Chair for Network Architectures and Services – Prof. Carle
Department of Computer Science
TU München

Master Course
Computer Networks
IN2097

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Chair for Network Architectures and Services

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

Questions

❑ Who is new at TUM?

❑ Who studies what?

- ▪ Diploma degree?
- ▪ 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 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: http, SCTP

- tools: svn, measurement tools, ...

- methods: plan solution, program, administer experiment setup, measure, reflect, document

⇨ course project

- Part 1: Internet protocols

    Overview on Computer Networks

    Application Layer

    Transport Layer

    Network Layer

    Link Layer

- Part 2: Advanced Concepts

    Node Architectures and Mechanisms

    Quality of Service

    Measurements

    Signalling

    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.

❑ The lecture slides are based to a significant extent on slides by Jim Kurose and Keith Ross

Jim Kurose
University of Massachusetts, Amherst

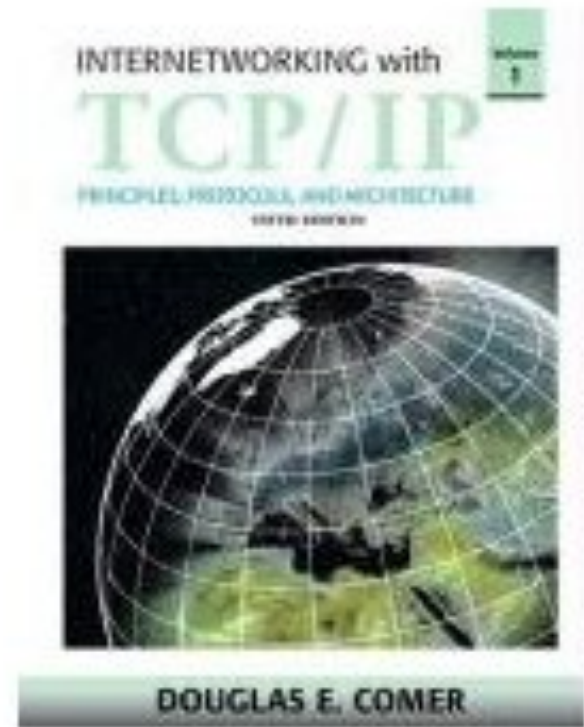Keith Ross
Polytechnic Institute of New York University
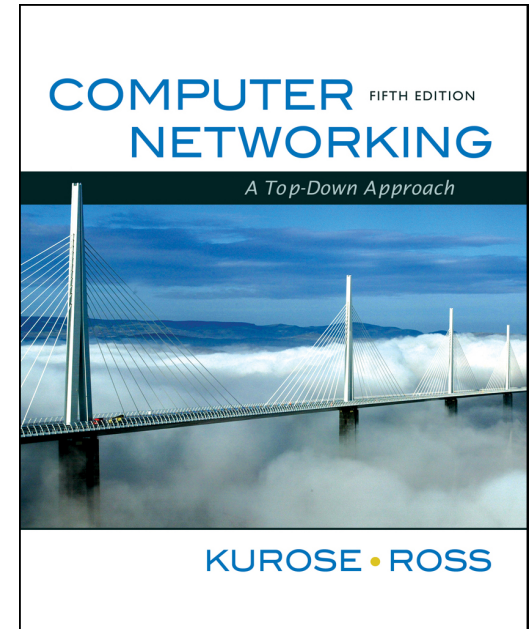
Books (2)

❑ 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
    - Friday, 10:15-11.45, MI H2
    - Monday, 16:15-17.45, MI H2
- TUMonline: registration required (for exam registration + Email)
- Students are requested to subscribe by October 19, 2012 for project http://www.net.in.tum.de/en/teaching/ws1213/ vorlesungen/masterkurs-rechnernetze/

    ⇨ link to registration form (needed for project login and svn access)

- Questions and Answers / Office hours
    - Prof. Dr. Georg Carle, carle@net.in.tum.de
        - After the course and upon appointment (typically Monday 18-19)
    - Christian Grothoff, Ph.D., grothoff@net.in.tum.de
        - Drop in or by appointment.
- Course Material
    - Slides made available online (may be updated during the course).

Registration for the project

- http://www.net.in.tum.de → Teaching → WS1213
  → Vorlesungen → Master Course Computer Networks
  → Registration for the project

- Registration for the project is open until October 19th

- The project has to be completed as individual work. This does not generally preclude any team work (e.g. discussion of problems or strategies) but copy&paste will be graded with FAIL.

- Please register only once. You will receive a confirmation mail after the registration period. In case of problems, please send a mail to guenther in.tum.de.

- To grant you access to the version control system and virtual machines needed for the project, we need your MyTUM/LRZ-ID. It is used for encrypted authentication against the LDAP database, i.e. we don't have to assign you individual passphares.

Registration for the project

- *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 guenther in.tum.de.

❑ Written exam at the end of the term

❑ Project
- will be graded
- can give you 50% bonus to your final exam
  → participation highly recommended!

❑ Final exam
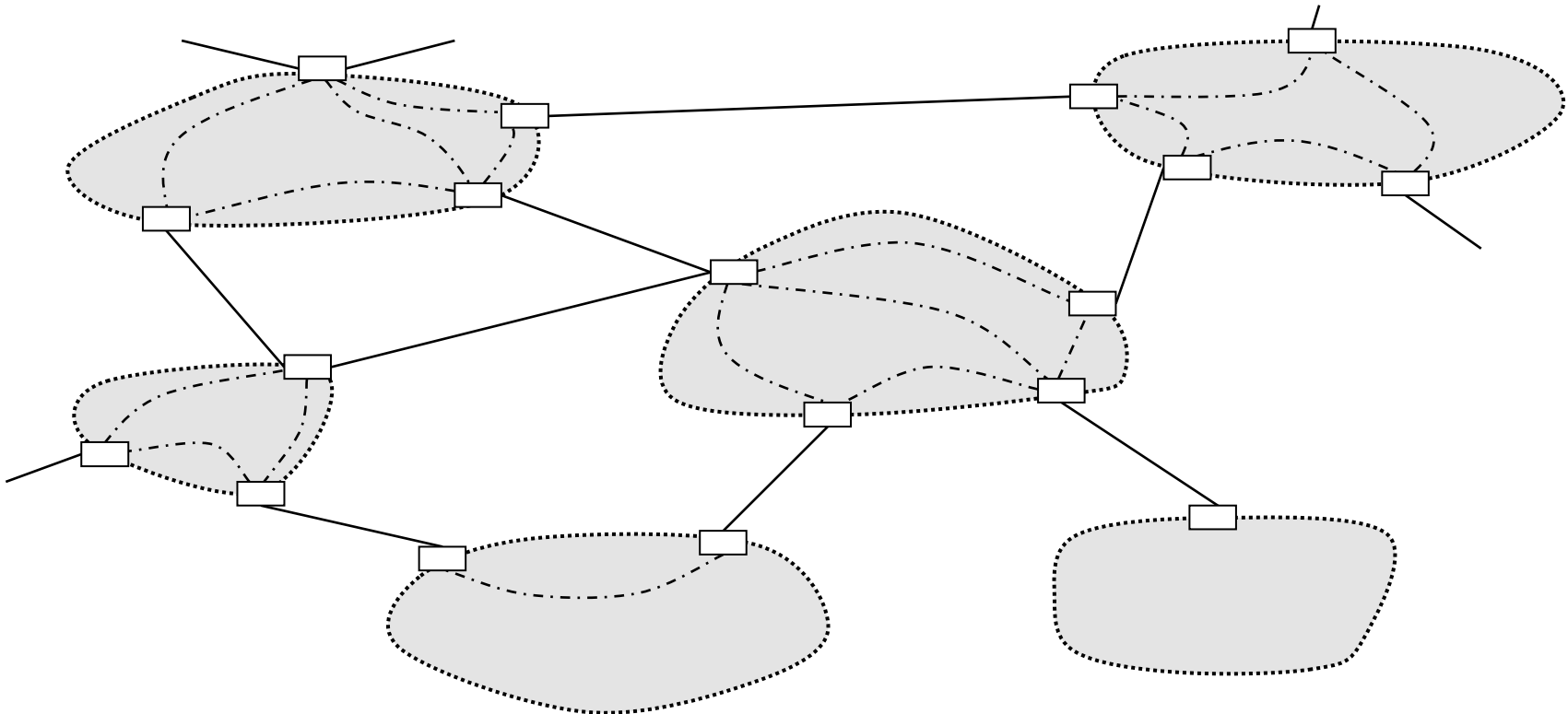- Date and location of written examination tba
- Weighting: 50% of final grade

Overview

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- Autonomous systems (AS level structure)

- Routers and hosts (IP level structure)

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

Transport Layer Services

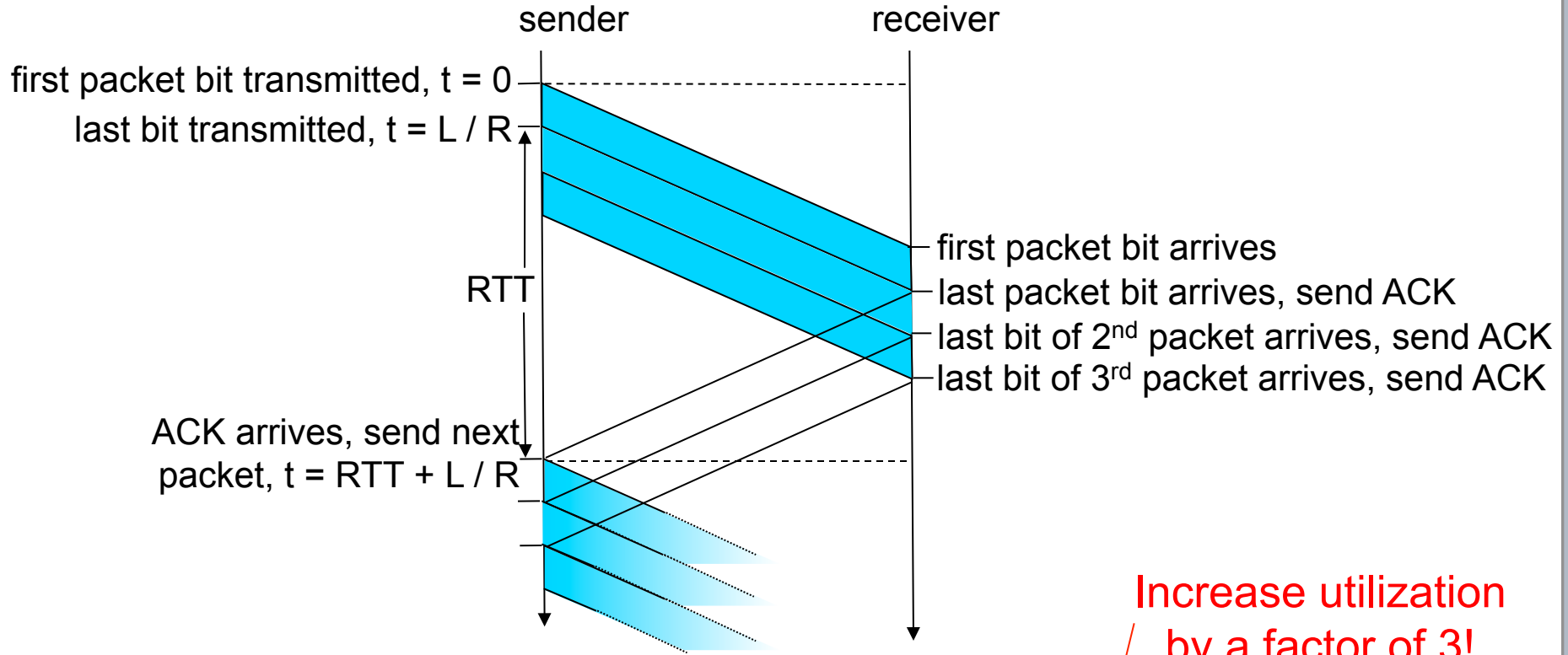- Transport-layer services
- Multiplexing and demultiplexing

- Connectionless transport: UDP

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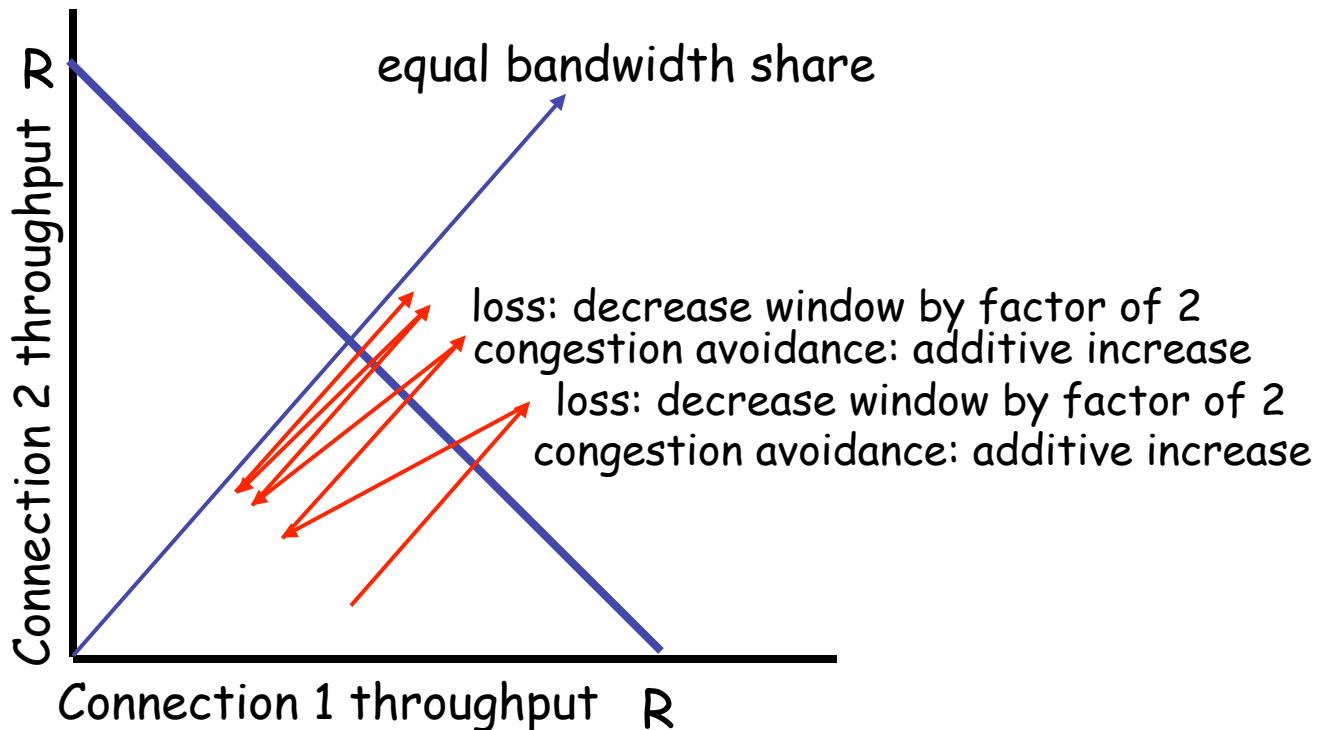
- SCTP

Pipelining for increased utilization

sender

receiver

first packet bit transmitted, t = 0

last bit transmitted, t = L / R

RTT

first packet bit arrives

last packet bit arrives, send ACK

last bit of 2nd packet arrives, send ACK

last bit of 3rd packet arrives, send ACK

ACK arrives, send next packet, t = RTT + L / R

Increase utilization by a factor of 3!

$$U_{sender} = \frac{3 * L / R}{RTT + L / R} = \frac{.024}{30.008} = 0.0008$$

Why is TCP fair?

Two competing sessions:

❑ Additive increase gives slope of 1, as throughout increases

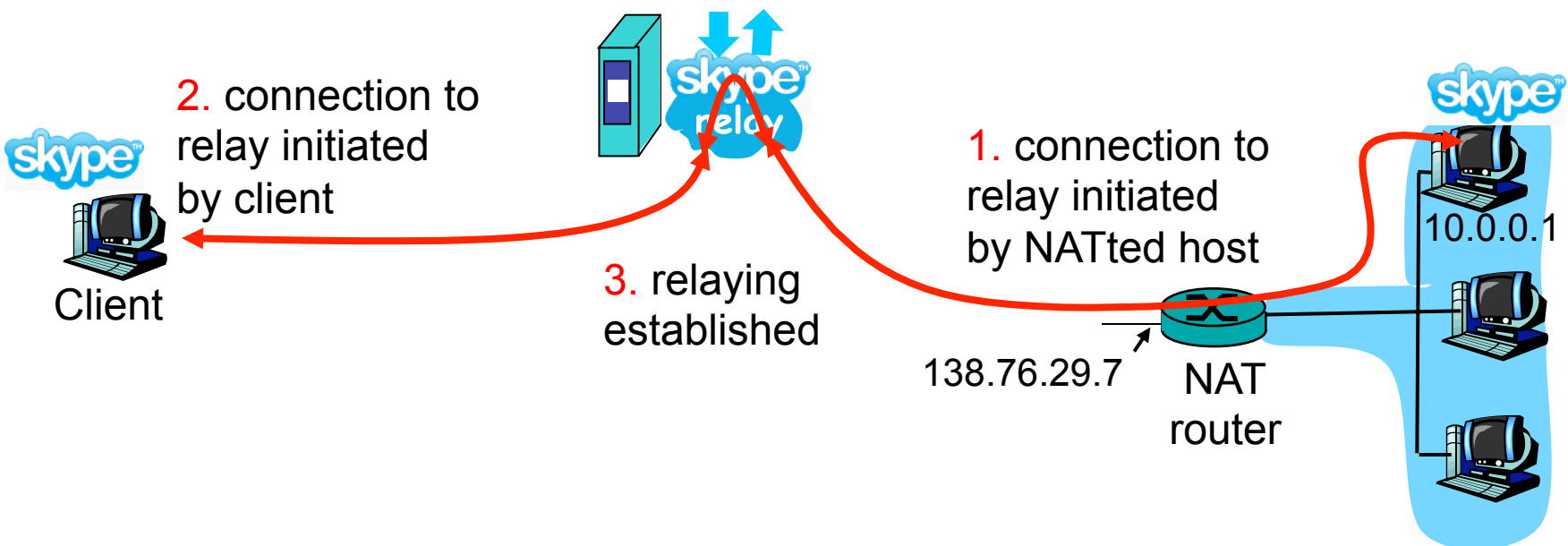❑ multiplicative decrease decreases throughput proportionally

equal bandwidth share

loss: decrease window by factor of 2
congestion avoidance: additive increase

loss: decrease window by factor of 2
congestion avoidance: additive increase

Connection 2 throughput

Connection 1 throughput

R

R

❑ First-Generation IP Routers
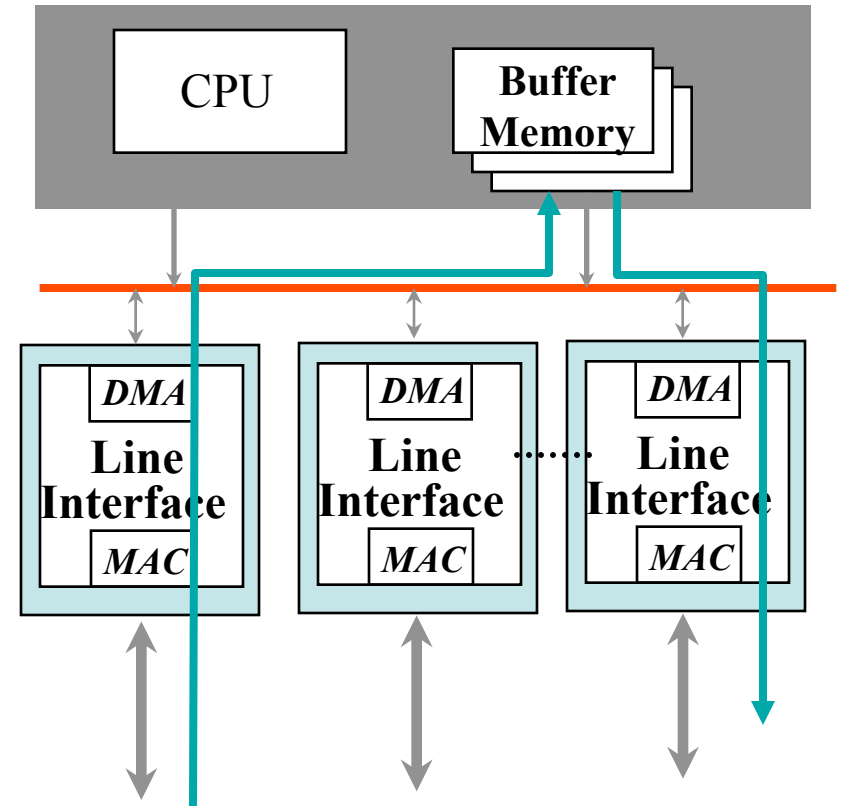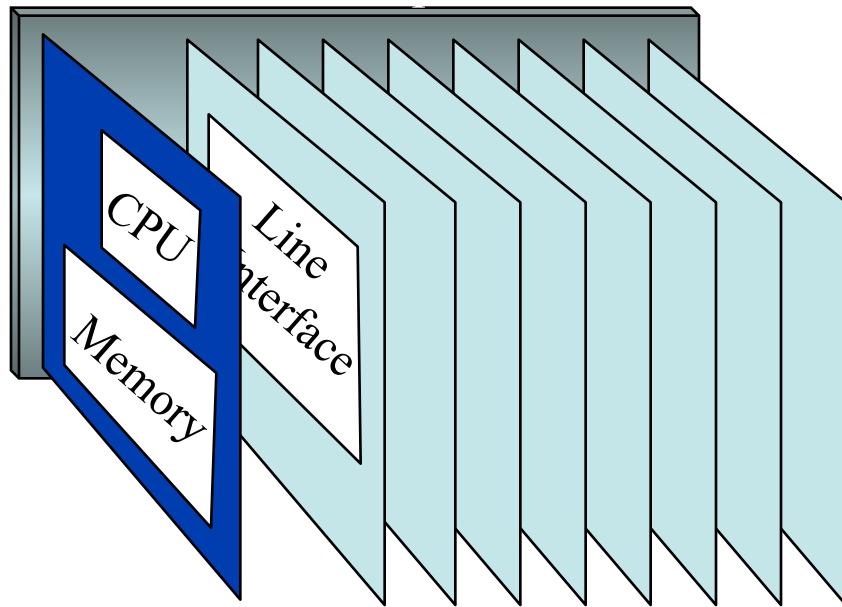
NAT Traversal

❑ 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

2. connection to relay initiated by client

Client

1. connection to relay initiated by NATted host

3. relaying established

138.76.29.7

NAT router

10.0.0.1

❑ Introduction

❑ Architecture & Mechanisms

❑ Protocols

  ▪ IPFIX (Netflow Accounting)

  ▪ PSAMP (Packet Sampling)

❑ Scenarios

❑ Standardized data export

❑ Monitoring Software

❑ HW adaptation, [filtering]

❑ OS dependent interface (BSD)

❑ Network interface
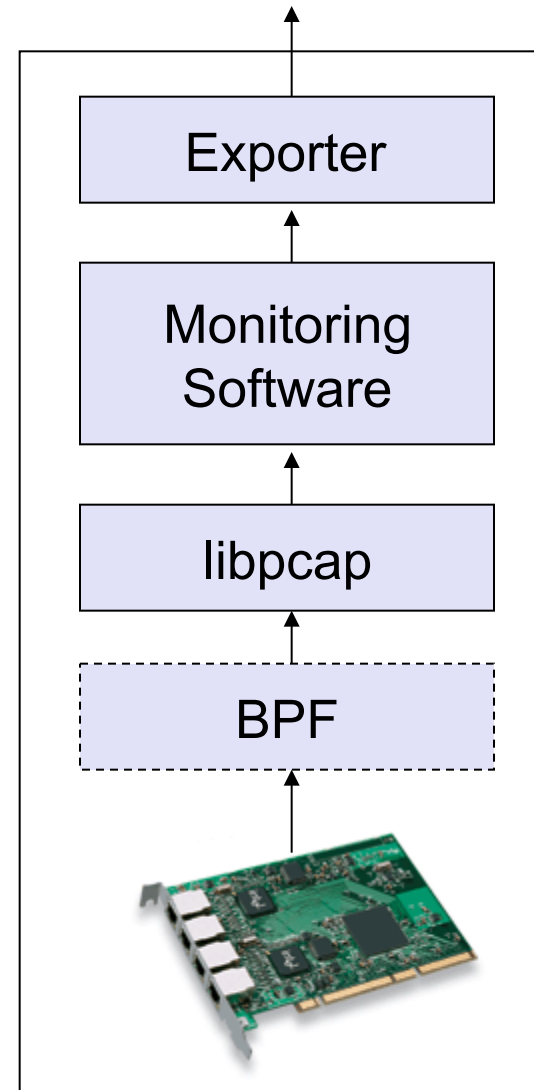
- ❏ Link virtualization
- ❏ Providing multiple classes of service
- ❏ Providing Quality-of-Service (QoS) guarantees
- ❏ QoS Architectures
  - ▪ Integrated Services
  - ▪ Differentiated Services

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

Voice over IP Example

Caller jim@umass.edu
places a call to keith@upenn.edu

(1) Jim sends INVITE message to umass SIP proxy.

(2) Proxy forwards request to upenn registrar server.

(3) upenn server returns redirect response, indicating that it should try keith@eurecom.fr

SIP registrar
upenn.edu

SIP registrar
eurecom.fr

SIP proxy
umass.edu

SIP client
217.123.56.89

SIP client
197.87.54.21

(4) umass proxy sends INVITE to eurecom registrar.

(5) eurecom registrar forwards INVITE to 197.87.54.21, which is running keith's SIP client.

(6-8) SIP response sent back

(9) media sent directly between clients.

Note: SIP ack messages not shown.
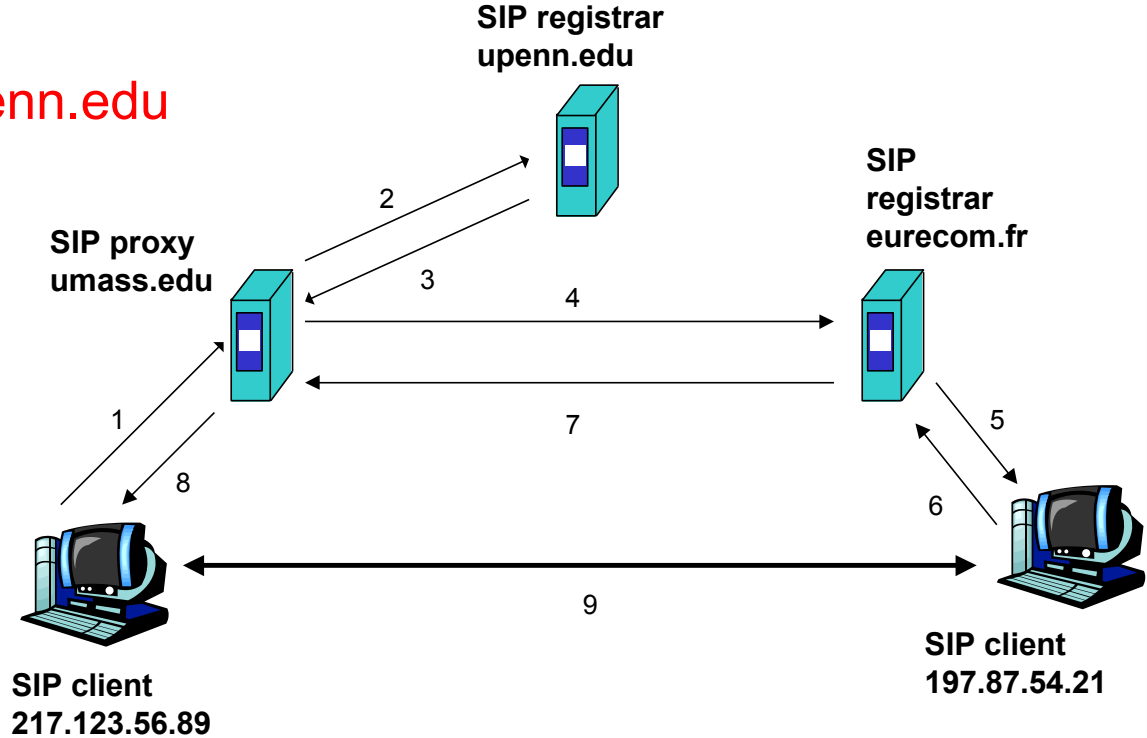
❑ Network design principles

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

❑ Future Internet approaches

Research
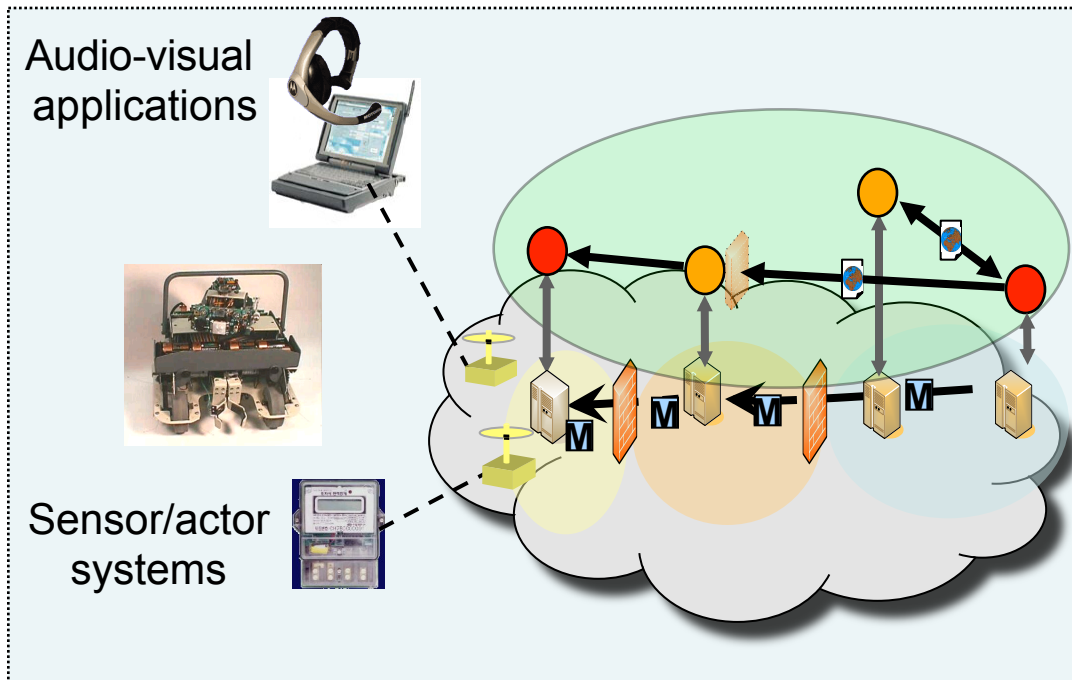
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Audio/video and real-time service

Peer-to-peer and overlay Networks

Mobile communications

Network monitoring

Autonomic management

Network security

Audio-visual applications

Sensor/actor systems

- Innovative mechanisms

- Measure and analyze the network

- Methods and tools for network engineering

Autonomic Home Networking

Today,

❑ Social and technical barriers

❑ No interconnection of mobile devices and other technical equipment

❑ Users are no experts in the field of networking (will not change)

→ Introduction of autonomic behavior important

Degree of freedom for the Autonomic Network Control

Self-Management ↓ ... ↓ **Manual interaction**

AutHoNe

❑ self-management and manual interaction
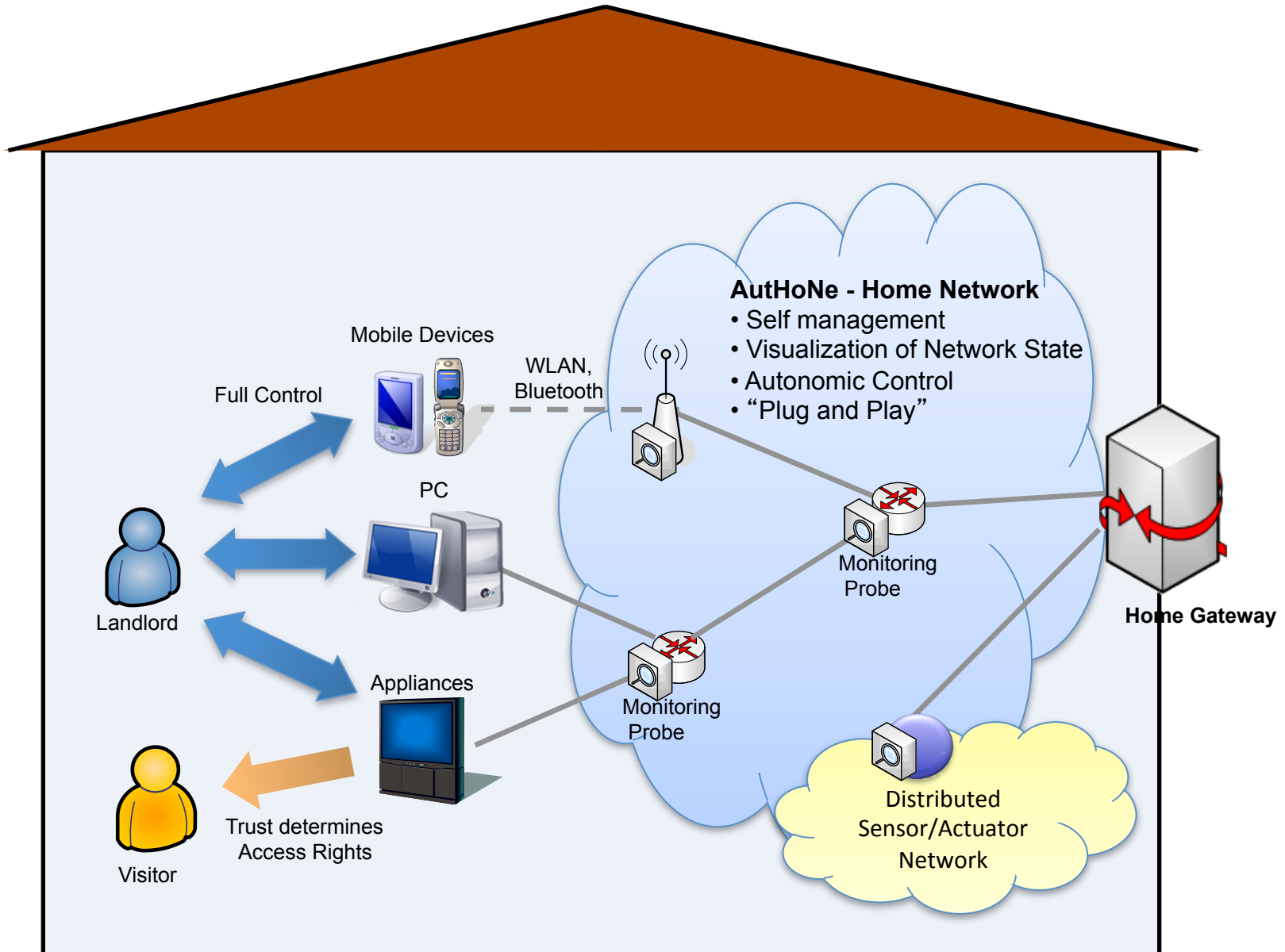
❑ adaption to users and environment
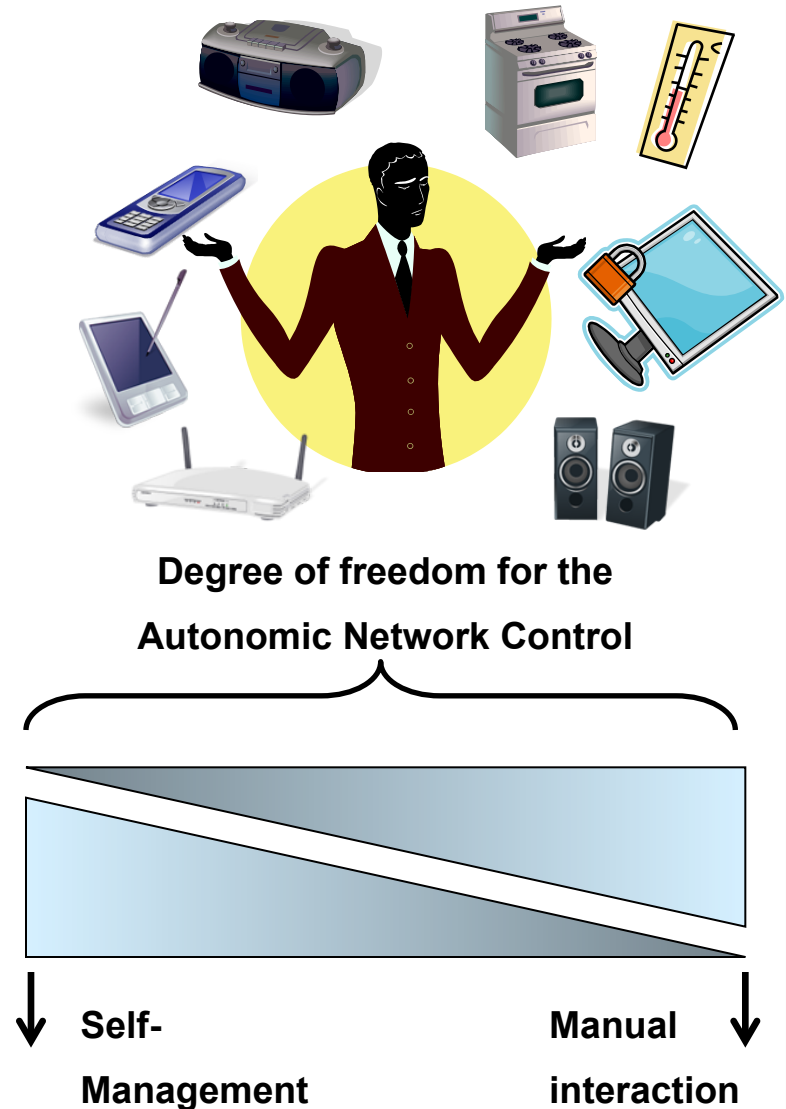
Future home networks

- A home gateway
  - connected to the Internet or service provider network.
- Multimedia devices
  - video, CD, DVD players, TVs, amplifiers, …
- Computers and peripherals
- Communication devices
- Body area devices
- Home appliances
  - lighting, heating, oven, …
- Networked sensors
  - temperature, acoustic, optical
- Networked actuators

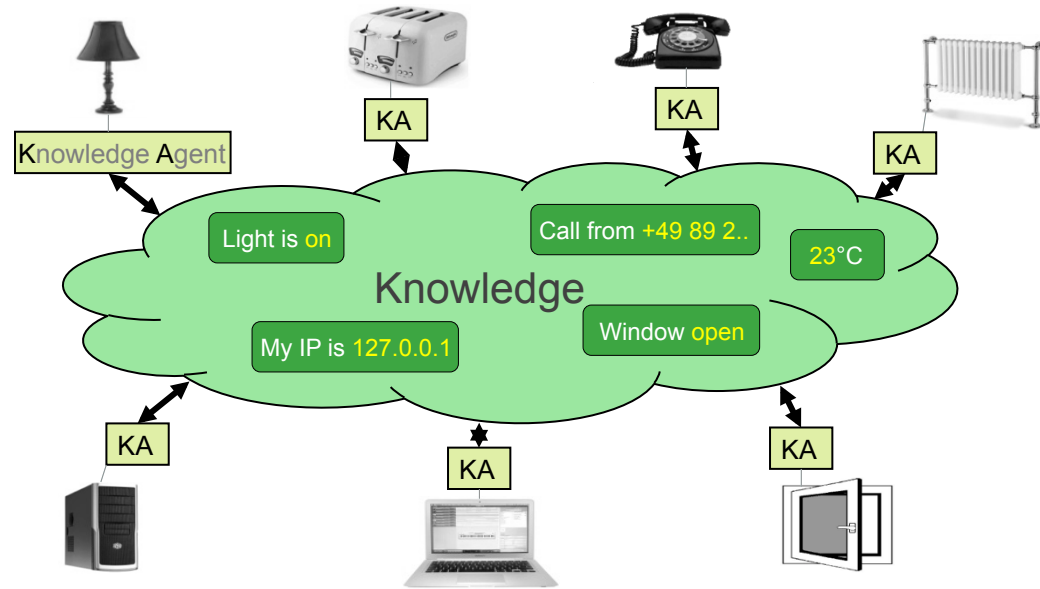**AutHoNe - Home Network**
- Self management
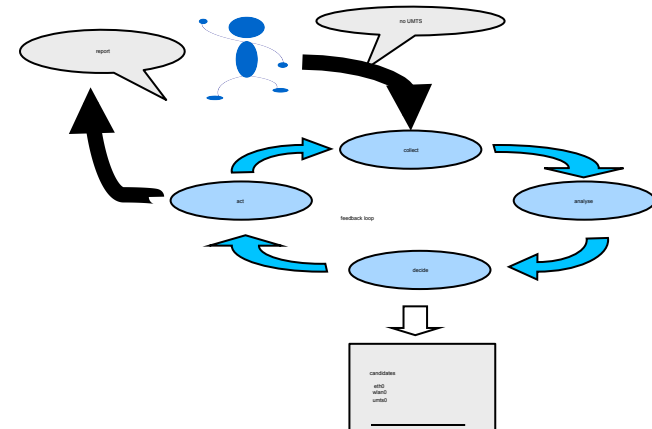- Visualization of Network State
- Autonomic Control
- "Plug and Play"

Mobile Devices

WLAN, Bluetooth

Full Control

PC

Landlord

Appliances

Trust determines Access Rights

Visitor

Monitoring Probe

Monitoring Probe

Home Gateway

Distributed Sensor/Actuator Network
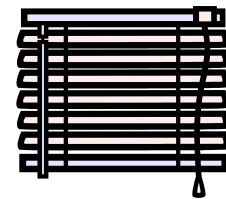
❑ **Knowledge Platform**

❑ **Autonomous Configuration and Management**
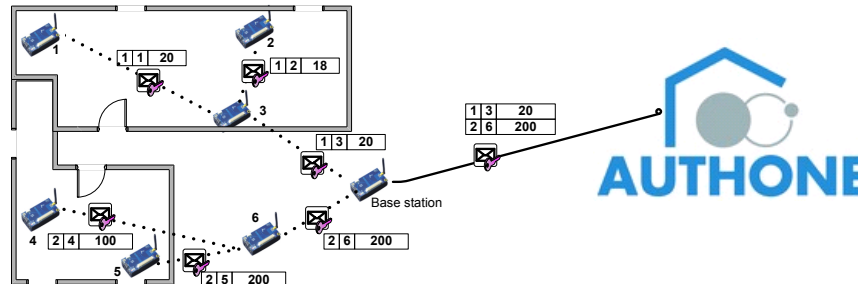
Basic concepts

□ **User Control**

- ▪ User-friendly
- ▪ Modes for normal users and experts

- No remote access
- Remote access by owner (no administrative control)
  ···
- Remote access by friends
 ···

□ **Interaction with Environment**

- ▪ Sensors
- ▪ Actuators

Scenario „Remote Service Access"

❑ Guests want to use services in a home network

- ▪ Establishment of trust between guest and home

- ▪ Reputation system

❑ Wish to access services in the foreign network

- ▪ Multimedia, device control, data exchange

❑ NATs do not allow direct communication

- ▪ NATs break the end-to-end paradigm of the Internet

- ▪ NAT/firewall traversal

❑ Scenarios for NAT traversal

- ▪ „Legacy Applications"
  - • Web/File Server
  - • P2P applications
  - • Home Automation

❑ Transparent to the user

Remote Access across Internet

Autonomic NAT/Firewall Traversal

Service

Users Home Network

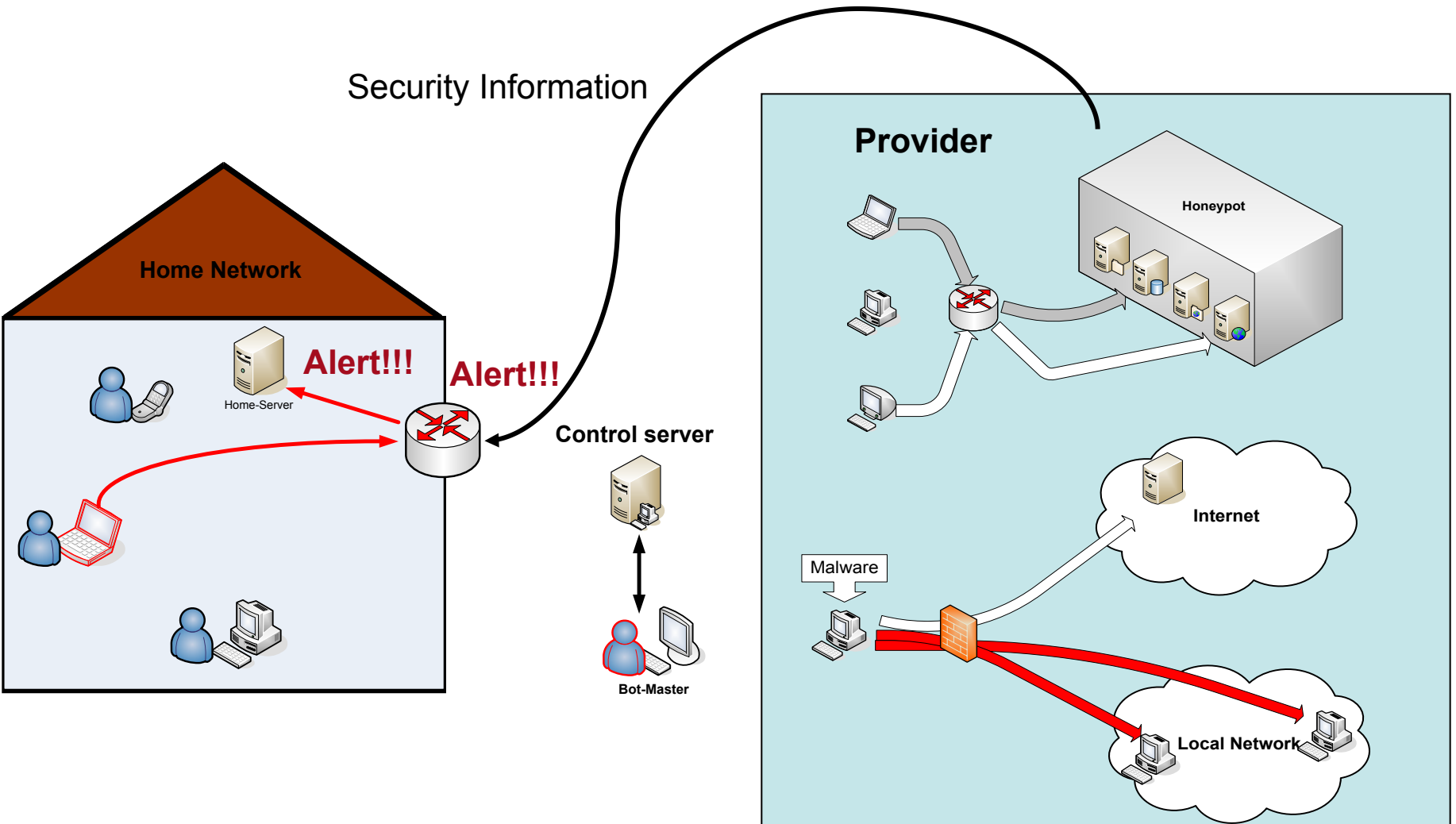Guest

Friends Home Network
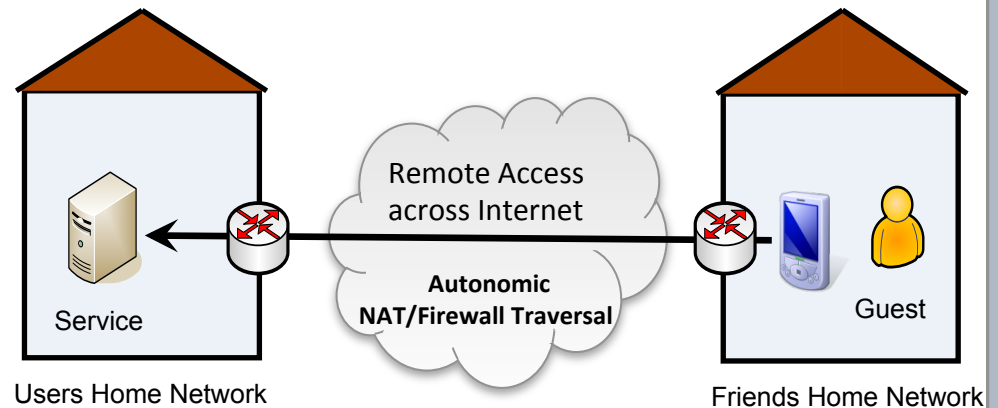
Scenario "Trust and Security"

❑ Security is a neglected field of home networking today

❑ Future Home networks require better security solutions, e.g. authentication and authorization mechanisms for access control

❑ Interoperability between home networks, e.g. access to shared services must be controlled
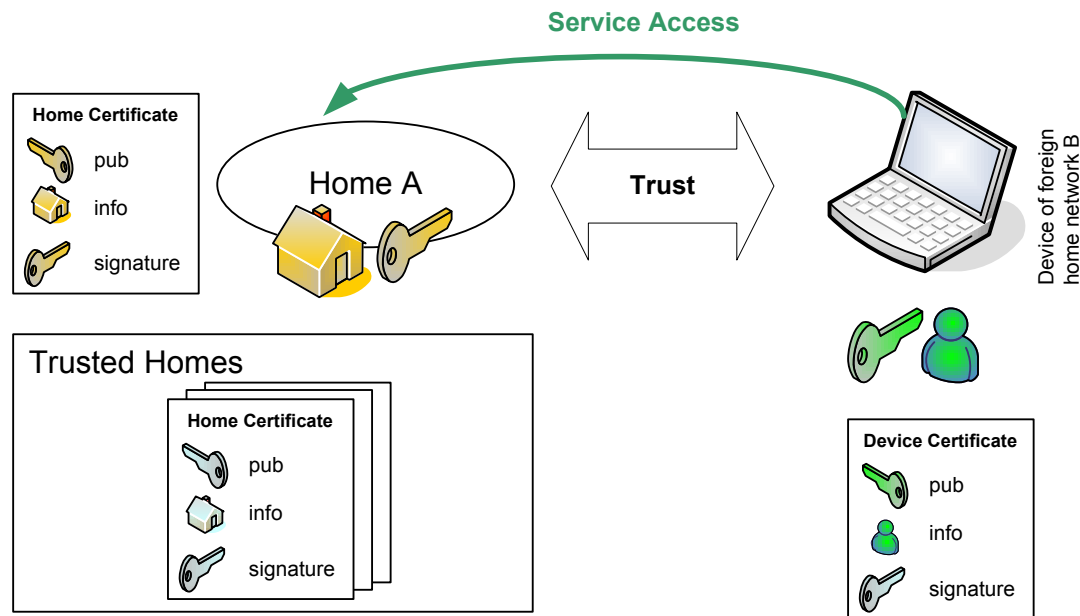
□ Provider-guided attack detection in home networks