Name	Vorname
Studiengang (Hauptfach)	Fachrichtung (Nebenfach)
Matrikelnummer	Unterschrift der Kandidatin/des Kandidaten

....
Note

TECHNISCHE UNIVERSITÄT MÜNCHEN

Fakultät für Informatik

- ☐ **Midterm-Klausur**
- ☒ **Final-Klausur**

- ☐ **Semestralklausur**
- ☐ **Diplom-Vorprüfung**
- ☐ **Bachelor-Prüfung**
- ☐ ....

- ☐ **Einwilligung zur Notenbekanntgabe per E-Mail / Internet**

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Prüfungsfach: Master Course: Computer Networks

Prüfer: Prof. Dr.-Ing. Georg Carle **Datum: February 16, 2013**

Hörsaal: .... **Reihe:** .... **Platz:** ....

Nur von der Aufsicht auszufüllen:

Hörsaal verlassen **von ...... : ......** **bis ...... : ......**

Vorzeitig abgegeben **um .... : ......**

Besondere Bemerkungen:

Trial exam

Master Course: Computer Networks

Prof. Dr.-Ing. Georg Carle
Chair for Network Architectures and Services
Department of Computer Science
Technische Universität München

Saturday, February 16, 2013
9:00 a.m. – 10:00 a.m.

- This exam consists of **14 pages** and a total of **4 problems** as well as an **additional handout** which contains a reference of protocol headers. Please make sure that you got a complete copy of all documents.
- Write your name and matriculation number in the header of **every** page.
- Do neither write with red / green colors nor use pencils.
- The total amount of credits is 50.
- This exam is **closed book**, i. e., lecture notes, homework, cheat sheets, pocket calculators etc. are **not** allowed.
- Turn off your mobile phones and put them into your bag.
- Problems marked by * can be solved without knowledge of previous results.
- **Results are only rated if your approach is reproducible**. If not instructed otherwise, state a reason for all your answers.

Aufgabe 1 Packet pair probing (16 credits)

16

Given the network depicted in Figure 1.1. Nodes i and j are connected via an asymmetric link, e.g. some kind of DSL connection. Consequently, the upstream and downstream bandwidth differ from each other, i. e., $r_{ij} \neq r_{ji}$. You may assume that node i is a router which connects the private network to the public one. Node j would then represent the first rotuer under control of your ISP.

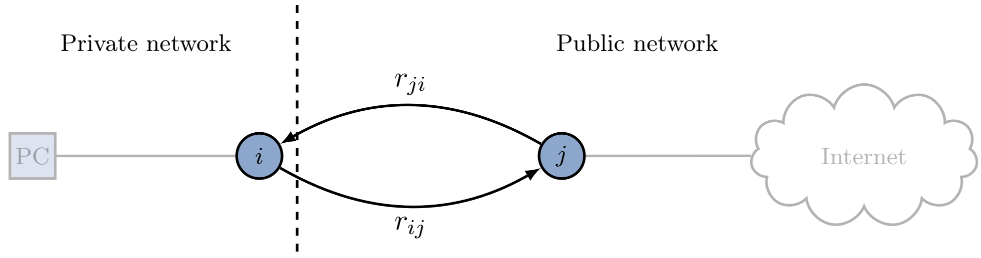

Figure 1.1: Logical network topology

In this problem we will develop an approach that allows node i to estimate the upstream bandwidth r_{ij}. Of course, we are looking for something more elaborate than simply saturating the connection. Instead, we seek for an approach that minimizes the amount of measurement traffic.

For simplicity we neglect layer 2 headers. The packet size x is there equivalent to the layer 3 PDU. You may further assume that there is no cross traffic that might influence the the measurement.

a)* State the serialization delay $s_{ij}(x)$ on the link from i to j as function depending on the packet size x. 1

b) Show or disprove $s_{ij}(x) = s_{ji}(x)$. 1

1

c)* State the propagation delay $p_{ij}(l)$ on the link from i to j as function depending on the length l of the physical connection (cable length) between i and j.

1

d) Show or disprove $p_{ij}(l) = p_{ji}(l)$.

(continue on next page)

Usually the downstream bandwidth is higher than the upstream bandwidth. We therefore assume $r_{ij} \leq r_{ji}$. Now consider the following exchange of messages:

1. Node i sends a packet of length x_1 to node j, e.g. an ICMP echo request.
2. Node j answers with a packet of the same length.
3. After a short while, node i sends another packet of length $x_2 > x_1$.
4. Node j answers again with a packet of length x_1 (not x_2).

You may neglect any processing delays at the nodes.

e)* Draw a diagram that shows this message exchange. Both serialization and propagation delays should be clearly visible in your diagram! 5

The message exchange allows node i to measure the RTT to j two times with slightly different settings.

1

f) Mark the two RTTs measurements RTT_1 und RTT_2 in your solution of subproblem e).

2

g) State RTT_1 und RTT_2 as function depending on the packet sizes x_1, x_2. Reuse your results from a), c), and e). Remember that node j only sends packets of length x_1.

3

h) Determine $\Delta := \mathrm{RTT}_2 - \mathrm{RTT}_1$ and simplify the result.

1

i) Derive an expression for the upstream bandwidth r_{ij}

Problem 2 Routing (11 credits)

11

In the lecture we learned about different types of routing protocols. This problem first covers general aspects of routing protocols and then discusses one type of protocols in more detail.

a)* Name all routing protocols you know (should be at least three). 2

b) Categorize all routing protocols you know according to their scope of application. 2

c) Categorize all routing protocols you know according to their mode of operation. 2

We now consider a generalized DV protocol which is used to populate routing tables of the nodes depicted in Figure 2.1. The edge weights represent costs, i. e., lower is better.

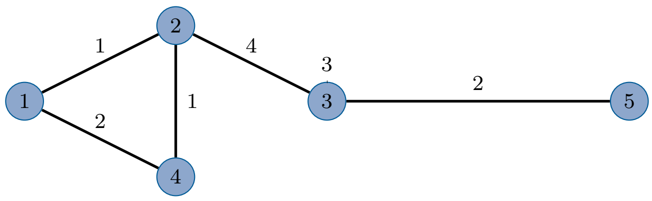

Figure 2.1: Sample topology

1

d)* Cast the network's distance matrix $\boldsymbol{D}$.

1

e)* The m-th power of $\boldsymbol{D}$ with respect to the min-plus product yields the shortest distances between all nodes. Determine m.

1

f)* Why is $\boldsymbol{D}^m$ symmetric?

1

g) Assume that nodes exchange their routing tables every 30 s. Estimate the time needed until all nodes have a common view of the network (starting with empty routing tables).

1

h) Propose a method to speed-up the convergence time (besides reducing the update interval).

Problem 3 **Transport protocols (16 credits)**

16

In this problem we consider the two transport layer protcols TCP and UDP.

a)* From an application developer's point of view, when would you prefer UDP over TCP? 2

b)* Explain the difference between flow and congestion control. 2

c)* Assume that a client just established a new TCP connection to a server and starts downloading a large file. Sketch a common development of the server's sending window over time. 2

d) Mark and name in your answer of (c) the different phases a TCP connections usually go through. 2

Depending on the TCP version, the sender reacts differently in case of packet loss, which is detected either by duplicate acknowledgements or timeouts. The exact differences between different TCP versions are of less interest here. Instead, we discuss in the following which meaning the detection method has from the sender's point of view.

2

e)* Explain how it may come to duplicate acknowledgements.

2

f) Do duplicate acknowledgements inevitably indicate packet loss?

1

g) Explain how it may come to a timeout.

1

h) Does a timeout inevitably indicate packet loss?

2

i) Which is the rationale to react differently on both events?

Problem 4 Protocol dissemination (7 credits)

7

Figure 4.1 shows the hexdump of some frame captured on a wired network (Ethernet II frame format). The dump contains the whole frame (except its FCS) beginning with the target MAC address. Now we will figure out the contents ...

```
0000   00 25 90 57 1f dc 28 37   37 02 32 41 08 00 45 00
0010   00 42 99 a8 00 00 40 11   b6 9e 83 9f 14 59 83 9f
0020   0e cd d4 1e 00 35 00 2e   c2 25 c2 51 01 00 00 01
0030   00 00 00 00 00 00 06 73   6c 61 63 6b 79 03 6e 65
0040   74 02 69 6e 03 74 75 6d   02 64 65 00 00 01 00 01
```

Figure 4.1: Hexdump, leftmost column indicates the hex offset from the beginning of the frame.

In the following problems you are asked to mark specific parts of the frame directly in Figure 4.1, i. e., for many problems you do not have to write anything in the answer box. Clearly state in Figure 4.1 the header names, protocol types, or the subproblem your markings belong to!

a)* Mark the link layer header in Figure 4.1. 1

b) Mark the network layer header in Figure 4.1. 1

c) Determine the TTL value. 1

d) Mark the transport layer header in Figure 4.1. 1

1

e) Which meaning does the payload have?

1

f)* Which parts of the frame are modified by an Ethernet switch?

1

g)* Which parts of the frame are modified by a router?

Additional space for solutions – plaese clearly indicate to which problem your notes belong and strike invalid solutions.