Department of Informatics
Technical University of Munich (TUM)

Note:
- During the attendance check a sticker containing a unique QR code will be put on this exam.
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Advanced Computer Networks

Module: IN2097
Examiner: Prof. Dr.-Ing. Georg Carle
Date: 10.02.2016
Exam: Final exam

	P 1	P 2	P 3	P 4
First correction				
Second correction				

Left room from ________ to ________

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Early submission at ________

Notes ________

Final exam

Advanced Computer Networks

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Wednesday, 10.02.2016
11:30 – 12:30

- This exam consists of
  - **16 pages** with a total of **4 problems** and
  - a two-sided printed **cheat sheet**.

  Please make sure now that you received a complete copy of the exam.
- Subproblems marked by * can be solved without results of previous subproblems.
- **Answers are only accepted if the 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.
- Allowed resources:
  - one printed **dictionary** German ⇔ native language **without annotations**
- Physically turn off all electronic devices, put them into your bag and close the bag.

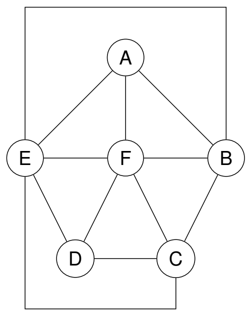
Problem 1 Quiz (7 credits)

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

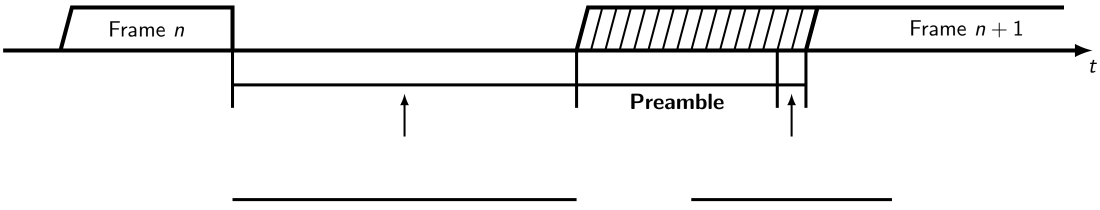
a)* Name and explain the two basic principles for handling I/O from hardware devices such as NICs.

b)* Hardware routers often posses a ternary content addressable memory (TCAM) module. This type of memory supports a third state `*` besides the usual binary states `0` and `1`. Explain why this kind of memory is beneficial with respect to implementing lookup tables for hierarchical address structures such as IP addresses.

c)* Determine the k-core such that k is maximized and the core is non-empty. State k and all nodes contained.



d)* The figure below shows the minimum idle time of the medium between two consecutive Ethernet frames. Name the remaining two fields during that time span.



Problem 2 NAT (14 credits)

a)* Explain two different approaches to mitigate or solve the IPv4 address scarcity.

b)* Explain the difference between private (as defined in RFC 1918) and public IPv4 addresses.

c)* Explain why NAT causes problems with peer-to-peer applications.

d)* How does an Application Layer Gateway (ALG) operate?

e) Is an ALG implemented on a host located behind a NAT, on a NAT router, or on a public server on the Internet?

f) Name two examples for protocols that can be handled by an ALG.

g)* Name two different approaches how a host located behind a NAT router can detect the public IP address assigned by the NAT.

Figure 2.1 (see next page) describes a simiplified 464XLAT setup, consisting of a client (PC1), a customer-side translator (CLAT), a provider-side translator (PLAT), and a public server (SRV). Both PC1 and SRV are legacy devices that do not support IPv6. We assume that a webbrowser on PC1 establishes a connection to a webserver running on SRV. The message (gray line) shown in Figure 2.1 represents the HTTP request sent by the client.

The CLAT and PLAT devices translate IPv4 packets into IPv6 packets and the other way round. The CLAT device performs stateless NAT46, i. e., it translates from the IPv4 address space into a special reserved IPv6 address space (`::ffff:0:0/96`). The PLAT device translates from the IPv6 address space into the IPv4 address space.

	i	ii
0		
1		
2		
3		

h)* Complete the header fields of the HTTP request that can be observed at the three indicated links in Figure 2.1. Assume that the PLAT device uses a random port binding strategy. If the content of a field is not uniquely defined from the given information, make a **meaningful** choice. **Important: Do not abbreviate your addresses. Use real values!**

	i	ii
0		
1		

i) Fill out the PLAT state table in Figure 2.1 after the HTTP connection was established. Use the same addresses and ports as specified in Problem 2h).

	i	ii
0		
1		

j) Why can the CLAT device operate statelessly while the PLAT device needs to keep state?

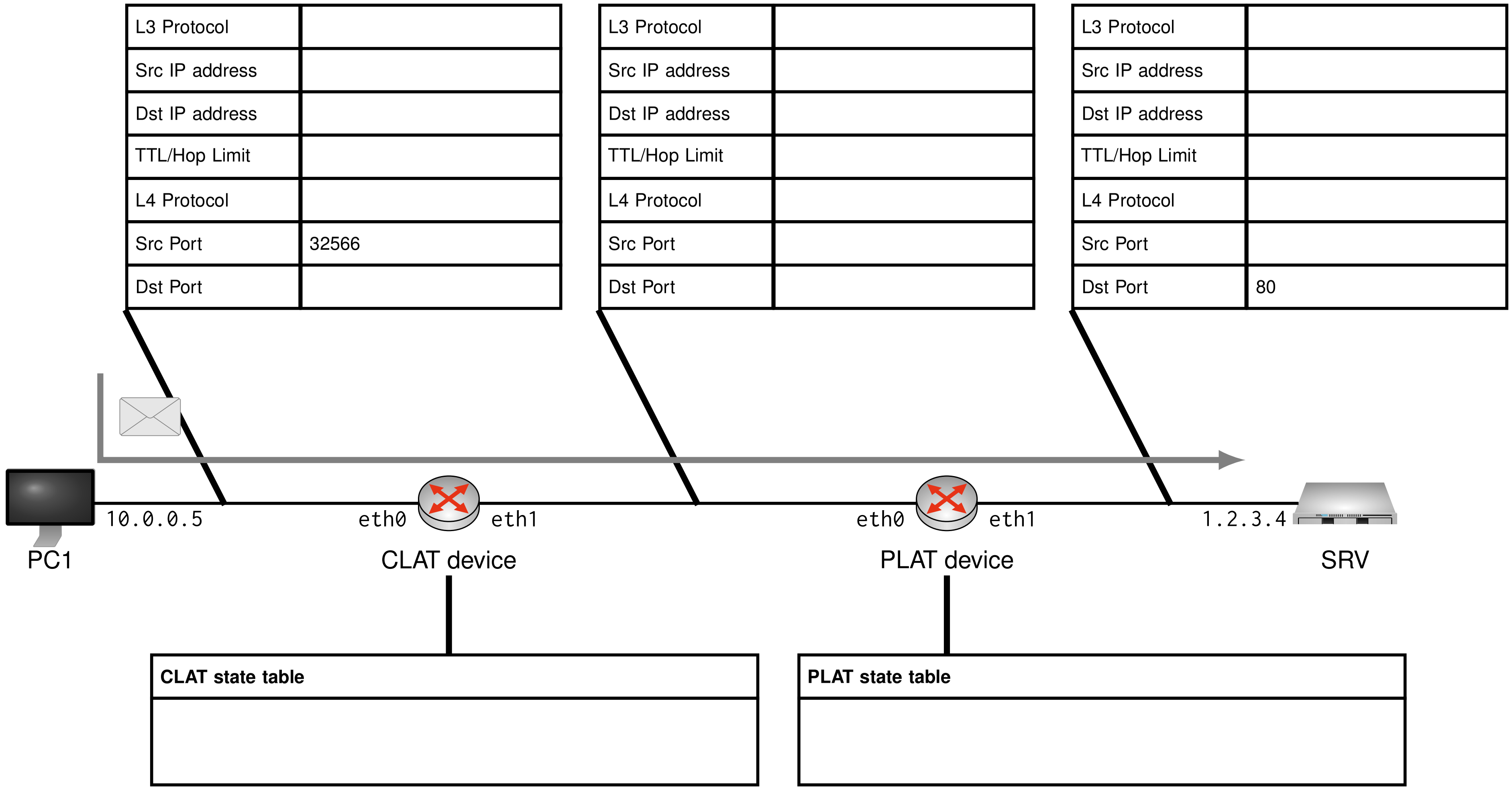


Figure 2.1: 464XLAT topology

Problem 3 Load Balancing & Traceroute (22 credits)

IP-based networks allow for complex network topologies. A popular tool to discover topologies for such networks is `traceroute`. However, one has to know the impact of techniques such as load balancing on traceroute to make use of this tool.

	i	ii
0		
1		
2		

a)* Explain the purpose of load balancing for network traffic.

	i	ii
0		
1		

b) Given redundant paths; explain which problems might arise if packets are routed independently of each other.

	i	ii
0		
1		

c) Explain the impact on transport layer protocols such as TCP.

d)* State the header fields that are needed to uniquely identify a flow in the context of transport layer protocols such as TCP or UDP.

e) Briefly explain how load balancing over redundant links can be accomplished, while avoiding the problems discussed in Subproblems 3b) and 3c).

f)* Explain how traceroute works. (Give a detailed explanation of the basic principle. You do not have to explain advanced variants of traceroute.)

g) How could load balancing be detected in the output of traceroute?

Figure 3.1 shows the actual topology of a network. On node *Src* traceroute was executed several times. The destination of the traceroute calls was node *Dst*. Every node in this topology only has a single unique IP address. No loopback links are present in this topology. Assume that routers are well-behaved and standards compliant.

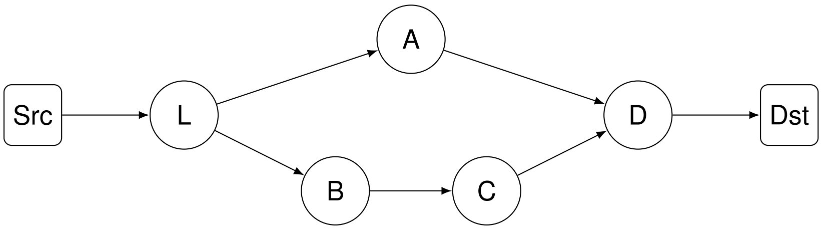


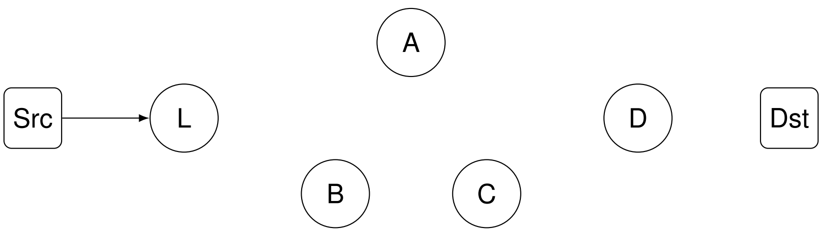
Figure 3.1: Actual network topology

```
[TTL] [IP]                [Delay]
1        80.181.192.164    9.4 ms    9.4 ms    9.3 ms
2       213.239.245.249   12.5 ms
        213.239.245.253   12.3 ms   12.4 ms
3       213.239.245.208   14.1 ms   13.9 ms
        213.239.245.249   13.9 ms
4       213.239.245.207   16.3 ms   16.6 ms
        213.239.245.210   16.4 ms
```

Listing 1: Output of traceroute

h)* Argue whether or not Listing 1 shows a valid output of traceroute for the topology depicted in Figure 3.1.

i) Complete the figure in the solution box with a minimal number of arcs such that it represents a valid topology for the output of Listing 1. Hint: Additional load balancers may be used.



j) Give a valid mapping between the IP addresses of Listing 1 and node names of your topology in Problem 3i).

IP address	Node name
80.181.192.164	
213.239.245.207	
213.239.245.208	
213.239.245.210	
213.239.245.249	
213.239.245.253	

From another run of traceroute someone inferred that the network's topology should be drawn as follows:

$$\text{Src} \rightarrow \text{L} \rightarrow \text{B} \rightarrow \text{D} \rightarrow \text{D} \rightarrow \text{Dst}$$

k)* State the paths that probes with TTL $\leq$ 4 sent from Src to Dst must have taken such that the topology above is valid. Base the answer either on your topology of Subproblem 3i) or on the topology given in Figure 3.1.

TTL	Path

Assume that the load balancer *L* in Figure 3.1 balances traffic on a per-flow basis. Furthermore, assume that traceroute sends TCP probes.

l)* Explain why traceroute fails to discover the correct topology under these circumstances.

m)* Suggest an improvement to traceroute such that the correct network topology can be discovered.

Problem 4 Wireshark (17 credits)

We consider the Ethernet frame (including link layer checksum) depicted in Figure 4.1 as hexdump in network byte order.

```
0x0000  ff ff ff ff ff ff 0c c4   7a 6b c3 75 08 06 00 01
0x0010  08 00 06 04 00 01 0c c4   7a 6b c3 75 81 bb 91 f2
0x0020  ff ff ff ff ff ff 81 bb   91 f2 b0 56 0d 0a
```

Figure 4.1: Hexdump of an Ethernet frame (including link layer checksum) in network byte order

Note: To solve this problem use the cheat sheet that is handed out separately.

a)* Explain the difference between network and host byte order.

b)* Reason whether or not there is a difference between network and host byte order for single byte values.

c)* Explain the difference between *protocol data unit (PDU)* and *service data unit (SDU)*.

d)* Mark and name *all* parts of the protocol specific information for layer 2 in Figure 4.1.
Note: Put your solution directly in Figure 4.1.

e) Briefly explain the purpose of **each** part.

To make it a bit easier, we let you know that the payload of the Ethernet frame in Figure 4.1 is ARP.

f)* How does a receiving node determine that the frame indeed carries an ARP payload?

g)* Explain the main purpose of ARP.

h) Reason which network layer protocol is being served.

i) Determine the opcode **and** meaning of the ARP packet.

j) Determine the source and target link layer addresses of the ARP packet.

k) State the source and destination network layer addresses of the ARP packet in the manner customary for that network layer protocol.

According to Subproblem 4k), you may be a bit skeptical how meaningful that frame is. However, the frame was captured on a real network as is and it makes perfectly sense as it is a *gratuitous* ARP packet.

l)* Explain what gratuitous ARP is being used for **and** how it works.

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