Chair of Network Architectures and Services
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Note:
- During the attendance check a sticker containing a unique code will be put on this exam.
- This code contains a unique number that associates this exam with your registration number.
- This number is printed both next to the code and to the signature field in the attendance check list.

Advanced Computer Networking

Module: IN2097 **Date:** Monday 10th April, 2017
Examiner: Prof. Dr.-Ing. Georg Carle **Exam:** Retake exam

	P 1	P 2	P 3	P 4	P 5
I					
II					

Working instructions

- This exam consists of
  - **16 pages** with a total of **5 problems** and
  - a two-sided printed **cheat sheet**.

  Please make sure now that you received a complete copy of the exam.
- Detaching pages from the exam is prohibited.
- Subproblems marked by * can be solved without results of previous subproblems.
- **Answers are only accepted if the solution approach is documented.** Give a reason for each answer unless explicitly stated otherwise in the respective subproblem.
- Do not write with red or green colors nor use pencils.
- The total amount of achievable credits in this exam is 60 credits.
- Allowed resources:
  - one **printed dictionary** English $\leftrightarrow$ native language
- Physically turn off all electronic devices, put them into your bag and close the bag.

Problem 1 Quiz (6 credits)

The following questions cover multiple topics and can be solved independently of each other.

0 1 2

a)* Explain an important difference between the two different variants of network calculus.

0 1

b)* Consider an IP packet with the destination address 192.168.0.100 and a router configured with the given routing table. Matching the destination IP address against the routes would generate three possible matches. How is this ambiguity resolved using Classless Inter-Domain Routing (CIDR)?

Destination subnet	Destination interface
192.168.0.0/24	3
192.168.0.64/26	2
192.168.0.96/27	1

0 1

c)* In the predecessor of CIDR, the classful networks, ambiguous routes were impossible to create. Explain why.

0 1

d)* To accelerate an Internet-wide scan, the amount of addresses to be scanned shall be reduced. Explain which addresses can be blacklisted for the scan if you have access to your upstream provider's BGP export.

0 1

e)* You want to save the complete IPv6 address space in an array. How many entries does the array have and how much memory (in TiB) do you need for this array. **Note:** 1 TiB = 1024 GiB

Problem 2 Loops (6 credits)

This problem is based on the topology depicted in Figure 2.1. The two Hosts H1 and H2 are connected to Switches S1 and S2 respectively. Switches S1 and S2 are connected with two separate cables.

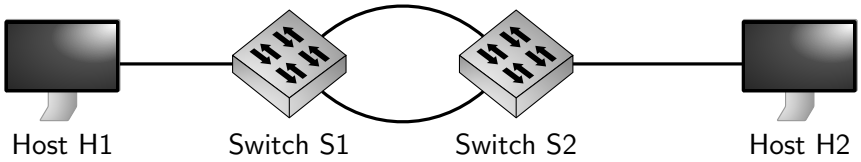


Figure 2.1: Network topology

a)* Hosts H1 and H2 are freshly booted. Host H1 wants to ping Host H2. Explain in detail which problems occur.

0 1 2 3

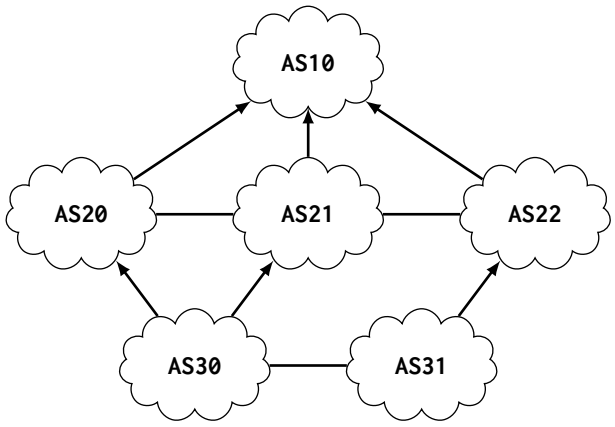
b) Describe solutions how this problem can be solved on ISO/OSI Layer 2 and Layer 1 respectively.

0 1 2

c) How is this problem solved for IP?

0 1

Problem 3 Routing - large scale (12.5 credits)



(a) AS topology

AS	Owned prefixes
AS10	192.0.10.0/24
AS20	192.0.20.0/24
AS21	192.0.21.0/24
AS22	192.0.22.0/24
AS30	192.0.30.0/24
AS31	192.0.31.0/24

(b) Owned prefixes

Figure 3.1: AS topology & prefixes

Figure 3.1a shows a number of different ASes and a topology reflecting their economical dependencies. Figure 3.1b lists the prefixes owned by the ASes.

Arrows show a customer provider relationship where the costumer (arrow bottom) pays money to a provider for transit traffic to the provider (arrow tip).

Furthermore, there are cost free traffic exchange arrangements between partner ASes, symbolized by lines. This agreement only holds for the two directly involved ASes. Every AS wants to get connectivity for its owned prefixes and wants to earn/save money by forwarding traffic to their customers/partners. In this example all providers announce the prefixes of their customers as they earn money from them.

0 ½

a)* Give the technical term for an AS that has at least two upstream providers (like AS30 in Figure 3.1a).

0 1

b)* How can an AS control the traffic it gets from its partner, provider or costumer ASes?

A client with the IP address `192.0.20.10` wants to send a UDP packet to `192.0.31.100` (see Table 3.1b).

0 1

c)* Name the source and destination AS.

d) Describe and justify the path (see Subproblem c)) for every AS the traffic takes through the topology given in Figure 3.1a.

0 1 2 3

From AS	To AS	Reason

e) There is a shorter way involving less ASes than the solution described in Subproblem d). Give a reason why this path is not taken.

0 1

f)* Which prefixes does AS30 announce to AS31, AS20 and AS21? Give short reasons for each announced prefix.

0 1 2

From AS	To AS	Announced prefix	Reason
AS 30			
AS 30			
AS 30			

g)* Which prefixes does AS21 announce to AS30, AS22 and AS10? Give a short reasons for each announced prefix.

0 1 2 3 4

From AS	To AS	Announced prefix	Reason
AS 21			
AS 21			
AS 21			
AS 21			
AS 21			
AS 21			
AS 21			

Problem 4 Latency investigation (11.5 credits)

This problem takes a closer look at the latency of a packet processing application. An experiment measures the end-to-end latency of this application.

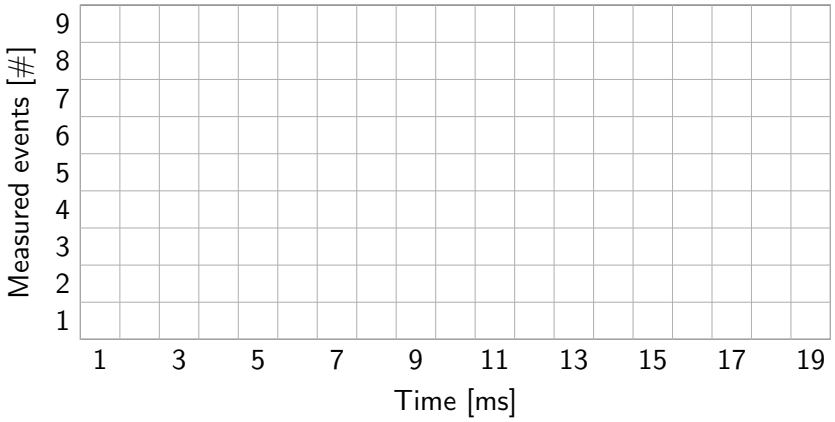


Figure 4.1: Latency distribution

An experiment measures 20 packets with the following latencies [in ms] at the receiving host:

5, 4, 10, 6, 7, 9, 8, 3, 6, 4, 4, 5, 7, 5, 5, 4, 5, 6, 13, 8

0
1
2

a)* Create a histogram in Figure 4.1 for the latency distribution of the given experiment data.

b) Determine the 25%, the 50%, the 75% and the 95% percentile of the previously created histogram in Figure 4.1.

0
1
2

0
1

c)* Calculate median and average of the histogram in Figure 4.1. Shorten the results as much as possible.

Assume that the shape of the latency distribution does not change even for longer experiments, i.e., the distribution for 1 million packets looks exactly the same as given in Figure 4.1.

d) Determine the probability of a packet never having a latency of more than 10 ms for a sequence of 100 packets sent. **Note:** Document your approach. You do not need to calculate the actual values.

0 1

e) Determine the probability of **at most one** packet having a latency of more than 10 ms for a sequence of 100 packets sent. **Note:** Document your approach. You do not need to calculate the actual values.

0 1

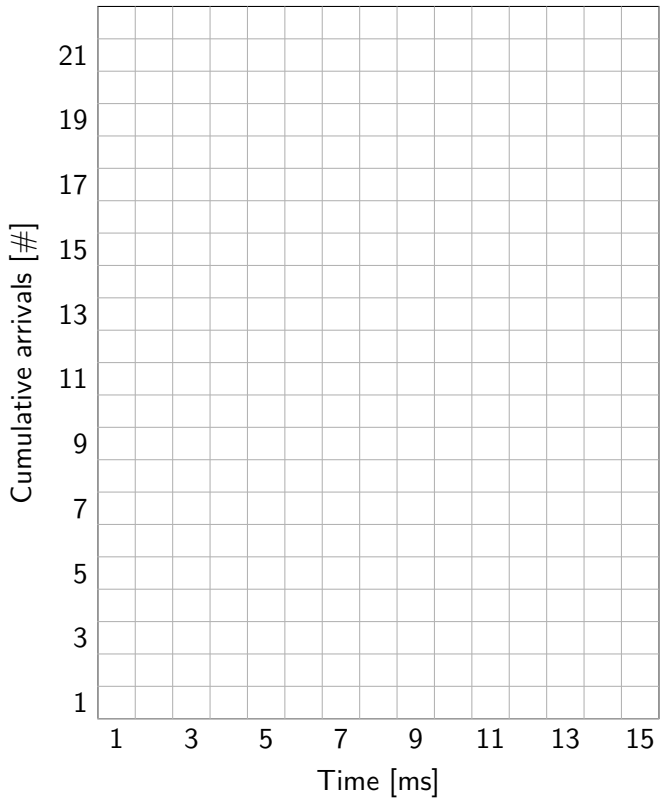


Figure 4.2: Cumulative arrival

f)* Create a graph of the cumulative arrival for the receiving host in Figure 4.2.

0 1 2

g) Create a linear arrival function γ characterized by the rate r and the burstiness parameter b for the cumulative arrival depicted in Figure 4.2. The arrival function should approximate the worst case latency as close as possible and have a rate r which is as low as possible. Give the values for r and b.

0 1 2

Problem 5 Network analysis (24 credits)

Consider the network topology depicted in Figure 5.1, where two hosts H1 and H2 want to communicate with each other. Host H1 accesses the Internet via an SDN-enabled switch and two routers R1 and R2. Host H2 is directly attached to the Internet.

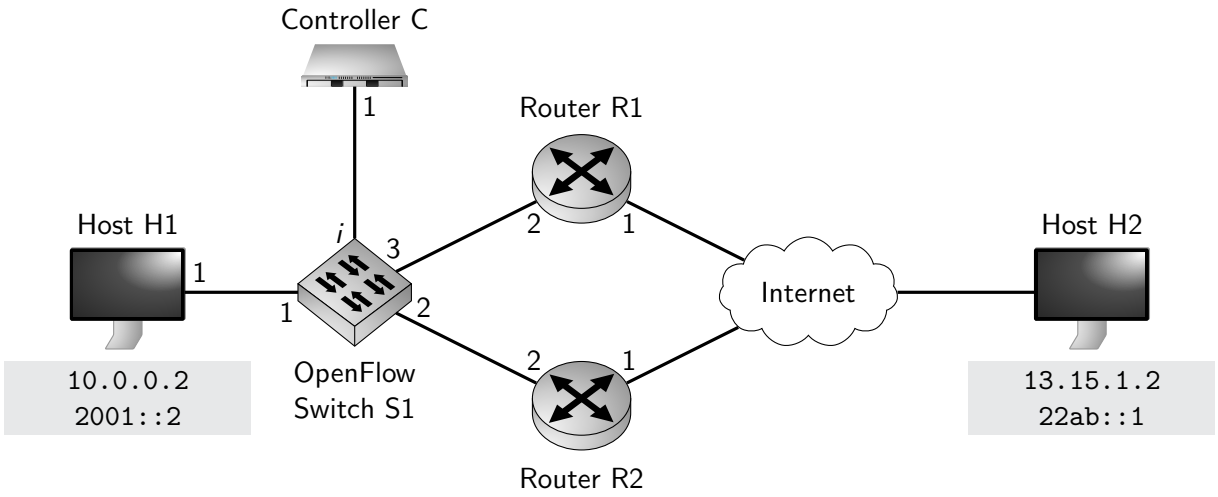


Figure 5.1: Network topology

The OpenFlow switch has a configuration interface named *i* reachable at `192.168.0.2`. Furthermore, the switch has three output ports named 1 to 3. Listing 1 gives the commands which configured this switch.

Listing 1: Open vSwitch commands

```
1 ovs-ofctl add-flow tcp:192.168.0.2 dl_type=0x86dd,nw_dst=22ab::1,priority=10000,actions=output:3
2 ovs-ofctl add-flow tcp:192.168.0.2 dl_type=0x0800,nw_dst=13.15.1.2,priority=10000,actions=output:2
3 ovs-ofctl add-flow tcp:192.168.0.2 priority=0,actions=controller
```

Note:

- To solve this problem, use the cheat sheet that is handed out separately.
- Give a reason for all answers, e.g., answering subproblem h) with “R1” without further comment gives no credit even if the answer might be right

0 1 a)* What is the general effect of specifying a `dl_type` in an OpenFlow rule? Where is the `dl_type` specified in Ethernet?

0 1 b) Look at Line 1 and Line 2 of the commands shown in Listing 1. What is the effect of the different values for `dl_type`.

c) Look at Line 1 of the commands shown in Listing 1. Explain what this command does and describe what the arguments `tcp:192.168.0.2`, `dl_type`, `nw_dst` and `actions` do in this example.

0 1 2

d) The IP address of Interface ~~1~~ 2 of Router R2 is not given in Figure 5.1. Give a sensible example for an IP address for that interface.

0

e) Host H1 and Router R2 already know the MAC addresses of each other. Host H1 pings Router R2. Despite ping packets arriving at R2, the response packets are not received by H1. Describe the way of the ping packets from Host H1 to ~~R1~~ R2 and back. Base your explanation on the interfaces (e.g., H1.1) given in Figure 5.1 and the rules specified in Listing 1.

0 1 2

f) What rule(s) has/have to be installed on Switch S1 to receive the replies at Host H1.

0 1

For the following problems you can assume that Host H1 and Routers R1 and R2 know each other's MAC addresses. Figure 5.2 shows a hexdump of an Ethernet frame, that Host H1 sent.

```
0x0000  00 25 90 57 22 4a 68 5b    35 ae 0b 32 08 00 45 00
0x0010  00 34 84 57 00 00 01 11    00 00 0a 00 00 02 0d 0f
0x0020  01 02 84 56 82 9b 00 20    bb 7e 00 00 00 00 00 00
0x0030  00 00 00 00 00 00 00 00    00 00 00 00 00 00 00 00
0x0040  00 00 5c d4 f6 00
```

Figure 5.2: Hexdump of Ethernet frame sent by Host H1 including FCS

0 1 2

g)* Mark and name all fields of the Ethernet frame.

h) Argue to which router this packet is forwarded to.

0 1

i) Take a look at the packet of the network layer protocol. What does the router do with such a packet? **Note:** You can assume that all checksums included are correct.

0 1 2

0 1

j) You assume that the packet was generated by the tool `traceroute`. Based on the observed packet, why is this a meaningful assumption.

0 1

k) Which L4 protocol is used by traceroute in this case?

l)* Another protocol which can be used for traceroute is TCP. These packets use port 80 and have the SYN flag set. Why are these meaningful default values?

0 1 2

The router which receives the packet, processes this packet, and generates an answer packet. In the following subproblems you create a hexdump of this answer packet.

Note:

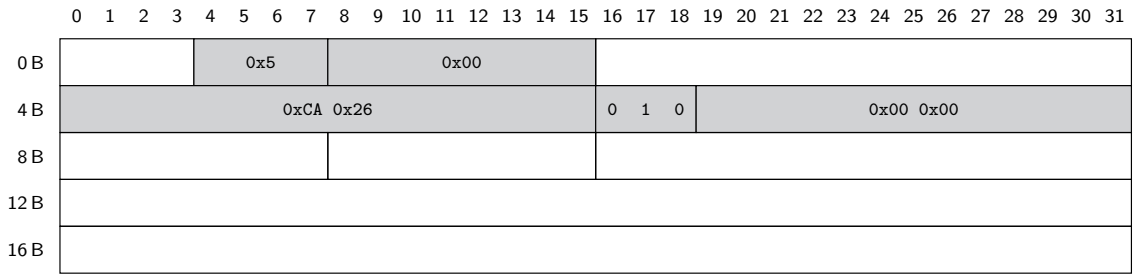
- Use hexadecimal values!
- Do not calculate checksums. Just fill in appropriately sized `0xFF` blocks.
- If values are unknown from Figures 5.1 or 5.2, create sensible values for the fields on your own.

m) Give the hexdump of the Ethernet frame created by the router after processing the packet. Replace the payload of the resulting frame with (. . .).

0 1 2

n) Give the hexdump of the IPv4 header contained as payload for the Ethernet frame generated in Subproblem m).

0 1 2 3



o) Give the hexdump of the remaining payload.

0 1 2

Additional space for solutions–clearly mark the (sub)problem your answers are related to and strike out invalid solutions.