Master Course
Computer Networks
IN2097

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Outline - Introductory Lession

- Knowing each other
  - Who studies what?
  - What ist your background?
- Learning Outcomes
- Course Outline
- Organisational Formalities
- Overview
- Research

Georg Carle

1985-1992: Studies of Electrical Engineering, University of Stuttgart

1988/1989: Master of Science, Brunel University, London, U.K.

1990: Ecole Nationale Supérieure des Télécommunications (ENST), Paris

1992-1996: PhD in Computer Science at University of Karlsruhe

1997: Postdoc at Institut Eurecom, Sophia Antipolis

1997-2002: Fraunhofer FOKUS, Berlin;
Head of Competence Center Global Networking

2003-2008: Professor, University of Tübingen

Since April 2008: Professor, Technical University Munich

2010-2013 Managing Director of Department of Computer Science

Since 1997 co-PI in many national and international projects

Vicechair of IFIP Working Group 6.2 Network and Internetwork Architecture

Member of Board of the German Computer Science Faculties Association

Member of Board of German Computer Science Univ.-Prof. Association

Questions

- Who is new at TUM?

- Who studies what?
  - Master in Informatics?
  - Master in Informatics – English Track?
  - 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 [Wirtschaftsinformatik]?
  - Other courses?

More Questions

- Which previous relevant courses?
  - IN0010 - Grundlagen Rechnernetze und Verteilte Systeme?
  - 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?
  - Setting up a (virtualized) unix / linux server?
  - Using up a (virtualized) unix / linux server?

Intended Learning Outcomes and Competences

- Goals of the course
  - Learn to take responsibility for yourself
  - Think about the topics
    (do not aim just being able to repeat content of theses 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 course

General Learning Outcomes

- Knowlege
  - 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

Learning Outcomes
- what students are expected to acquire from the course

- Knowledge, Understanding, Applying
  - protocols:
    application layer, transport layer, network layer, data link layer
  - concepts:
    measurements, signalling, QoS, resilience

  ⇨lectures, exercise questions
  final examination
- Applying, Analyzing, Synthesis, Assessment
  - special context: network properties, TCP
  - tools: svn, measurement tools, ...
  - methods: plan solution, program, administer experiment setup, measure, reflect, document

  ⇨course project

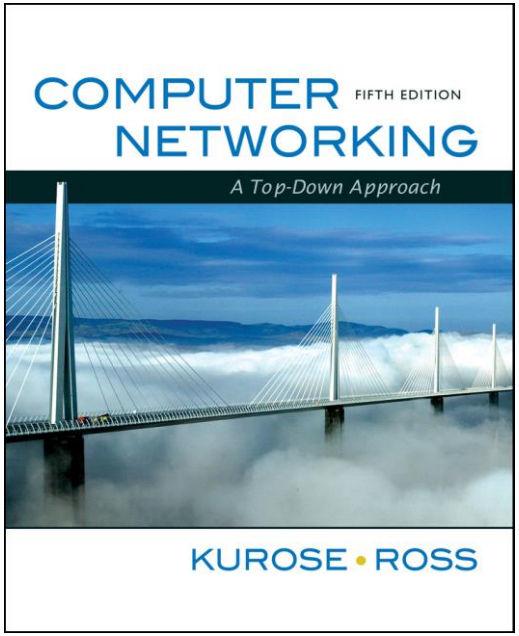
Course Overview (Tentative)

- Part 1: Internet protocols
  - Overview on Computer Networks
  - Link Layer
  - Internet Structure
  - Transport Layer
  - Application Layer
- Part 2: Advanced Concepts
  - Measurements
  - Quality of Service
  - Node Architectures and Mechanisms
  - Network Management
  - Signalling
  - Software-Defined Networking
  - Resilience
  - Design Principles and Future Internet

Books (1)

Acknowledgements

- *Significant parts of this lecture are based on the book* *Computer Networking: A Top Down Approach* , Jim Kurose, Keith Ross Addison-Wesley, 5th edition, April 2009.
- Many lecture slides are based on slides by Jim Kurose and Keith Ross



Jim Kurose
University of Massachusetts, Amherst

Keith Ross
Polytechnic Institute of New York University

Books (2)

- A further book relevant for the course:
  Douglas Comer
  Internetworking With TCP/IP Volume 1:
  Principles Protocols, and Architecture,
  Addison-Wesley, 5th edition, 2005

Douglas Comer
Purdue University

Course organization

- Time slots
  - Monday, 10:15-11.45, MI 00.13.009A
  - Tuesday,16:15-17.45, MI 00.13.009A
- TUMonline
  - registration required for access to course infrastructure
  - exam registration will be required
- Questions and Answers / Office hours
  - Prof. Dr. Georg Carle, carle@in.tum.de
    - After the course and upon appointment (typically Monday 18-19)
  - Oliver Gasser, gasser@net.in.tum.de
    - coordinates exercises
    - upon appointment, or just drop in
- Course Material
  - Slides made available online (may be updated during the course)
  - Additional supporting material will be provided during the course

Exercises

- Approach to exercises
  - Is new, may be adapted during course
- Exercises
  - Upon announcement, within time slots of the lecture.
- Exercise sheets
  - Will be distributed before exercise time slot
  - You will have deadlines to upload your solution sheet via svn
- Exercise solutions
  - Solutions will be explained in exercise time slots
- Exercise correction
  - You are expected to correct your own exercise solution and upload your corrected solution via svn by 2nd deadline
- Exercise bonus
  - Necessary condition to obtain a bonus of 0,3 in final exam that your solutions and/or corrections are sufficiently serious

Projects

- 2 projects offered
  - MiniNet project: Network emulation in a virtual machnie
  - MeasrDroid project: measurement app that communicates with server
- Steps
  - Familiarize with infrastructure
  - Project plan
  - Software setup
  - Programming
  - Experiments
  - Documentation
- Your project deliverables will be graded

Infrastructure for Exercises and Project

- SVN
  - Every student receives an svn account
  - For exercises: allows you to submit your
    - Exercise solutions
    - Exercise corrections
  - For project
    - Allows to manage your code
    - Allows to submit your project deliverables
- Virtual machine
  - Every student receives a virtual machine
  - Hosted within the Autonomous System operated by chair I8
  - ssh keys for access to virtual machine provided by svn

Access to Course Infrastructure

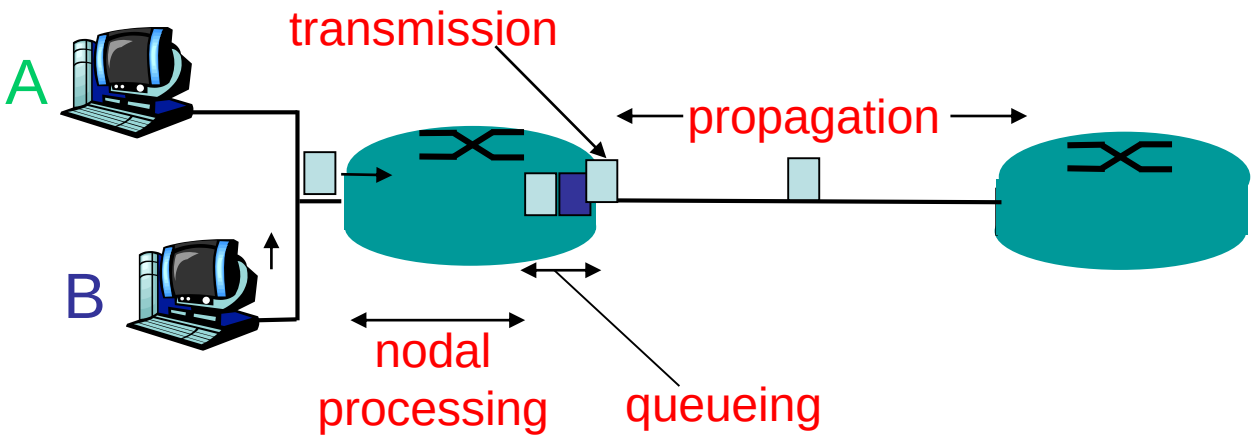
- *What is the MyTUM-/LRZ-ID?*
  It is a 7 digit alphanumeric ID that you have been assigned at the begin of your study.
- *I don't know / forgot it, what should I do?*
  Logon to TUMOnline. Under "Resources", choose "E-mail Addresses". You find your MyTUM-ID below your alias addresses, e.g. **xa93kep**@mytum.de.
- *I don't have an ID, what can I do?*
  Get one. If you are an exchange student, you can register for an ID at the "Info Point" in the computer science building. In case you are not a student of TUM and also no exchange student (e.g. LMU), then we have problem. (In this case please write to: gasser@in.tum.de cc: carle@in.tum.de).

Examination and Grading

- Written exam at the end of the term
  - Key element for final grade
- Exercise bonus
  - bonus of 0,3 in final exam if your solutions and/or corrections are sufficiently serious & project submissions are sufficient
- Project
  - Submissions will be graded
  - Can give significant bonus (details will be announced) to your final exam
    → participation is expected
- Final exam
  - Date and location of written examination to be announced

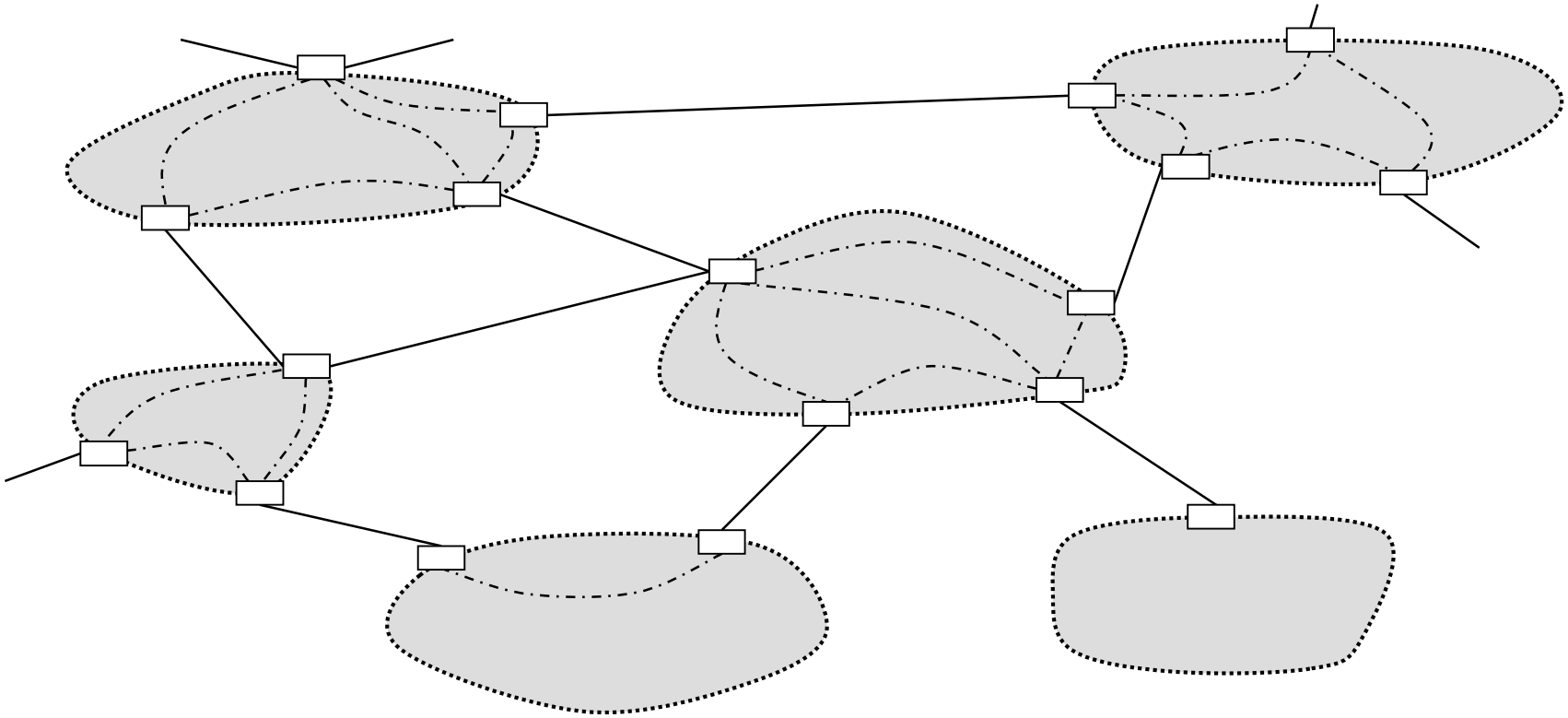
Overview

Sources of Delay



Internet Structure

- Autonomous systems (AS level structure)
- Routers and hosts (IP level structure)



Network Layer - Routing

- Routing algorithms
  - Link state
  - Distance Vector
  - Hierarchical routing
- Routing in the Internet
  - RIP
  - OSPF
  - BGP
- Broadcast and multicast routing

Transport Layer Services

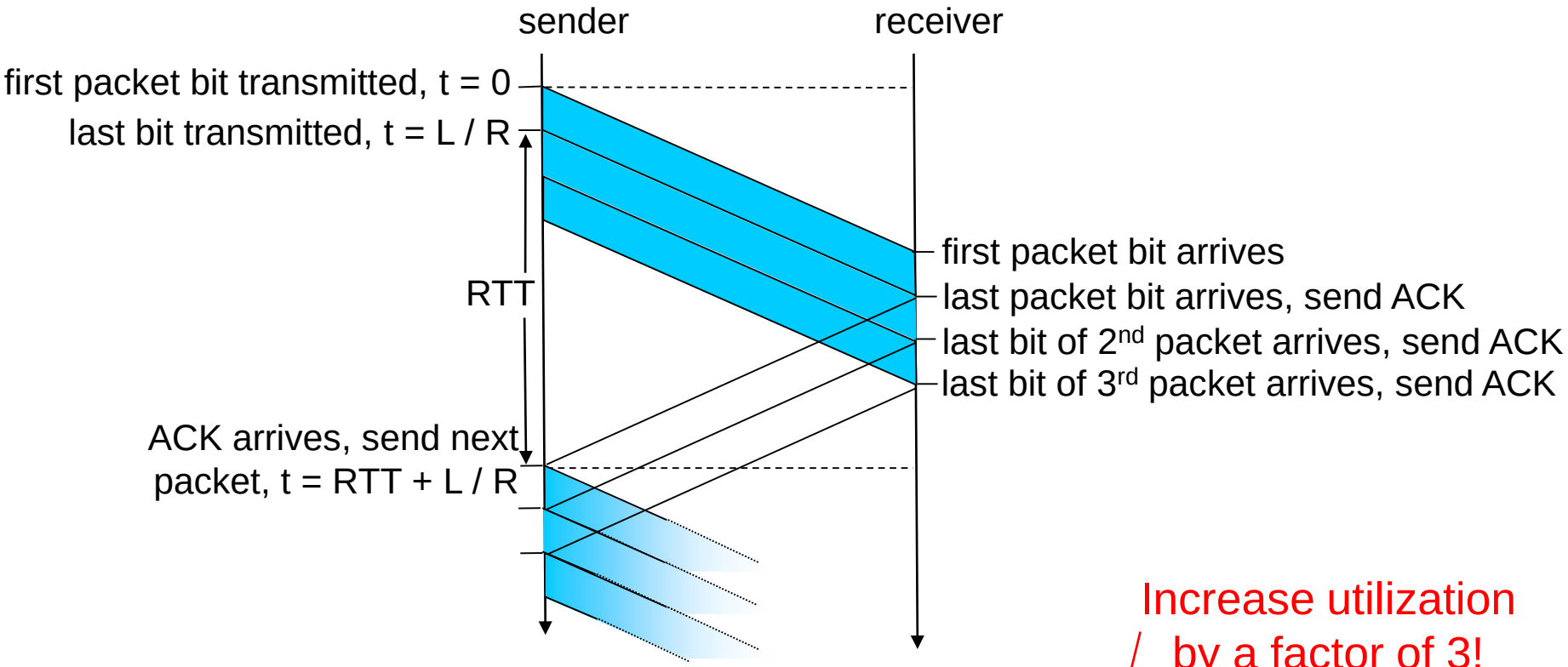
- Transport-layer services
- Multiplexing and demultiplexing

- Connectionless transport: UDP

- Connection-oriented transport: TCP
  - segment structure
  - reliable data transfer
  - flow control
  - connection management
- TCP congestion control

- SCTP

Pipelining for increased utilization



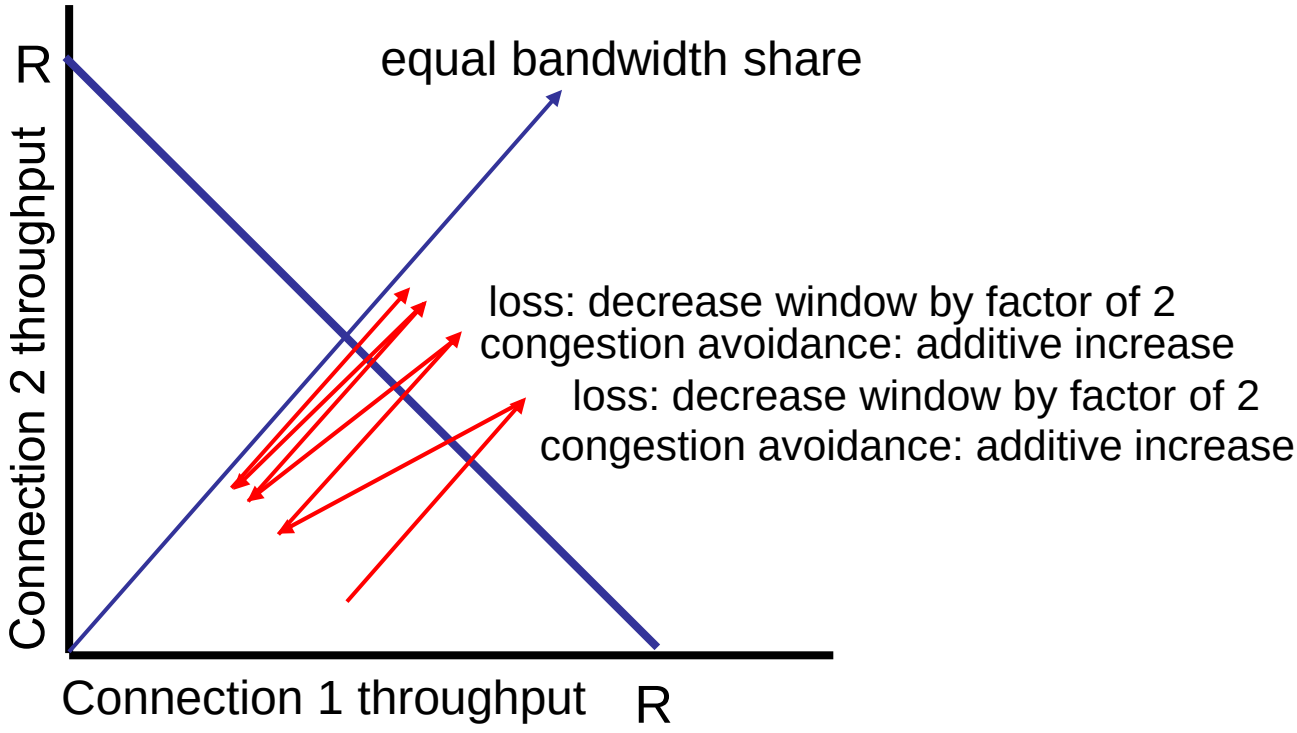
Increase utilization by a factor of 3!

$$U_{sender} = \frac{3 * L / R}{RTT + L / R} = \frac{0,024}{30,008} = 0,0008$$

Why is TCP fair?

Two competing sessions:

- Additive increase gives slope of 1, as throughout increases
- multiplicative decrease decreases throughput proportionally

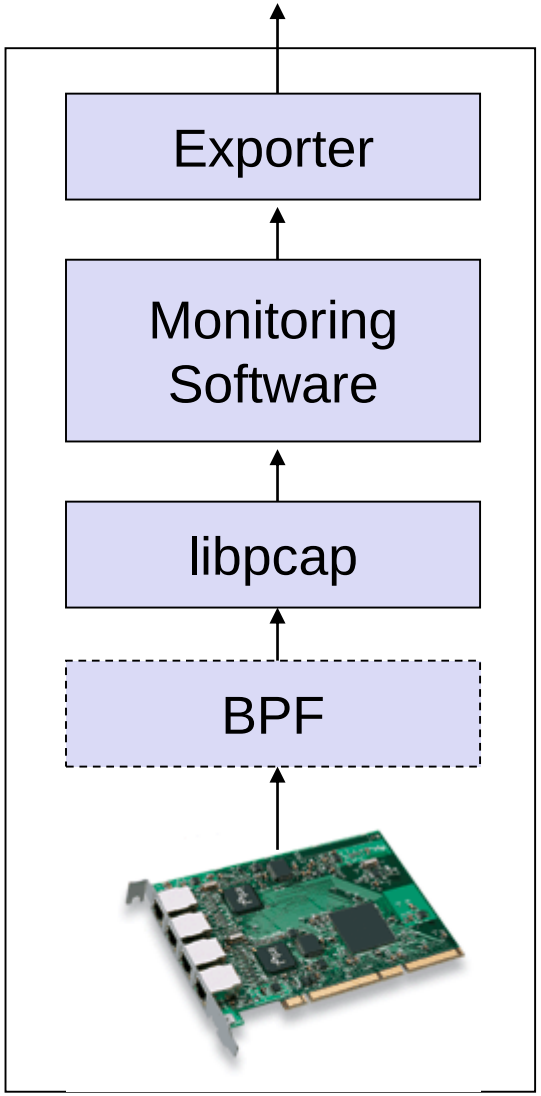


Network Measurements

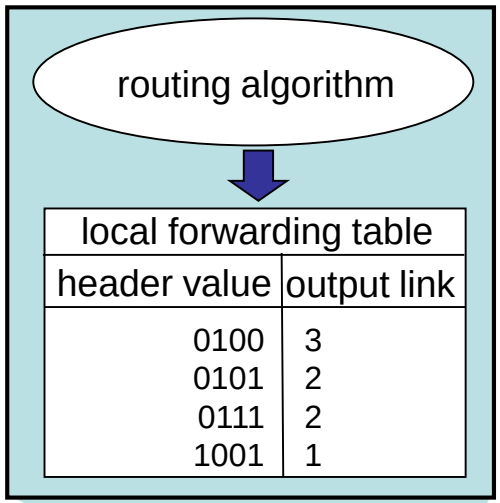
- Introduction
- Architecture & Mechanisms
- Protocols
  - IPFIX (Netflow Accounting)
  - PSAMP (Packet Sampling)
- Scenarios

Monitoring Probe

- Standardized data export
- Monitoring Software
- HW adaptation, [filtering]
- OS dependent interface (BSD)
- Network interface

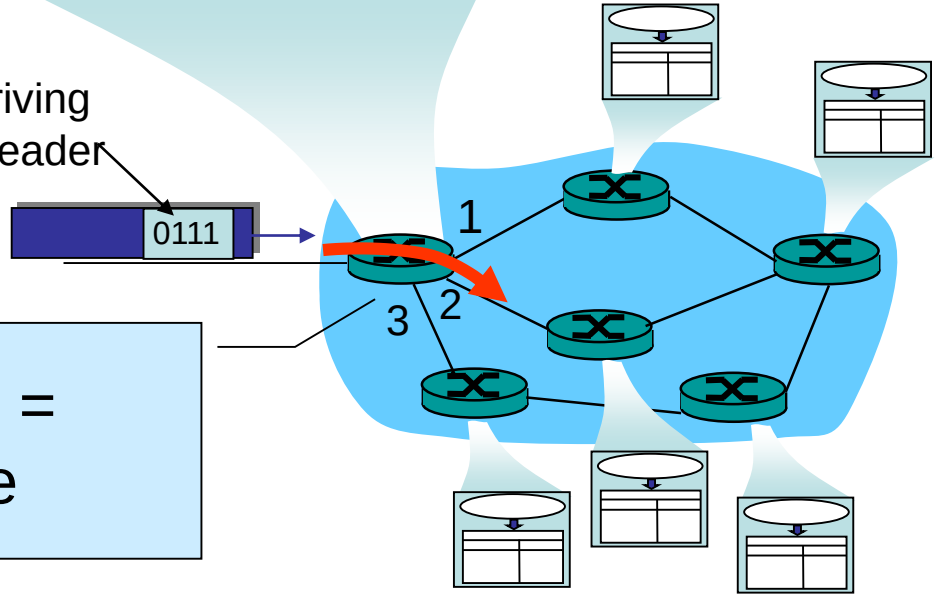


Data Plane and Control Plane



Routing = control plane

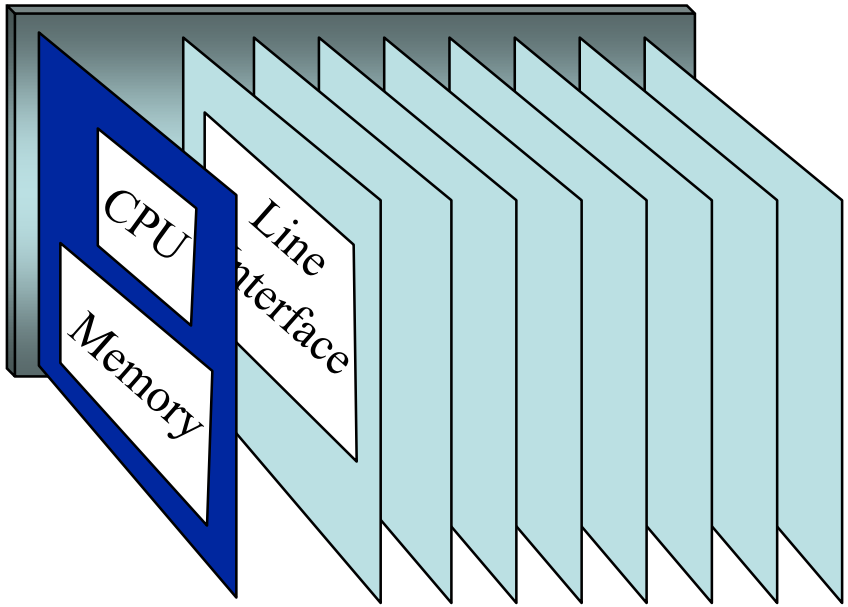
value in arriving packet's header

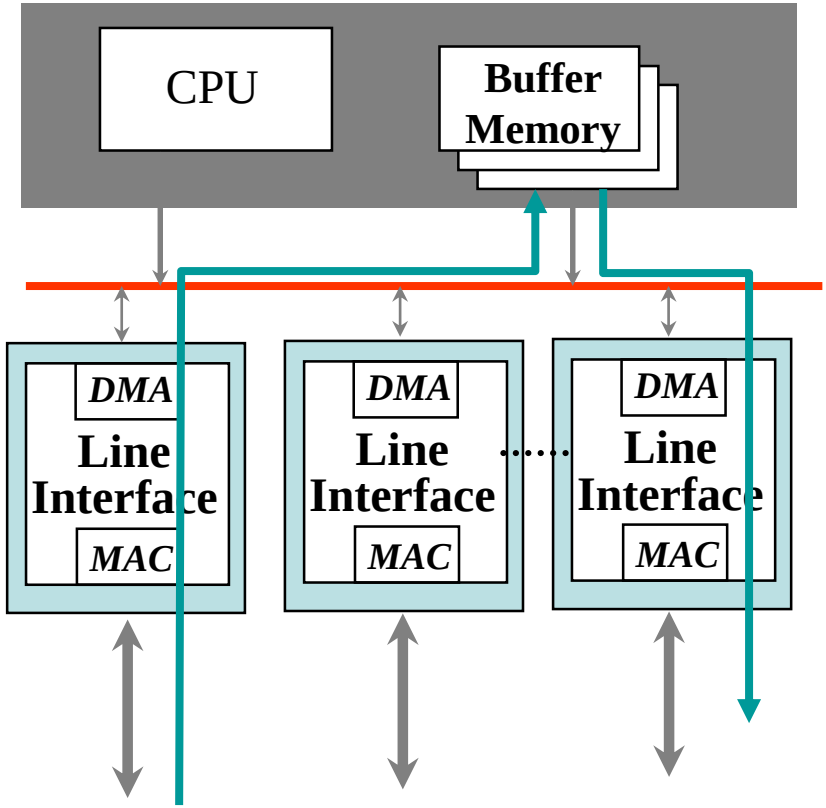


Forwarding = data plane

Node Architectures and Mechanisms

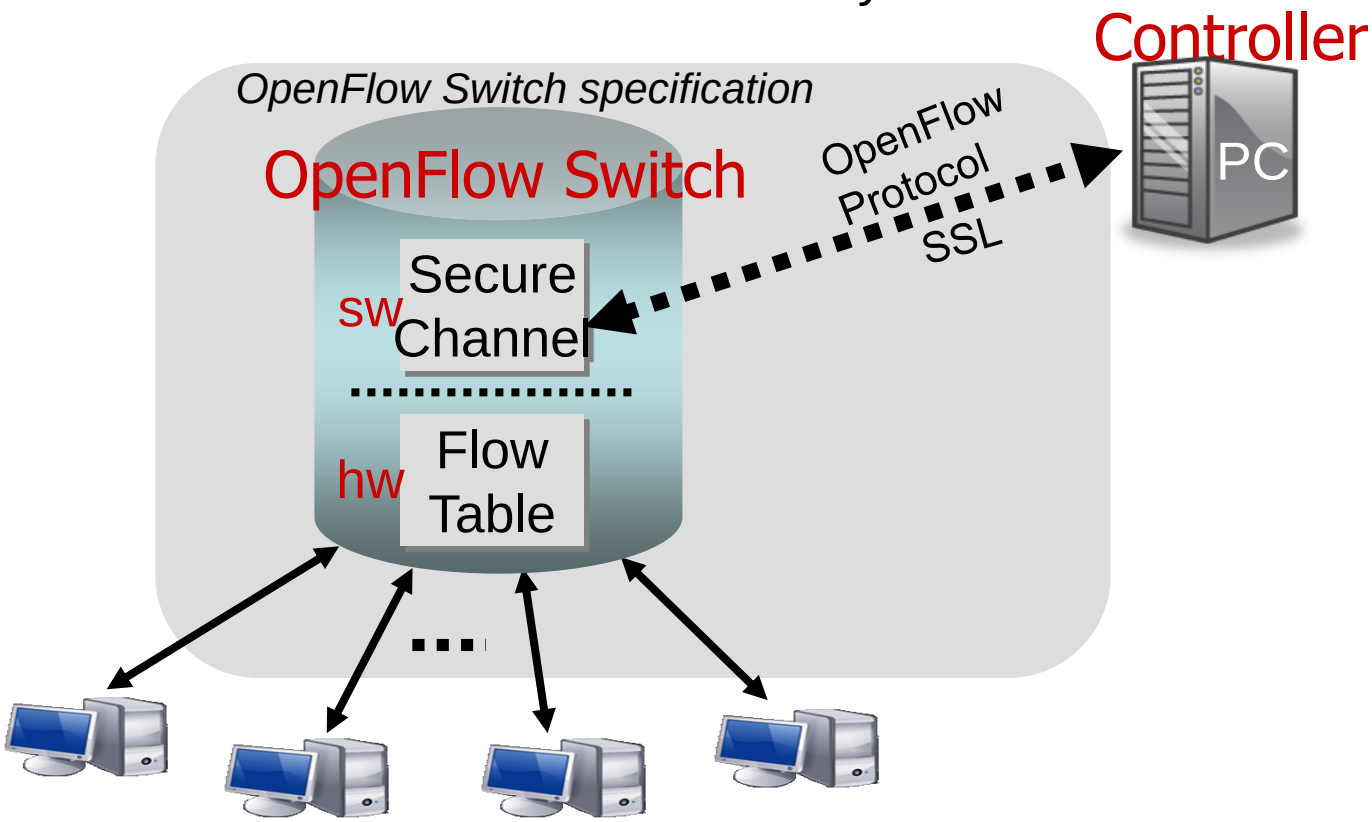
- First-Generation IP Routers





Software Defined Networking

- Example: OpenFlow Switch architecture, Stanford University
- Concept: separation of switch fabric, and switch control
- Allows for cheap switches, centrally controlled by switch manager
- ⇨ Assessment: suitable for low-latency data center communication

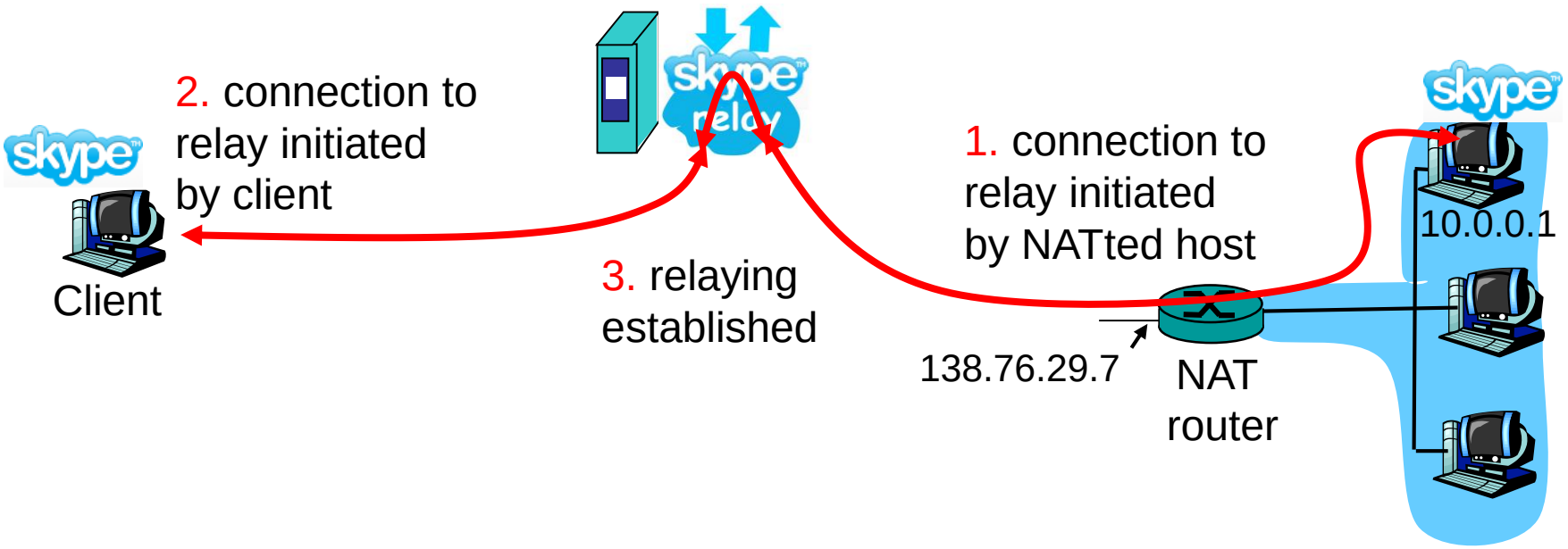


The Stanford Clean Slate Program

http://cleanslate.stanford.edu

NAT Traversal

- One of several NAT traversal solutions: relaying (e.g. used in Skype)
  - NATed client establishes connection to relay node
  - External client connects to relay node
  - relay node forwards packets between two connections



Quality-of-Service Support

- Link virtualization
- Providing multiple classes of service
- Providing Quality-of-Service (QoS) guarantees
- QoS Architectures
  - Integrated Services
  - Differentiated Services

Signaling

Signaling: exchange of messages among network entities to enable (provide service) to connection/call

- Before, during, after connection/call
  - call setup and teardown (state)
  - call maintenance (state)
  - measurement, billing (state)
- Between
  - end-user <-> network
  - end-user <-> end-user
  - network element <-> network element
- Examples
  - Q.921, SS7 (Signaling System no. 7): telephone network
  - Q.2931: ATM
  - RSVP (Resource Reservation Protocol)
  - H.323: Internet telephony
  - **SIP** (Session Initiation Protocol): Internet telephony

Design principles and Future Internet

- Network design principles
  - common themes: indirection, virtualization, multiplexing, randomization, scalability
  - implementation principles
  - network architecture: the big picture, synthesis

- Future Internet approaches

Teaching and Research at Chair for Network Architectures and Services

Teaching

- Lectures

  Summer Semester:
  - Introduction to Computer Networking and Distributed Systems (IN0010), 6 ECTS – 3L+2E (3 h/week lectures, 2 h/week exercises), Bachelor Level
  - Peer-to-Peer-Systems and Security (IN2194), 5 ECTS – 3L+1E, Master
  - Discrete Event Simulation (IN2045), 4 ECTS – 2L+1E , Master

  Winter Semester:
  - Master Course Computer Networks (IN2097), 5 ECTS – 3L+1E , Master
  - Network Security (IN2101), 5 ECTS – 3L+1E , Master
- Seminars, 4 ECTS – 2S (2 h/week seminar)
  - Seminar – Network Architectures and Services: Network Hacking (IN0013)
  - Advanced Seminar - Innovative Internet Technologies and Mobile Communications (IN8901)
  - Advanced Seminar – Future Internet (IN8901)
  - Advanced Seminar – Sensor Networks(IN0014), with Prof. Baumgarten
- Lab Courses, 8 ECTS
  - Bachelor Practical Course – Internet Lab (IN0012)
  - Master Practical Course – Computer Networks (IN2106)

Selected Activities

- EU Projects
  - Project Intermon - INTER-domain QoS Monitoring, modelling and visualisation
  - Project Mobility and Differentiated Services in a Future IP Network
  - Project DIADEM Firewall - High-Speed Distributed Firewalling
  - Project ResumeNet – Resilient Future Internet
  - Project SecFuNet – Security of Future Networks
  - Project EINS – Network of Excellence in Internet Science
- National Projects
  - Siemens, Nokia 3GET, Scalenet, SelfMan
  - BMBF AutHoNe, BaaS, ANSII, SASER, Peeroscope
- Scientific Committees
  - COST263 “Quality of future Internet Services”
  - COST290 “Wireless Multimedia Networks”
  - COST703 “Data Traffic Monitoring and Analysis for future networks”
  - COST1303 “Algorithms, Architectures and Platforms for Enhanced Living Environments”
  - IFIP Working Group 6.2 “Network and Internetwork Architecture”
  - IEEE Technical Committee on High Speed Networking
- Internet-Standardisation
  - IETF: IPFIX, PSAMP, NSIS, P2PSIP
  - IRTF: AAAArch: Authentication, Authorisation and Accounting Architecture