Advanced Computer Networking (ACN)

IN2097 – WiSe 2019-2020

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Chapter 0: Introduction & Organization

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Bibliography
Professional career:

1985 - 1992 Studies of Electrical Engineering, University of Stuttgart, Germany
1988 - 1989 Master of Science, Brunel University, London, UK
    1990 Ecole nationale Supérieure des Télécommunications (ENST), Paris, France
1992 - 1996 PhD in Computer Science at University of Karlsruhe, Germany
    1997 Postdoc at Institut Eurecom, Sophia Antipolis, France
1997 - 2002 Fraunhofer FOKUS, Berlin, Germany
    Head of Competence Center Global Networking
2003 - 2008 Professor, University of Tübingen, Germany
2008 - * Professor, Technical University of Munich, Germany

Further positions:

- Since 1997 co-PI in many national and international projects
- Since 2013 Information Officer of Department of Informatics at TUM (previously Managing Director)
- Secretary of IFIP Working Group 6.2 Network and Internetwork Architecture
- Co-chair of ITG Working Group 5.2.2 Network Security
- Member of Board of German Computer Science Univ.-Prof. Association
• Who is new at TUM?
• Who studies what?
  • Master in Informatics?
  • Master in Informatics - english track?
  • Master in Informatics: Games Engineering?
  • Master in Information Systems \((Wirtschaftsinformatik)\)?
  • Master in Communications Engineering MSCE?
  • Other master courses?
  • Bachelor in Informatics?
  • Bachelor in Informatics: Games Engineering?
  • Bachelor in Information Systems?
  • Other courses?
• Previous relevant courses?
  • Grundlagen Rechnernetze und Verteilte Systeme (GRNVS)?
  • Other courses in Computer Networks?
  • iLab (Internet Lab)?
  • Other networking lab courses?
  • What else?

• Other related courses?
  • Network Security?
  • Peer-to-Peer Communications and Security?

• Other relevant skills?
  • C programming skills?
  • Using a (virtualized) Unix / Linux server?
Goals of the course

• Learn to take responsibility for yourself
• Think about the topics
  • Do not aim just being able to repeat content of these slides without deeper understanding
• Learn to *reflect* on technical problems
• Learn to apply your knowledge
• Understand the principles
  • What is the essence to be remembered in some years?
  • What would you consider suitable questions in an exam?
• Learn from practical project performed during the course
General learning outcomes

• Knowledge
  • Being able to reproduce facts

• Understanding
  • Being able to explain properties with own words

• Applying
  • Apply known methods to solve questions

• Analyzing
  • Identifying the inherent structure of a complex system

• Synthesis
  • Creating new solutions - from known elements

• Assessment
  • Identifying suitable criteria and perform assessment
General learning outcomes

• Knowledge, Understanding, Applying
  • Protocols: data link layer, network layer, transport layer, application layer
  • Concepts: measurements, signaling, QoS, resilience
    ⇒ Lectures, exercise questions, final exam

• Analyzing, Synthesis, Assessment
  • Special context: network properties
  • Tools: git, measurement tools, DPDK, ...
  • Methods: plan solution, program, administer experiment setup, measure, reflect, document
    ⇒ Course project
Course overview (*to be modified …*)

- **Part 1: Internet protocols - an overview on computer networks link layer**
  - Overview on computer networks
  - Link layer
  - Software-Defined Networking
  - Internet structure
  - Transport layer
  - Application layer

- **Part 2: Advanced concepts**
  - Measurements
  - Quality of Service
  - Node architectures and mechanisms
  - Network management
  - Signaling
  - Resilience
  - Design principles and future Internet
Acknowledgements:

Significant parts of the course are based on this book:


Jim Kurose, University of Massachusetts, Amherst, USA

Keith Ross, Polytechnic institute of New York University, USA
Introduction

Acknowledgements

Additional book relevant for the course:


(a) Douglas Comer, Purdue University, Amherst, USA
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Times and addresses

- **Time slots**
  - Tuesday, 16:15 - 17:45, Interims HS 1
  - Thursday, 14:15 - 15:45, Interims HS 2

- **TUMonline**
  - Registration is required for access to course infrastructure
  - Exam registration is required (estimated start: end of November)

- **Course material**
  - Slides are available online (may be updated during the course)
  - Additional supporting material (exercise sheets, exams of previous semesters)
  - Web address: http://acn.net.in.tum.de
Questions and answers / office hours

- Prof. Dr.-Ing. Georg Carle
  - Contact: carle@net.in.tum.de
  - After course and upon appointment (typically Monday 18:00)

- Teaching assistants
  - Sebastian Gallenmüller
  - Max Helm
  - Benedikt Jaeger
  - Patrick Sattler
  - Johannes Zirngibl

- Coordination of exercises and project
  - Contact: acn@net.in.tum.de
  - Upon appointment or just drop by
Course organization

Exam

• Exam date (preliminary): February 12, 2020 starting 10:30 am
• Closed book, cheat sheet will be provided by us
• Written exam at the end of the semester (75 min, 75 credits)
• Official date and location to be announced via TUMonline

Bonus

• Exercise (up to 60 credits)
• Project (up to 10 credits)
• No teamwork allowed
• bonusCredits = min(15, (creditsExercise/6 + creditsProject))
• finalGrade = grade(creditsFinalExam + bonusCredits)
• Bonus is only added IFF the final exam is passed without bonus, i.e., 4.0 or better

People caught cheating in any submission are excluded from the entire bonus system. Adhere to the official guidelines of the Department of Informatics:

• EN, http://go.tum.de/854881
• DE, http://go.tum.de/246064
Retake Exam

- There will be a written retake exam
- The retake exam usually takes place at the end of March/begin of April
- The bonus will also be valid for the retake exam
- You need to register for the retake exam separately (usually starting at mid of March)
- You do not need to be registered for the main exam to participate in the retake exam
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Approach to Exercises

• Self correction
• Gain insight by reviewing own mistakes

Regular 2-week exercise process

1. New problem is released on a Thursday (first on Oct. 24)
2. Submission via git as an electronic notebook on a Thursday one week later
3. Discussion of solution during the Thursday lecture slot
4. Submission of self-corrected solution until Tuesday of the following week
Self correction methodology

• Learn from your mistakes
• Improve your solution
• **Do not copy the presented sample solution, adapt your own solution!**
• Correct mistakes in first submission
• Submit via git
Exercise and project

Submission process

- Everyone gets an individual git repository
- **Note:** There are different git repositories for downloading lecture slides or the project code
- Access with personal SSH public key
- Put the submission in the correct folder
  - e.g., tutorial00/
- Commit **and push** to origin/master before the deadline
- More details provided on exercise sheet 0
Exercise and project

Grading

- After final submission we will grade your initial solution and the correction
- Grades will be published in your individual git repository
- Solution will be released after grading is finished
Exercise and project

Jupyter Notebook

- Will be used for the exercises
- Think of it as an interactive worksheet
- Write python code and plot graphs directly in your answers
- Accessible via your browser
- Hosted on a VM (no configuration required)
import pandas as pd
import numpy as np
import matplotlib

from matplotlib import pyplot as plt
import seaborn as sns

ts = pd.Series(np.random.randn(1000), index=pd.date_range('1/1/2000', periods=1000))
ts = ts.cumsum()

df = pd.DataFrame(np.random.randn(1000, 4), index=ts.index,
                  columns=['A', 'B', 'C', 'D'])
df = df.cumsum()
df.plot(); plt.legend(loc='best')

Figure 1
Exercise and project

Project software router

- Implement a software router
- Using the packet processing framework DPDK
- Programming language: C or C++
- You get virtual machines for setting up your router

- Submissions using git repository
- Project deliverables are graded
Exercise and project

Step 1

- Login into your virtual machines
- Configure the VM setup
- Compile & configure DPDK
- Test your setup with a simple DPDK forwarding example
- Submission: scripts configuring router and clients
Exercise and project

Step 2

- Command line interface
- Router should answer the clients’ ARP requests
- Sanity checks on IP packets
- Do routing decision and forward packets accordingly

Step 3

- Implement a routing table
- Algorithm of choice: DIR-24-8
- Integrate routing table into your software router

Step 4

- Measure throughput/latency your implementation
- Plot your measurement results
- Create a test report of your findings
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• Who wrote an exam with TUMexam yet?
• Under development at I8 since 2015
• Several students involved
• In use at chairs from mathematics, computer science and mechanical engineering

Advantages for Students:
• Online review process
  1. Receive corrected exam as PDF
  2. Give justified feedback about the correction
  3. We update the correction if needed
• Final points are summed up automatically → less error prone
• No additional interference while taking the exam
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Lecture overview

Sources of delay

- Processing
- Queuing
- Propagation
- Transmission
Lecture overview
Internet structure

- Autonomous systems (AS level structure)
- Routers and hosts (IP level structure)
Tunneling is the art of encapsulating datagrams inside other datagrams. Most widely known examples are VPNs.
Lecture overview
Network layer - routing

Routing algorithms
- Link state
- Distance Vector
- Hierarchical routing

Routing in the Internet
- RIP
- OSPF
- BGP

Broadcast and multicast routing

Example OSPF network
Lecture overview

SDN

Data plane

Control plane

VM1 to VM3: W -> Z -> Y
VM2 to VM4: W -> X -> Y

Switch W
Switch X
Switch Y
Switch Z

Hypervisor 1
VM1
VM2
Hypervisor 2
VM3
VM4
• Network traffic is constantly growing
• Growth/Scaling can be achieved using CDNs
Lecture overview
Transport layer services

- Transport-layer services
- Multiplexing and demultiplexing
- Connectionless transport: UDP
- Connection-oriented transport: TCP
  - Segment structure
  - Reliable data transfer
  - Flow control
  - Connection management
- TCP congestion control
- SCTP
Lecture overview
Pipelining for increased utilization

\[ U_{\text{sender}} = \frac{3 \cdot L/R}{RTT + L/R} \]
Lecture overview
TCP Congestion Control

Congestion is bad...

- So... How exactly do we control it? → Ongoing research effort

TCP Reno

TCP Cubic
Why is TCP fair?

Two competing sessions:

- Additive increase gives slope of 1, as throughput increases
- Multiplicative decrease decreases throughput proportionally
Lecture overview
Does 36 year old TCP even have a place here?

Newer alternative: Google QUIC
• Way faster development cycle
• Built-in encryption support
• 0-RTT handshake (with a bit of luck...)
• No head-of-line blocking
• IP mobility proof
• Shiny new toy the cool kids play with :)

Let's squeeze all out of it
• TCP BBR
• Newest Congestion algorithm from Google
• Gets high throughput ...
• ... while maintaining low latency
• No need to adapt applications
Lecture overview
Network measurements

- Introduction
- Architecture & mechanisms
- Protocols
  - IPFIX (netflow accounting)
  - PSAMP (packet sampling)
- Scenarios
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