routing ☐ Inter-AS routing

7. Name the **routing protocol class** from subtask 1 that does the OSPF implement.

   Link state routing.

8. The **Routing Information Protocol** (RIP) is a protocol for…

   ☒ Intra-AS routing ☐ Inter-AS routing

9. Name the **routing protocol class** from subtask 1 that does the RIP implement.

   Distance vector routing.

10. When RIP is used, each Router only communicates with its **direct neighbors**. Name **advantages** and **drawbacks** of this method.

    Advantage: The network is not flooded $\Longrightarrow$ protocol causes little overhead.

    Drawback: Long convergence time because updates propagate slowly.

11. When RIP is used, the path cost (metric) only depends on the number of Routers (**hops**), which need to be passed on the way to the destination network. Name a **drawback** of this method.

    The metric hop count often results in routes, which are not optimal, because all network segments have an equal weight.

12. When OSPF is used, **all Routers** communicate with each other. Name **advantages** and **drawbacks** of this method.

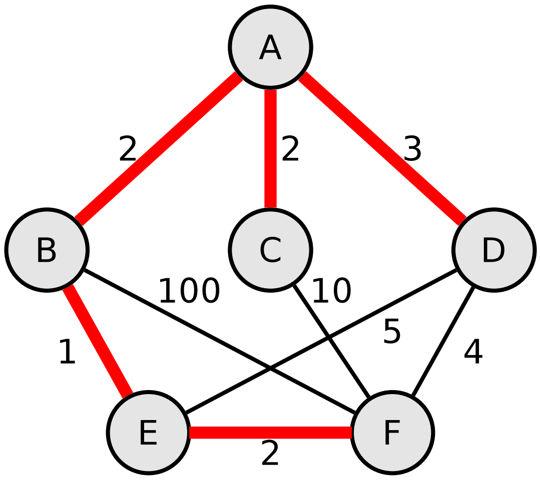
    Advantage: Short convergence time.

    Drawback: The network is flooded $\Longrightarrow$ protocol causes strong overhead.

Exercise 14 (Dijkstra's Algorithm)

1. Calculate the shortest path from node A to all other nodes using Dijkstra's algorithm.

Source: Jörg Roth. Prüfungstrainer Rechnernetze. Vieweg (2010)



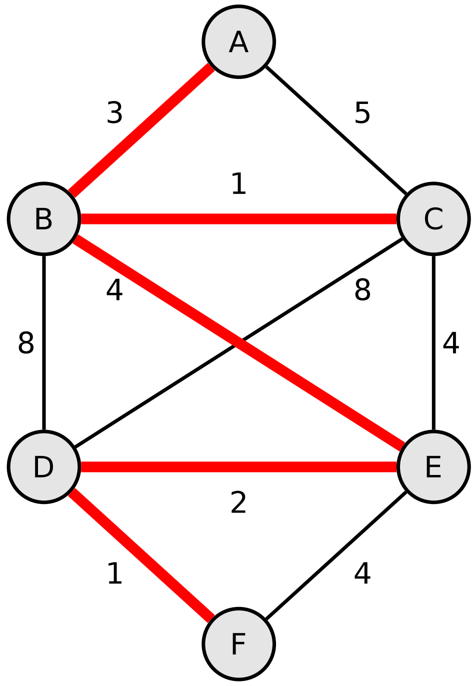
	Distance values					
	Initial	Step 1	Step 2	Step 3	Step 4	Step 5
d_A	**0** ← min	<u>0</u> ✓	0 ✓	0 ✓	0 ✓	0 ✓
d_B	∞	**2** ← min	<u>2</u> ✓	2 ✓	2 ✓	2 ✓
d_C	∞	2	**2** ← min	<u>2</u> ✓	<u>2</u> ✓	<u>2</u> ✓
d_D	∞	3	3	**3** ← min	<u>3</u> ✓	<u>3</u> ✓
d_E	∞	∞	3	3	**3** ← min	<u>3</u> ✓
d_F	∞	∞	102	12	7	**5** ← min

The active node is underlined.

Nodes visited = {A, B, C, D, E, F}

Shortest paths = {A, A⟶B, A⟶C, A⟶D, B⟶E, E⟶F}

2. Calculate the shortest path from node A to all other nodes using Dijkstra's algorithm.



	Distance values					
	Initial	Step 1	Step 2	Step 3	Step 4	Step 5
d_A	**0** ← min	<u>0</u> ✓	0 ✓	0 ✓	0 ✓	0 ✓
d_B	∞	**3** ← min	<u>3</u> ✓	3 ✓	3 ✓	3 ✓
d_C	∞	5	**4** ← min	<u>4</u> ✓	4 ✓	4 ✓
d_D	∞	∞	11	11	**9** ← min	<u>9</u> ✓
d_E	∞	∞	7	**7** ← min	<u>7</u> ✓	7 ✓
d_F	∞	∞	∞	∞	11	**10** ← min

The active node is underlined.

Nodes visited = {A, B, C, E, D, F}

Shortest paths = {A, A⟶B, B⟶C, B⟶E, E⟶D, D⟶F}

Exercise 15 (Internet Control Message Protocol)

1. 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.

2. Give two examples for command line tools, which use ICMP.

   ping, traceroute

Exercise 16 (IPv6)

1. Simplify these IPv6 addresses:

    - `1080:0000:0000:0000:0007:0700:0003:316b`

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

    - `2001:0db8:0000:0000:f065:00ff:0000:03ec`

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

    - `2001:0db8:3c4d:0016:0000:0000:2a3f:2a4d`

      Solution: `2001:db8:3c4d:16::2a3f:2a4d`

    - `2001:0c60:f0a1:0000:0000:0000:0000:0001`

      Solution: `2001:c60:f0a1::1`

    - `2111:00ab:0000:0004:0000:0000:0000:1234`

      Solution: `2111:ab:0:4::1234`

2. Provide all positions of these simplified IPv6 addresses:

    - `2001::2:0:0:1`

      Solution: `2001:0000:0000:0000:0002:0000:0000:0001`

    - `2001:db8:0:c::1c`

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

    - `1080::9956:0:0:234`

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

    - `2001:638:208:ef34::91ff:0:5424`

      Solution: `2001:0638:0208:ef34:0000:91ff:0000:5424`

    - `2001:0:85a4::4a1e:370:7112`

      Solution: `2001:0000:85a4:0000:0000:4a1e:0370:7112`