Chair of Network Architectures and Services
Department of Informatics
Technical University of Munich

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:**	Friday 3rd March, 2017
Examiner:	Prof. Dr.-Ing. Georg Carle	**Exam:**	Final 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.
- Answers can be given in **English** or **German**
- 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** German $\leftrightarrow$ native language
- Physically turn off all electronic devices, put them into your bag and close the bag.

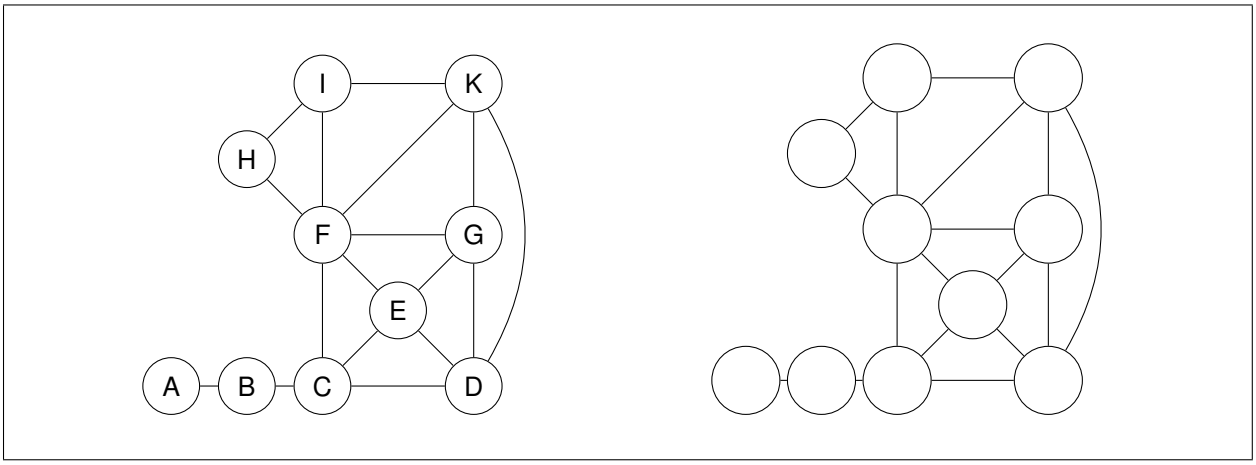
Problem 1 Quiz (7 credits)

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

0
1
2

a)* Perform the k-core algorithm for the topology shown in the solution box.

1. List the k value for every node in the graph, i. e. the current k value when the node is removed.
2. Mark the core of the network after applying the k-core algorithm.



0
1

b)* Modern network interface cards (NICs) use standardized switchable transceivers, such as the SFP module. What is a benefit of such a system compared to a NIC with a fixed transceiver?

0
½

c)* Give the technical term for the "cost free traffic exchange arrangement" between ASes.

0
1

d)* Name two routing protocols besides BGP.

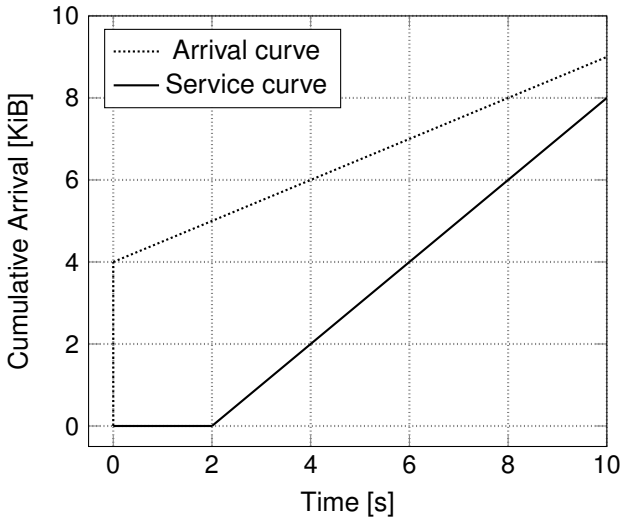


Figure 1.1: Arrival and service behavior of a packet processing system

e)* Determine the rate R and the latency L for the service curve from the graph in Figure 1.1.

0
1

f)* Mark the delay bound in Figure 1.1 and give the value in the answer box.

0
1

Problem 2 Routing - small scale (17.5 credits)

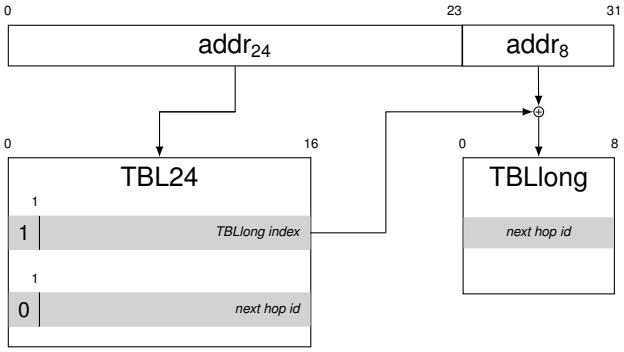


Figure 2.1: Table data structures used by DIR-24-8

The routing table is one of the key data structures of routers. This data structure is necessary for answering the forwarding decision based on the routes added. The following exercise uses the DIR-24-8-BASIC routing table, which utilizes a two-stage lookup process:

- **First stage:** This stage is used for routes with a prefix of /24 or shorter. The IP address to be looked up is split in two parts, the most significant 24 bit ($addr_{24}$, see Figure 2.1) and the least significant 8 bit ($addr_8$, see Figure 2.1). For this stage, only $addr_{24}$ is used. $addr_{24}$ acts as an index to table TBL24. TBL24 contains 2^{24} 16 bit entries, i. e., exactly one entry for each of the 2^{24} values $addr_{24}$ can have. Such an entry in TBL24 has the most significant bit set to 0 and directly contains the next hop id.

- **Second stage:** This stage is used for routes with a prefix /25 or higher. In this case the 2^{24} entries in TBL24 are not enough and therefore a second table called TBLlong is used. Such a more specific entry has the most significant bit set to 1. Its least significant 15 bit together with the $addr_8$ part of the IP address is used as an index to TBLlong to get the corresponding next hop id.

0 1

a)* Calculate the size of the TBL24 data structure in MiB (**Note:** 2^{20} B = 1 MiB).

0 1

b)* Assume that 256 /25 subnets or smaller are supported. Calculate the maximum size of the TBLlong data structure in KiB (**Note:** 2^{10} B = 1 KiB).

0 ½

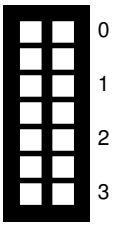
c)* Calculate the maximum number of next hop ids which can be handled by the described DIR-24-8 implementation.

Consider a DIR-24-8 that contains the following routes:

Table 2.1: Example routes

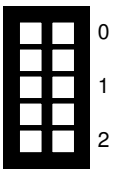
label	destination subnet	next hop id
A	10.4.0.0/23	1
B	10.8.16.0/24	2
C	10.16.0.16/32	3

d)* Give the number of accesses to TBL24 and TBLlong for the routing table containing the addresses given in Table 2.1.



Destination address	Accesses to TBL24	Accesses to TBLlong
10.8.16.232		
10.16.0.16		
10.4.1.16		

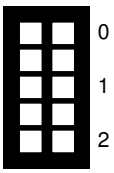
e)* Enter the entries for the route with label **A** given in Table 2.1 into a DIR-24-8 routing table. Assume that TBLlong is empty. Include the indices of each entry in each array. **Note:** Use hexadecimal values.



Index	Entry TBLlong index / next hop id

Index	Entry Next hop id

f)* Enter the entries for the route with label **C** given in Table 2.1 into a DIR-24-8 routing table. Assume that TBLlong is empty. Include the indices of each entry in each array. **Note:** Use hexadecimal values.



Index	Entry TBLlong index / next hop id

Index	Entry Next hop id

0
1
2

g) According to the creators, DIR-24-8 is an algorithm which only can be used for IPv4. Give a reason why this algorithm is not used for IPv6 and its larger 128 bit addresses.

0
1
2
3

h) Look at your solution for Problem d). What are the differences for memory accesses and what could be the reason for handling the routes differently?

0
1
2

i) Look at your previous results concerning the memory consumption and the number of data structure accesses of DIR-24-8. Argue whether the authors optimized their algorithm either for the memory consumption or data structure accesses.

Problem 3 Internet-wide Measurements (13.5 credits)

a)* Name three differences between the measurement tools nmap and ZMap.

0
1

You are now conducting an IPv4-wide measurement using ZMap to evaluate the security of home routers over the course of two weeks. You are probing one specific UDP port per target IP address.

b)* Describe two time-related phenomena that could bias your measurements.

0
1
2

Before starting the scan, you decide which target IP addresses will not be scanned. Table 3.1 shows your subnet blacklist compiled from complaints from previously conducted scans.

Table 3.1: Blacklist

Subnet
123.45.6.2/26
8.8.8.0/24
47.23.1.128/28
8.8.4.4/25
123.45.6.5/32
12.33.254.17/28
8.8.4.196/27

c)* How many IP addresses are omitted in the scans due to the blacklist shown in Table 3.1?

0
1

0
½

d)* Which additional IP addresses should you blacklist in your scanning effort if you have access to your upstream's BGP export?

The number of target IP addresses shall be denoted by n. We send a fixed UDP payload of 18 B. The scan starts on Feb 2, at 16:00:00 and ends on Feb 16, at 15:59:59.

0
1

e)* Calculate the size of the layer 2 Ethernet frame which contains the given UDP datagram. Assume minimal sized headers for all protocols. **Hint:** There is a cheat sheet.

0
1

f)* The measurement tool generates Ethernet frames with a rate of 1024 kbit/s. How many packets per second are sent?

0
1

g) Determine the number of targets n over the whole measurement period. **Note:** Document your approach, and fill in the values. You do not need to calculate the result.

Now let us look at the responses. The UDP response rate is p, the ICMP destination unreachable (type 3) rate is q. The UDP response payload is double the request payload. The ICMP response contains the original IP header and the first 8 B of the original IP packet's payload. Assume minimally-sized headers without additional extensions or options.

0
½

h)* Calculate the Ethernet frame size s_{UDP} for the UDP response?

i)* Calculate the Ethernet frame size s_{ICMP} for the ICMP response?

0
½

j) How much layer 2 payload P do we receive from the scans? **Note:** Document your approach. You do not need to calculate the result.

0
½

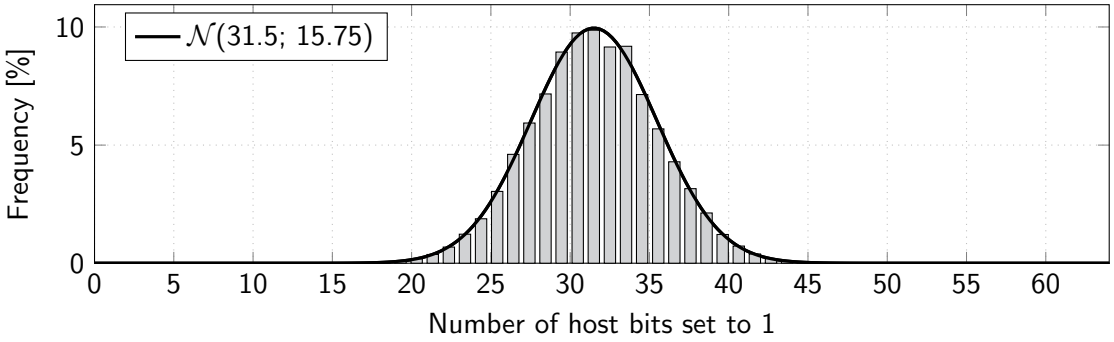


Figure 3.1: Host bit distribution of observed devices

In addition to the active IPv4 measurements you are conducting passive IPv6 measurements at an IXP observation point. Figure 3.1 shows the hostbit distribution, i. e., the number of bits set to '1' in the interface identifier of the observed IPv6 addresses.

k)* What type of devices do we mostly see at the observation point? Explain your reasoning!

0
1
2

l) Why does the normal distribution $\mathcal{N}$ approximate the hostbit distribution?

0
1

m) Why do we use $\mu = 31.5$ instead of $\mu = 32$?

0
½

Problem 4 Wireshark (18 credits)

We consider the IP packet depicted in Figure 4.1 as hexdump in network byte order.

```
0x0000  34 e6 d7 a6 c1 d0 0c c4    7a 90 f2 32 08 00 45 10
0x0010  00 3c 14 b1 40 00 40 06    f4 e0 0A 10 20 40 0A 10
0x0020  20 41 00 16 9a 9e 74 19    b7 ea 50 4a be c5 80 18
0x0030  01 5c 31 49 00 00 01 01    08 0a 5f 1a f8 4b 00 50
0x0040  43 72 00 00 00 b0 d2 aa    0f c9 3b b6 35 2a
```

Figure 4.1: Complete hexdump of an Ethernet frame

Note:

- To solve this problem, use the cheat sheet that is handed out separately.
- Give a reason for all answers, e. g. answering subproblem c) with “UDP” without further comment gives no credit even if “UDP” was correct.
- Marking headers / fields directly in Figure 4.1 is probably a good idea.

0 1 2

a)* Mark and name all header / trailer fields on layer 2 of the Ethernet frame in Figure 4.1.

b)* What is the purpose of the FCS?

0 1

0 1

c) What is the type of the L3-PDU?

0 1

d) Mark the end of the layer 3 header in Figure 4.1.

e) Determine the source and destination address of layer 3. Write the addresses in their usual, human readable form.

0 1 2

f) What is the type of the L4-PDU?

0 1

g) What is most likely the application layer protocol?

0 1

h) Determine the beginning of the L4-SDU.
Hint: TCP headers are aligned at 4 B boundaries.

0 1 2

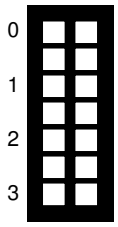
Table 4.1: TCP options

Type	Description
0	End of option list
1	No-Operation (NOP)
2	Maximum segment size
3	Window scale
4	SACK permitted
5	SACK
8	Timestamps

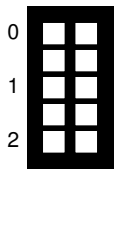
The hexdump shown in Figure 4.2 represents the second TCP segment exchanged while establishing a connection. The header includes multiple TCP options, among others the window scaling option. The first byte of each option specifies its type, the second byte its total length in multiples of 1 B. An exception is the `NOP` option used for padding, which has a fixed length of 1 B. Table 4.1 lists some common TCP options and the type values.

```
0x0000  01 bb e3 cc 3a 11 77 ad    a4 f6 55 2c a0 12 71 20
0x0010  a1 fd 00 00 02 04 05 b4    04 02 08 0a 6a 12 1f 2e
0x0020  62 bf 17 47 01 03 03 09
```

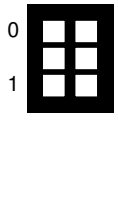
Figure 4.2: Hexdump of a TCP segment during handshake (including TCP header)



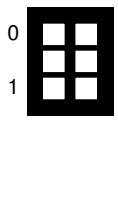
i)* List the options that are contained in the segment of Figure 4.2 in the order of their appearance.



j)* Explain how window scaling works.



k)* Which particular problem is addressed by the window scaling option?



l) Determine the window scaling factor as power of 2.

Problem 5 SSH (4 credits)

Consider the network topology displayed in Figure 5.1. Client C is connected to Server S via an ssh connection. The ssh connection uses the default router on Server S via the Internet.

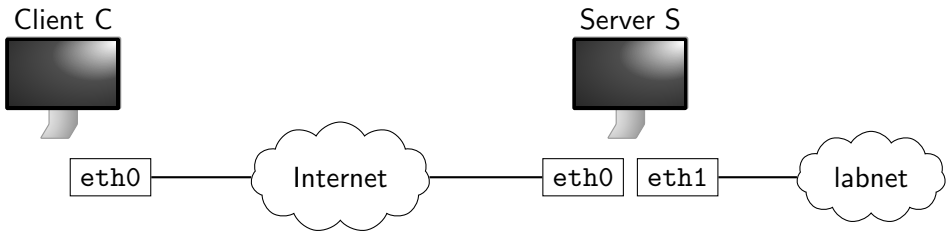


Figure 5.1: Network topology

a) Which packets take the default route in general?

0
1

Server S has a second interface attached to an internal lab network. Now, the default route on Server S is changed via the ssh connection towards the lab network. After that you do not get any answer back from the Server S. You type *reboot* and press enter in your still open ssh console on Client C.

b) Explain and reason in detail what happens next.

0
1
2
3

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