Master Course
Computer Networks
IN2097

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Written Examination

- Saturday, February 16, 2013, from 9:00 to ~10:15
  - Lecture hall HS1
- Procedure
  - printed examination given - no own paper needed
  - closed book
    - no supplementary material allowed
    - and no calculator
  - language dictionary allowed
  - turn off mobile phones

What to expect? How to prepare?

- Homework 1
  - Understanding encapsulation
- Homework 2
  - Media Access Control: CSMA/CD, Exponential Backoff
  - Classless Inter-Domain Routing, IPv4 Subnetting
- Homework 3
  - TCP and SCTP SYN Cookies
  - TCP Congestion Avoidance
- Homework 4
  - Traceroute and routing paths
  - Routing protocols
- Homework 5
  - Middleboxes Processing of packets - hole punching
  - Delay in packet networks - transmission times, ...
- Homework 6
  - RTTs - Delay distribution, minimum RTT, empirical mean, ...

The Project

- feedback on submitted results -

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

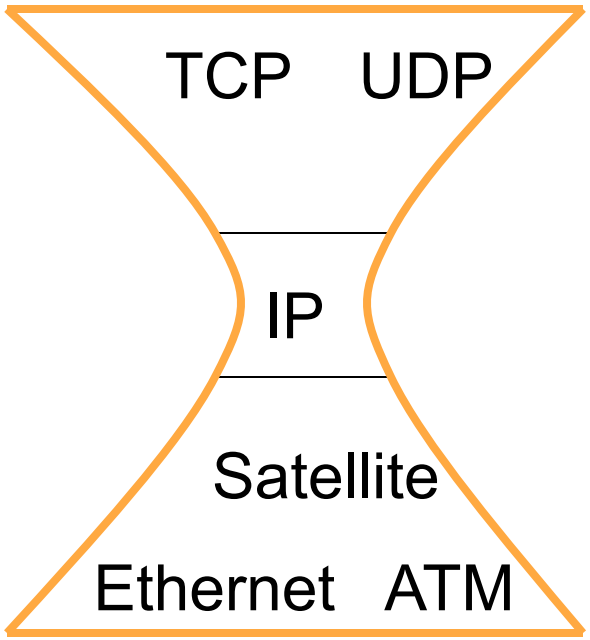
Chapter:
Internet Architecture

Internet Architecture Overview

- Internet evolution and „Future Internet“ concepts
  - Internet evolution
    - QoS, multicast
    - Security
    - IPv6, SCTP, …
  - Economic implications, „tussle space“
  - Innovations and „Future Internet“ concepts
    - Mobility and Locator–ID split
    - In-network congestion control
    - Modules instead of layers
    - Delay-tolerant/disruption-tolerant networking
    - Content-based networking/Publish–subscribe architectures
    - Evolutionary vs. Revolutionary/Clean-slate

Internet Architecture

- Packet-switched datagram network
- IP is the glue (network layer overlay)
- IP hourglass architecture
  - All hosts and routers run IP
  - IP hides transport/application details from network
  - IP hides network details from transport/application
- Stateless architecture
  - No per-flow state inside network
  - Intelligence (i.e., state keeping) in end hosts, but not in core



IP hourglass

Summary: Minimalist Approach

- Dumb network
  - IP provides minimal functionalities to support connectivity
  - Addressing, forwarding, routing
- Smart end system
  - Transport layer or application performs more sophisticated functionalities
  - Flow control, error control, congestion control
- Advantages
  - Accommodate heterogeneous technologies (Ethernet, modem, satellite, wireless)
  - Support diverse applications (telnet, SMTP, FTP, X11, Web, ssh, SSL/TLS, POP, IMAP, Peer-to-Peer, …)
  - Decentralized network administration

The KISS principle

- KISS = “Keep it simple and stupid!”
- Success of…
  - IP
  - Ethernet
  - RISC processors
- To be avoided - Contrast to KISS
  - “Building complex functions into network optimizes network for small number of services, while substantially increasing cost for uses unknown at design time”

Internet architecture: Some explicit or implicit assumptions

- A research network
  - No economic/business/judicial aspects, no competition
  - Cooperative, perhaps even altruistic participants
- Knowledgeable and responsible end users; administrators even more so
- Almost no malicious participants
  - Perhaps some malicious users? (⇨ password protection),
  - …but no malicious systems administrators,
  - …and certainly no malicious network operators
- A couple of thousand nodes, perhaps a million users
- No mobility: End hosts will not shift their position within network
- Most links are wired; packet loss indicates network congestion
- Just a temporary solution

- **…and yet it still works!? Amazing!**

Rethinking Internet Design

What's changed?

- Operation in untrustworthy world
  - Endpoints can be malicious
  - If endpoint not trustworthy, but want trustworthy network ⇨ more mechanism in network core
- More demanding applications
  - End-end best effort service not enough
  - New service models in network (IntServ, DiffServ)
  - New application-level service architecture built on top of network core (e.g., CDN, P2P)

Rethinking Internet Design

What's changed (cont.)?

- ISP service differentiation
  - ISP doing more (than other ISPs) in core is competitive advantage
- Rise of third party involvement
  - Interposed between endpoints (even against will of users)
  - e.g., Chinese government, US content industry
- less sophisticated users

All five changes motivate shift away from end-to-end!

What's at stake?

"At issue is the conventional understanding of the "Internet philosophy"

- freedom of action
- user empowerment
- end-user responsibility for actions taken
- lack of control "in" the net that limit or regulate what users can do

The end-to-end argument fostered that philosophy because they enable the freedom to innovate, install new software at will, and run applications of the users' choice"

Blumenthal and Clark, 2001
"Rethinking the design of the Internet: The end to end arguments vs. the brave new world" ACM Transactions on Internet Technology.
also published in Communications Policy in Transition: The Internet and Beyond, B. Compaine and S. Greenstein, Eds., MIT Press, Sept. 2001.
http://groups.csail.mit.edu/ana/Publications/PubPDFs/Rethinking%20the%20design%20of%20the%20internet2001.pdf

⇨compare with current debate on network neutrality

Technical response to changes

- Trust: emerging distinction between what is “in” network (us, trusted) and what is not (them, untrusted).
  - Ingress filtering
  - Firewalls
- Modify endpoints
  - Harden endpoints against attack
  - Endpoints/routers do content filtering
    - e.g. parental control
  - CDN, ASPs: rise of structured, distributed applications in response to inability to send content (e.g., multimedia, high bandwidth) at high quality

Technical response to changes

- Add functions to the network core:
  - Filtering firewalls
  - Application-level firewalls
  - NAT boxes
  - Transparent Web proxies

All operate *within* network, making use of application-level information

- Which addresses can do what at application level?
- If addresses have meaning to applications, NAT must "understand" that meaning. Difficult!

Future Internet: Some readings

- Mark Handley: *Why the Internet only just works.*
  BT Technology journal, 2006
- Anja Feldmann: *Internet Clean-Slate Design: What and Why?*
  Editorial note, ACM CCR, 2007
- Akhshabi, Dovrolis: *The evolution of layered protocol stacks leads to an hourglass-shaped architecture.*
  Proceedings of ACM SIGCOMM, 2011

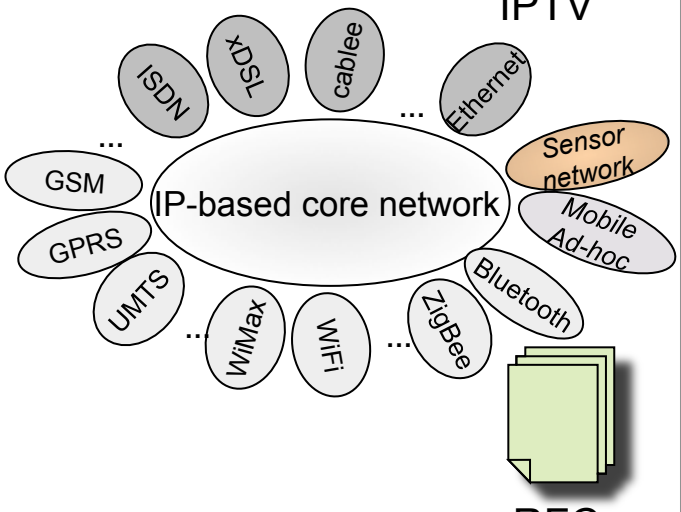
- Note: with a TUM IP address, you can download most scientific articles for free if you enable the LRZ proxy: http://www.lrz.de/services/netzdienste/proxy/journals-access/

Networking Research related to Network Measurements

Challenges and Goals

- Network growth
  - Network traffic
  - Number of nodes
  - ⇨Scalability
- Growing complexity and heterogeneity
  - Variety of network access technologies
  - Specific devices
  - Functional extensibility
  - ⇨ Controllability and flexibility
- Personell expensive and error-prone
  - ⇨ Automation of decisions in the network
- Threats of attacks
  - ⇨ Availability and security

IPTV



RFCs

rule database

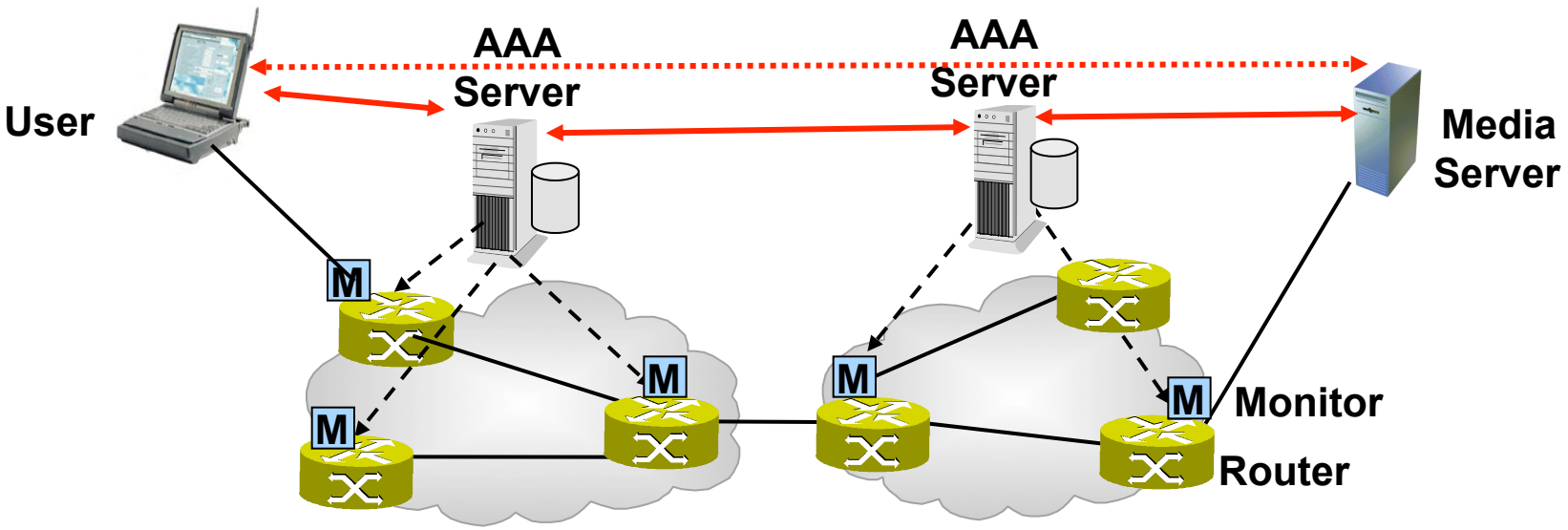
attacker

Internet Trends and Innovative Concepts

- Innovative approaches
  - Knowledge plane (Clark - MIT)
  - Inspection-and-action boxes (Katz - UC Berkeley)
  - NSF FIND (Future Internet Network Design)
    GENI (Global Environment for Networking Innovations)
  - Autonomic Networking (c.f. Dagstuhl perspektives seminar)
- Relevant components
  - Instrumentation of the network
  - Intelligent processing
  - Initiating actions based on derived information
  - Concept „Measuring – Processing – Reacting“
- Applications
  - Protection from Distributed Denial-of-Service (DDoS) attacks
  - Quality improvements for Internet telephony

Internet Instrumentation

- Commercial internet services
  - Capturing ressource usage and surveillance of quality-of-service
- AAA server for Authentification, Authorisation and Accounting



Standardistion contributions to IETF/IRTF (Carle et al.):

- Policy-based Accounting (RFC3334)

Patents (Carle et al.)

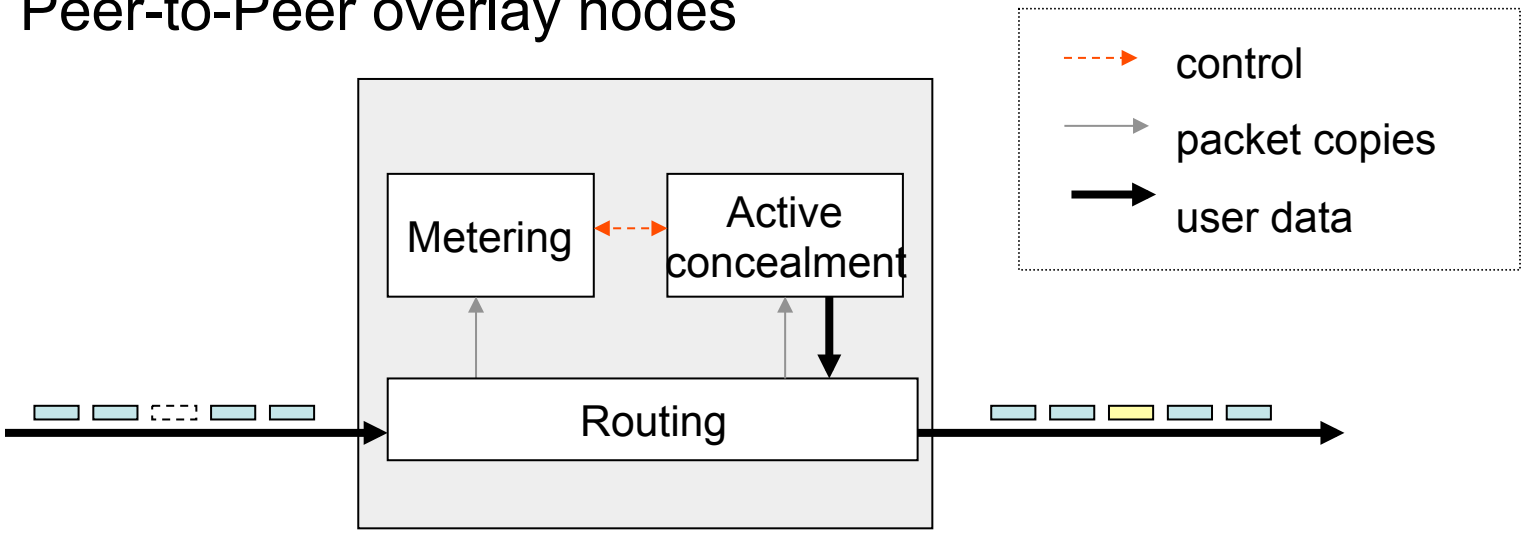
- Network Traffic Measurement System
- Contents Measurements System
- Network Measurement Configuration Apparatus

What is an Active Network ?

- Depends on who you ask!
- active services: application-level services exploiting position within the network to provide enhanced service
  - CDN
  - streaming media caches
- capsule approach: packets carry programs, active node executes program when code-carrying packet arrives to active node
  - code may determine what to do with packet
  - may implement other service: e.g., network management, reliable multicast

Error concealment for Internet Telephony

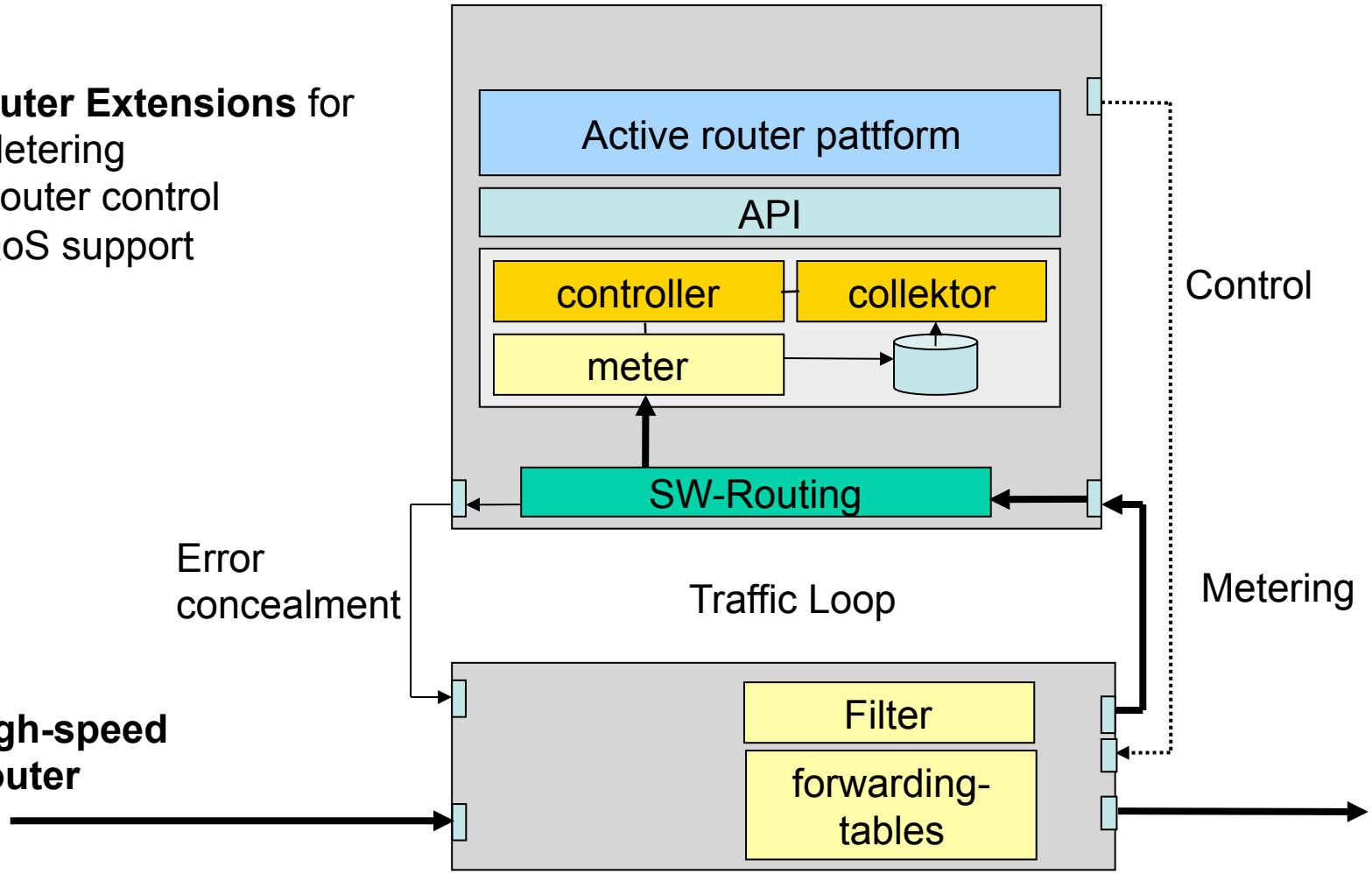
- Problem
  - Packet loss due to congestion
- Approach
  - Error concealment
- Implementation alternatives
  - Active routers
  - Peer-to-Peer overlay nodes



⇨„Measuring – Processing – Reacting“ for Internet Telephony

Architecture for active High-speed Router

Router Extensions for
- Metering
- Router control
- QoS support



the end