Institute of Computer Science
University of Würzburg
Prof. Phuoc Tran-Gia

Pathways to Next Generation Networks

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University of Würzburg
Germany

www.german-lab.de

euronf
NETWORK OF EXCELLENCE

Pathways to Next Generation Networks

▶ **Boom of Next Generation Network Projects**

- Growing funding and diversity
- Growing number of testbeds & experimental facilities
- Virtualization efforts of most areas in networking and applications
- One network or a polymorphic "network of networks"

▶ **The G-Lab Experimental Facilities**

- Concept and project structure
- Some exemplary results

▶ **Future network: quo vadis?**

- Emerging trends
- One network or polymorphic networks

Next Generation Network Experimental Facilities

Testbeds and experimental facilities

analytical studies

experiment-driven research

generic testbed & experimental facilities

adaptable testbed & experimental facilities

dedicated testbeds

Test cases and Federation of Experimental Facilities

Federated Test Facility *University of Würzburg*
Institute of Computer Science
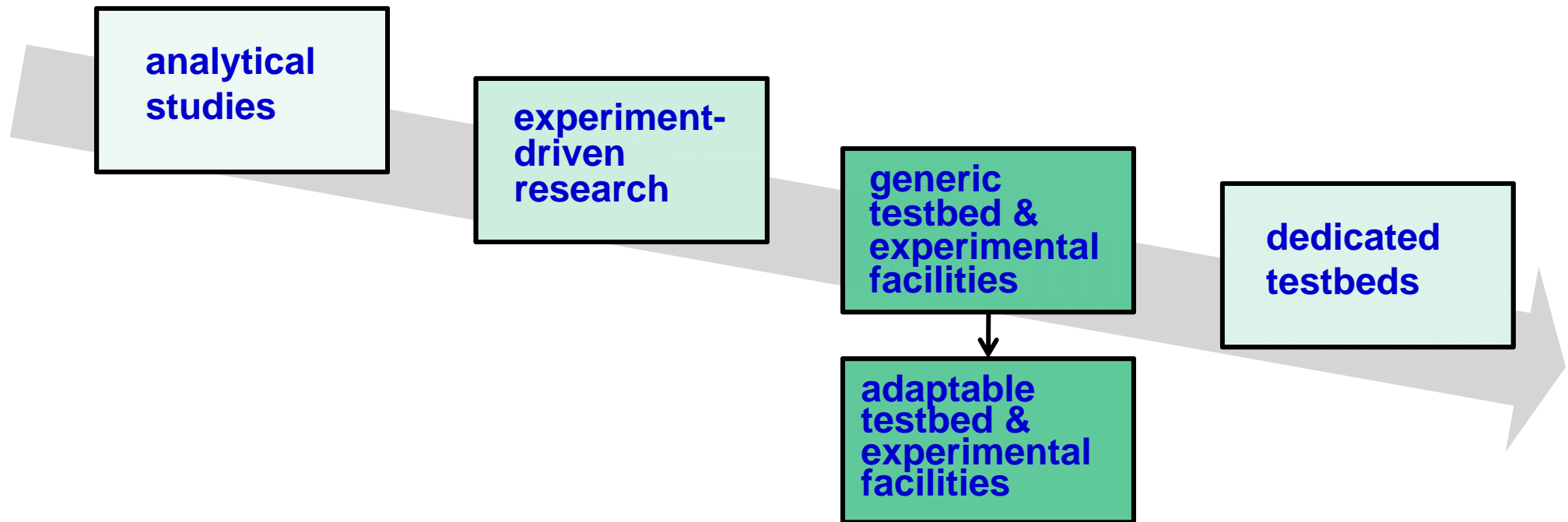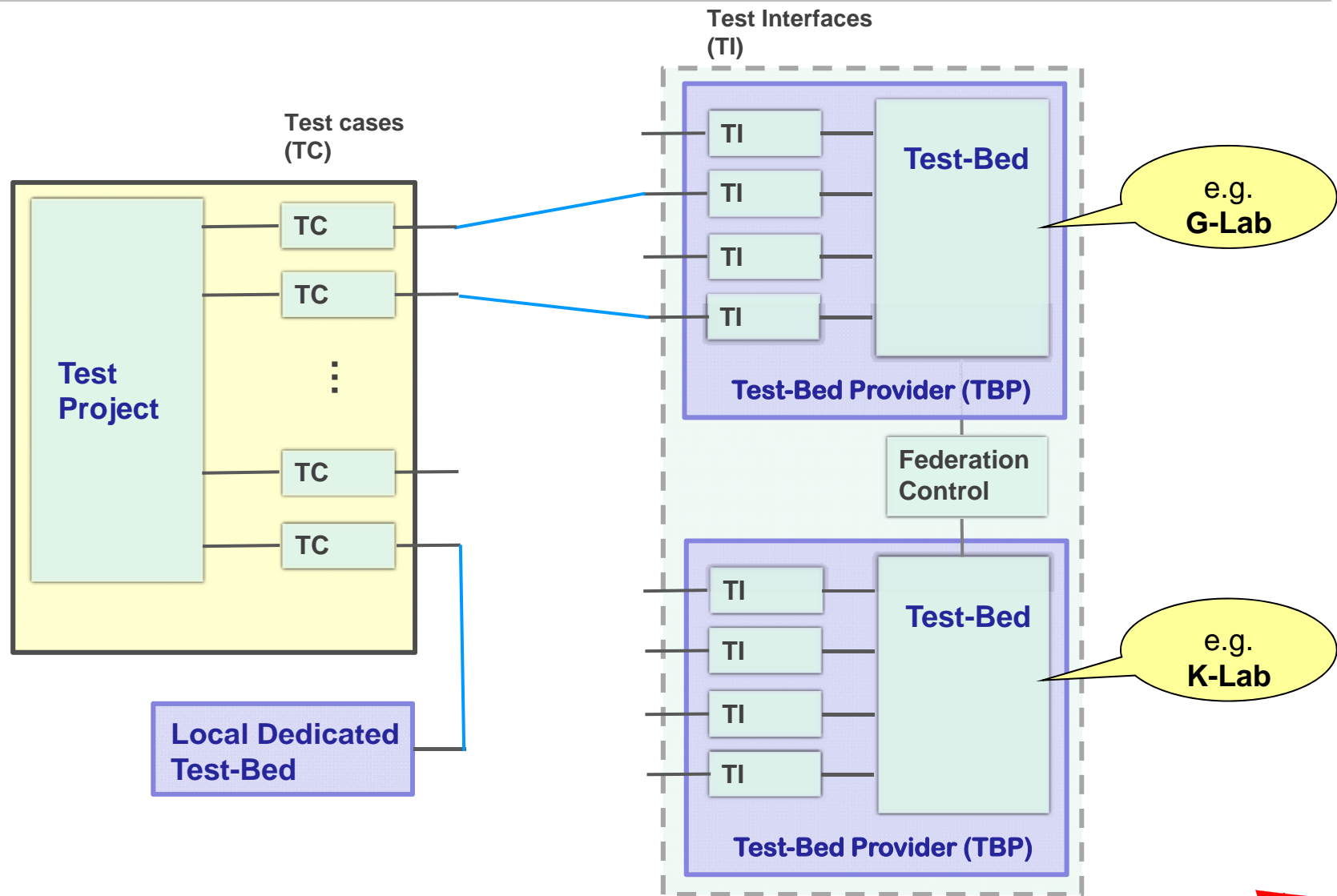
Purpose of experimental facilities

Possible Future

network evolution

? ? ? ? ?

Current Internet

Improve current network design with that solution in mind!

Search for optimal solution using clean slate approach

Timeline

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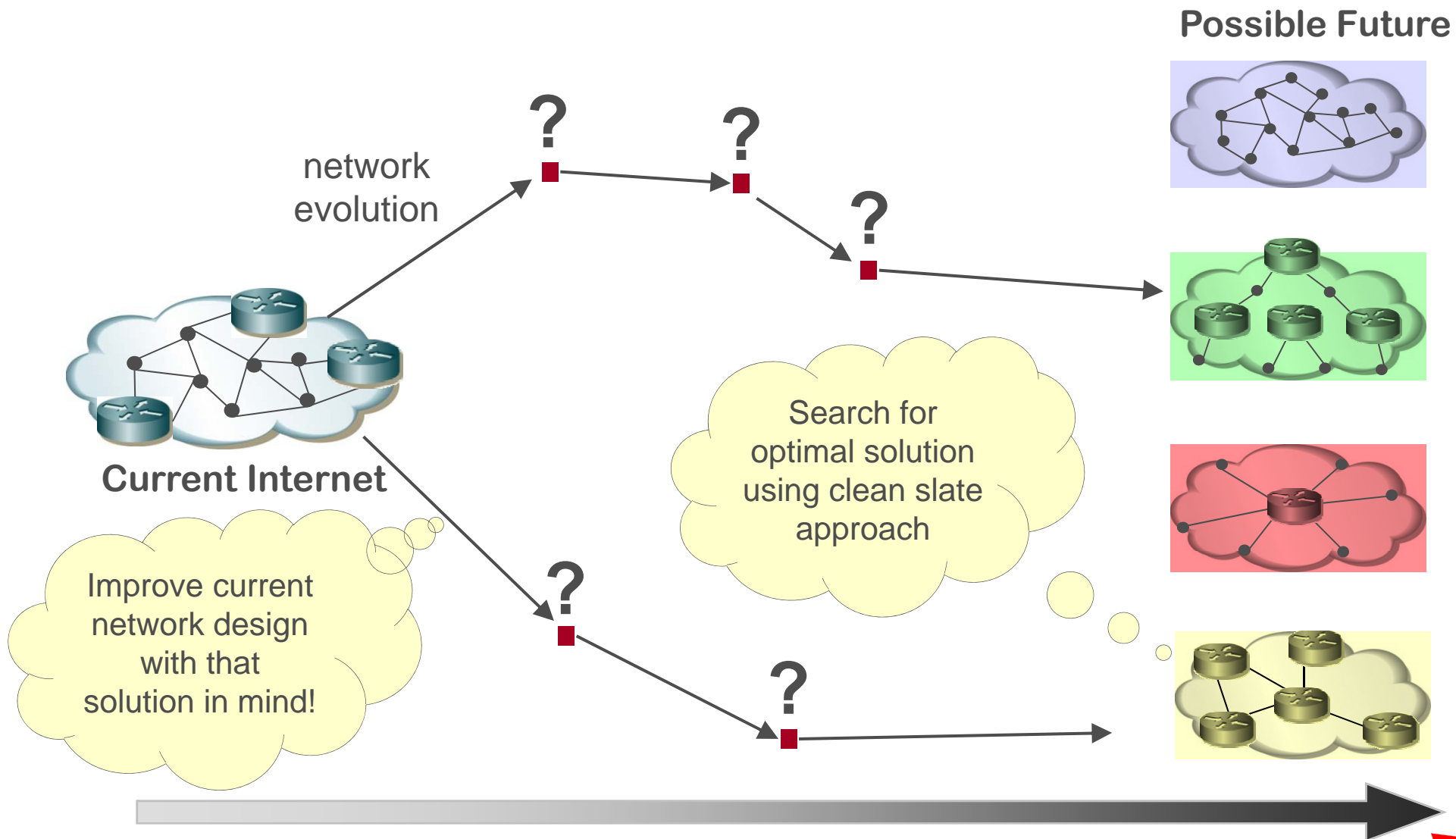
Slice Concept
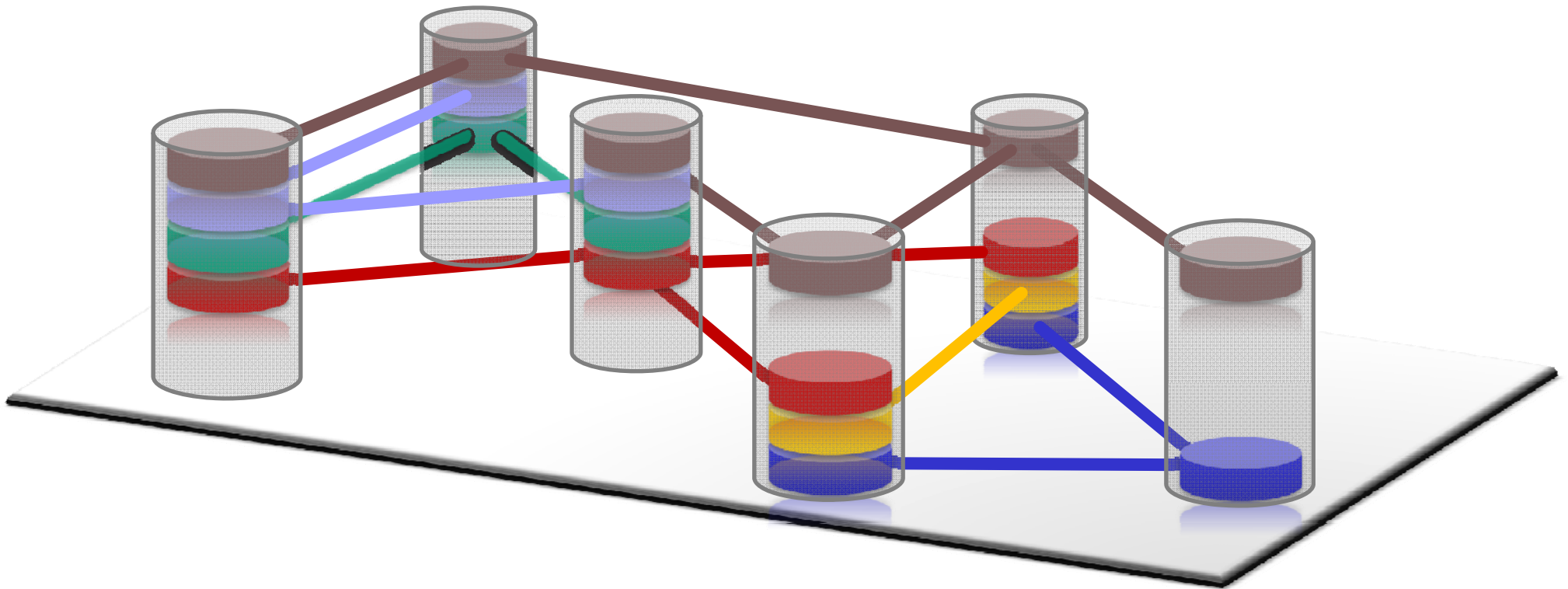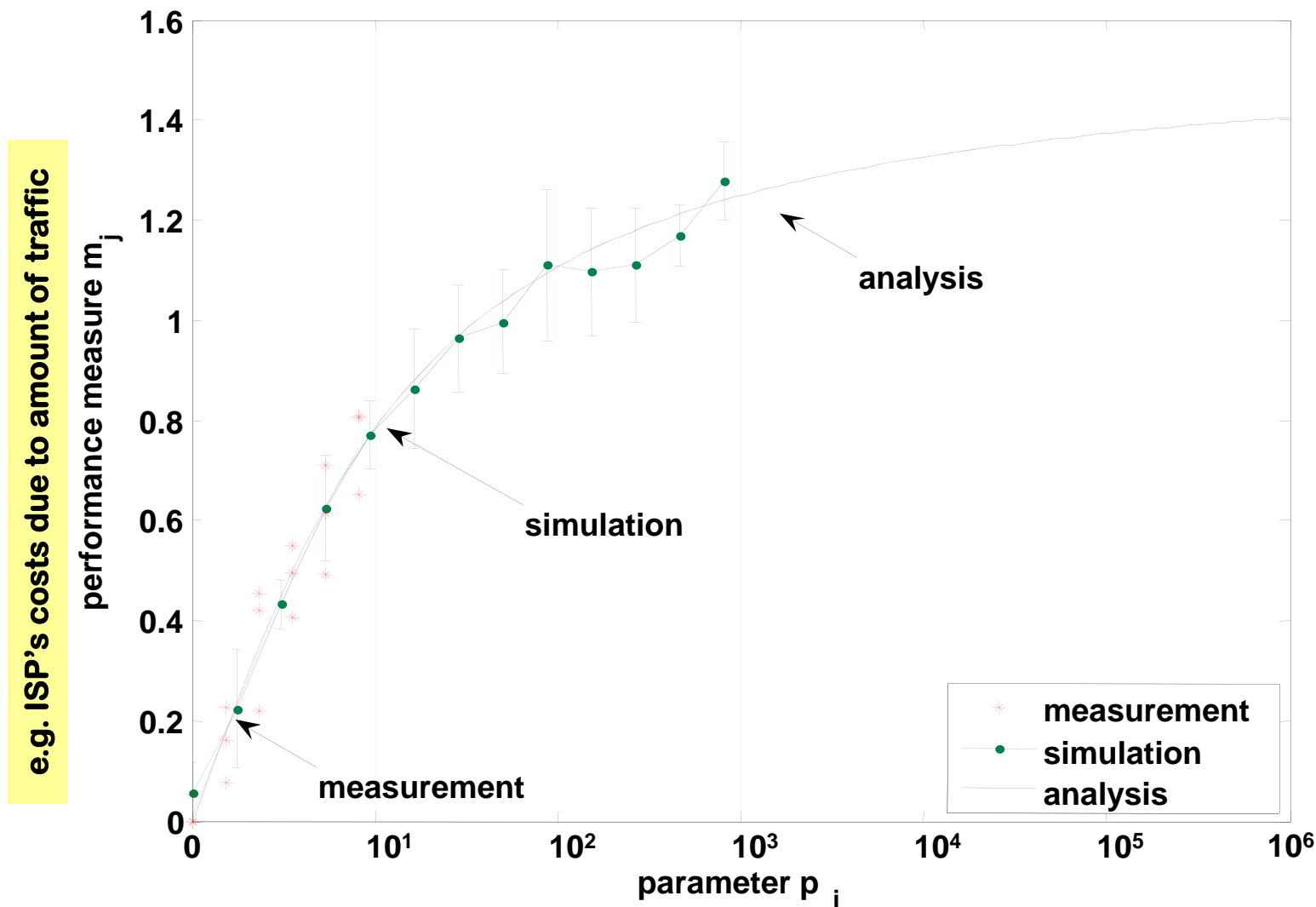
Federation: current situation

▶ **Situation**

- many generic testbeds
- very few Test Cases and interface to testbeds are well-defined
- most Test Cases can be tested locally, or investigated using simulation or analytic approaches
- federation concepts, when exist, are not use-case oriented

▶ **Chalenges**

- bringing users to the testbed, easy-to-use guideline for future potential users
- deal with scalability questions, combine with other analysis methods
- systematic use-case design and federation concept
- define use-cases to show interworking possibility of existing test-beds

Measurement, Simulation, Analysis
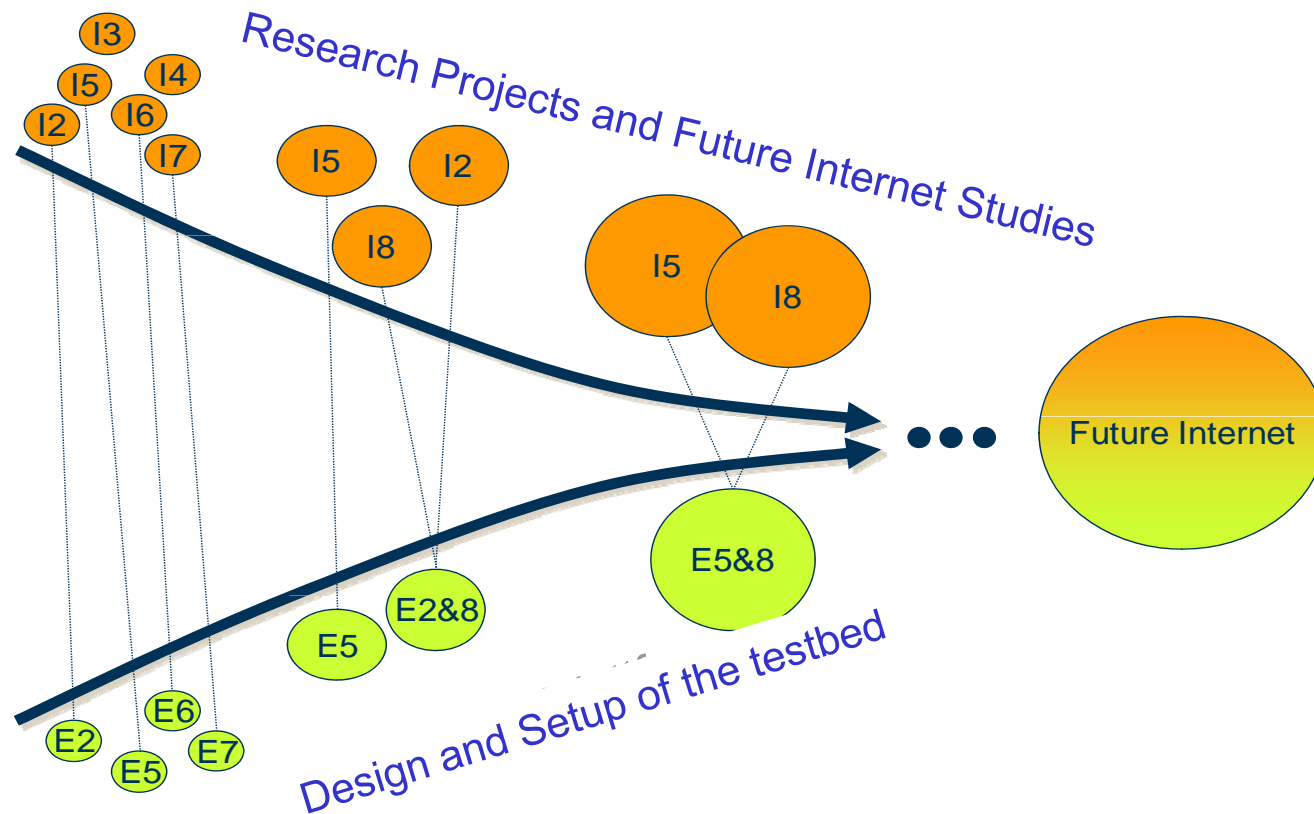
Pathways to Next Generation Networks

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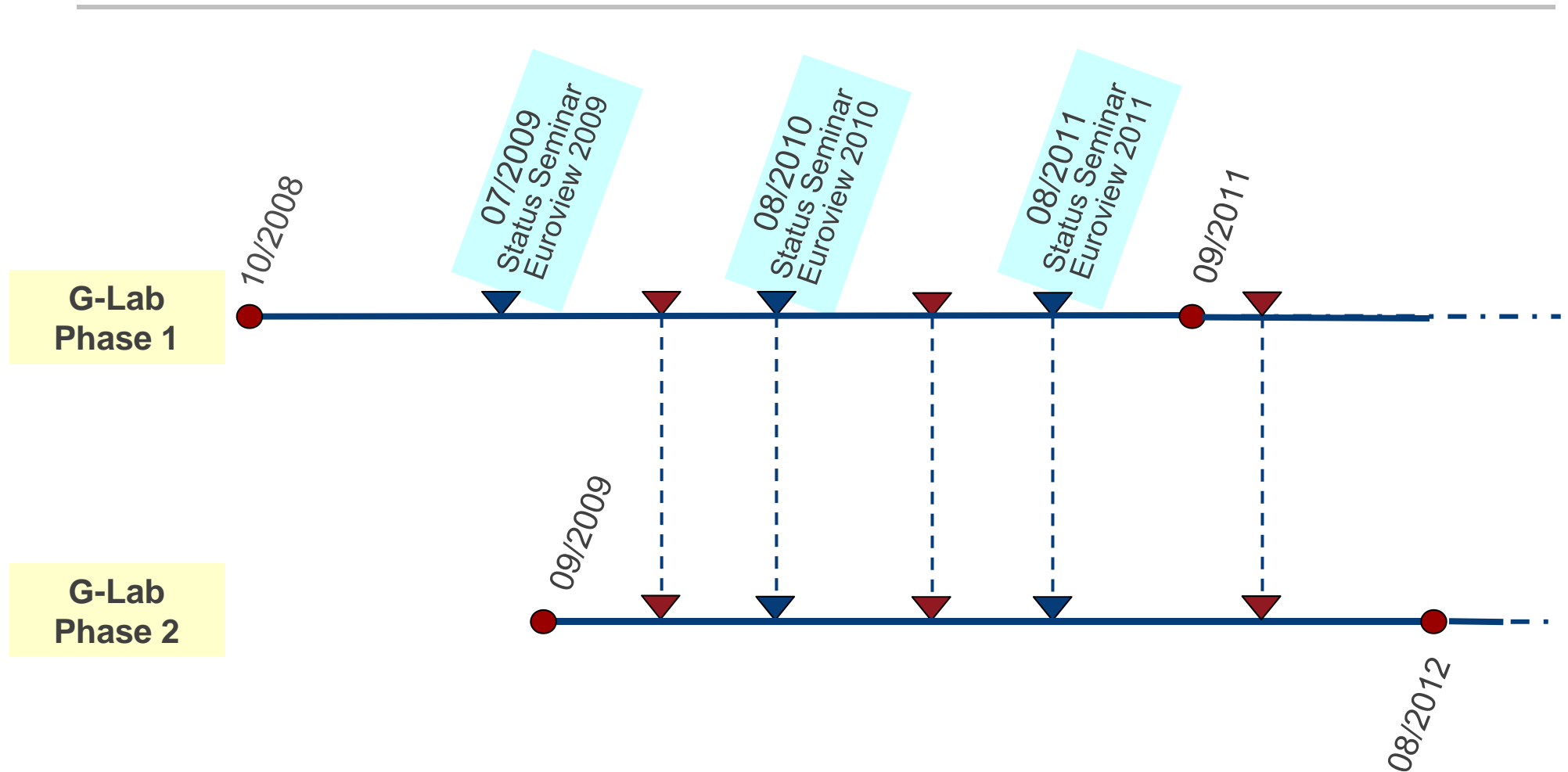- One network or a polymorphic "network of networks"

▶ **The G-Lab Experimental Facilities**

- Concept and project structure
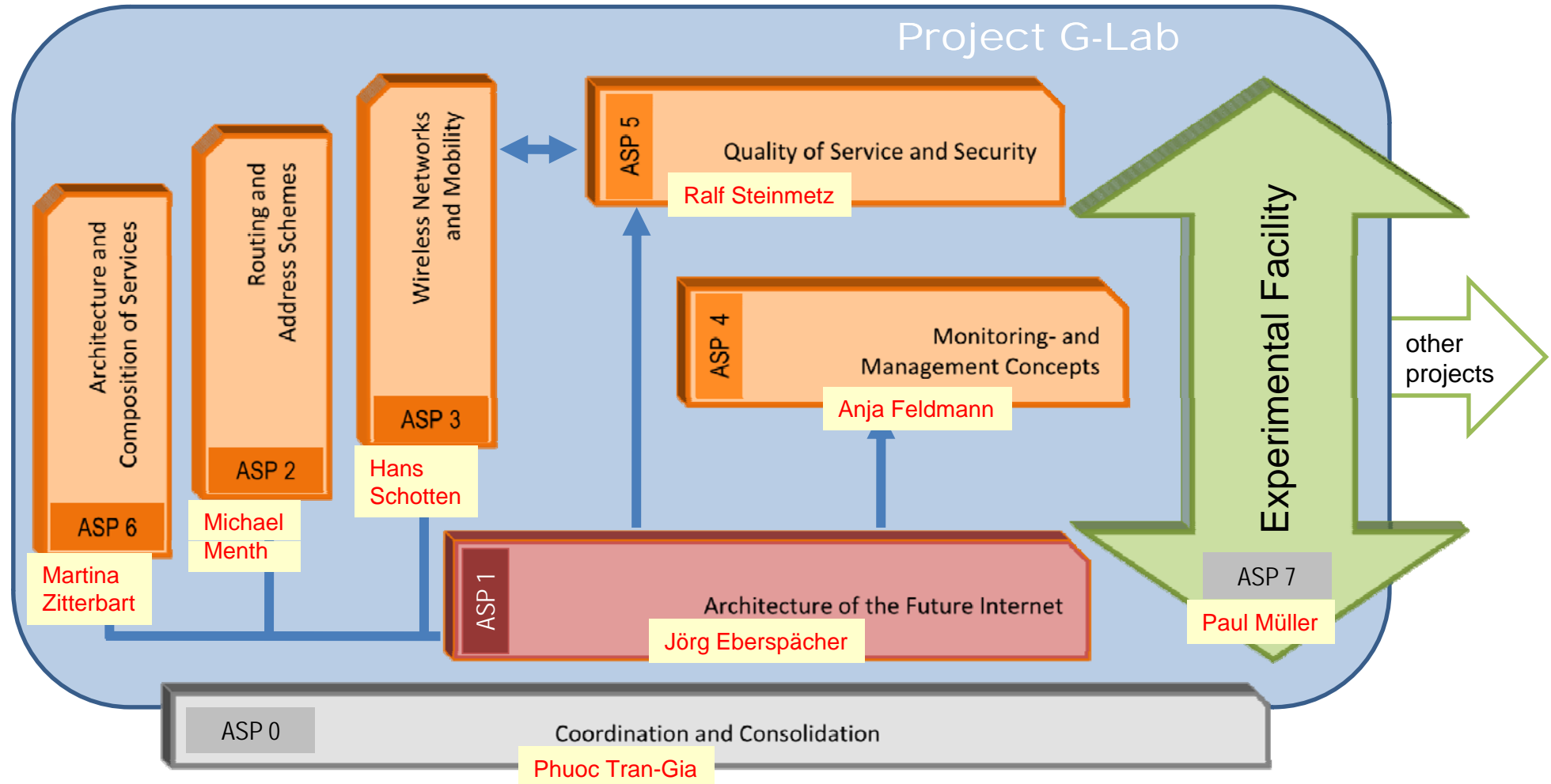- Some exemplary results

Example: G-Lab project objective and pathway

Research Projects and Future Internet Studies

I3
I5
I4
I2
I6
I7
I5
I2
I8
I5
I8

Design and Setup of the testbed

E5&8
E2&8
E5
E6
E2
E5
E7

Future Internet

G-Lab Timeline

G-Lab Phase 1

10/2008

07/2009 Status Seminar Euroview 2009

08/2010 Status Seminar Euroview 2010

08/2011 Status Seminar Euroview 2011

09/2011

G-Lab Phase 2

09/2009

08/2012

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G-Lab Phase 1 Project Structure

Project G-Lab

Architecture and Composition of Services — ASP 6 — Martina Zitterbart

Routing and Address Schemes — ASP 2 — Michael Menth

Wireless Networks and Mobility — ASP 3 — Hans Schotten

Quality of Service and Security — ASP 5 — Ralf Steinmetz

Monitoring- and Management Concepts — ASP 4 — Anja Feldmann

Architecture of the Future Internet — ASP 1 — Jörg Eberspächer

Experimental Facility — ASP 7 — Paul Müller

other projects

Coordination and Consolidation — ASP 0 — Phuoc Tran-Gia

Phuoc Tran-Gia

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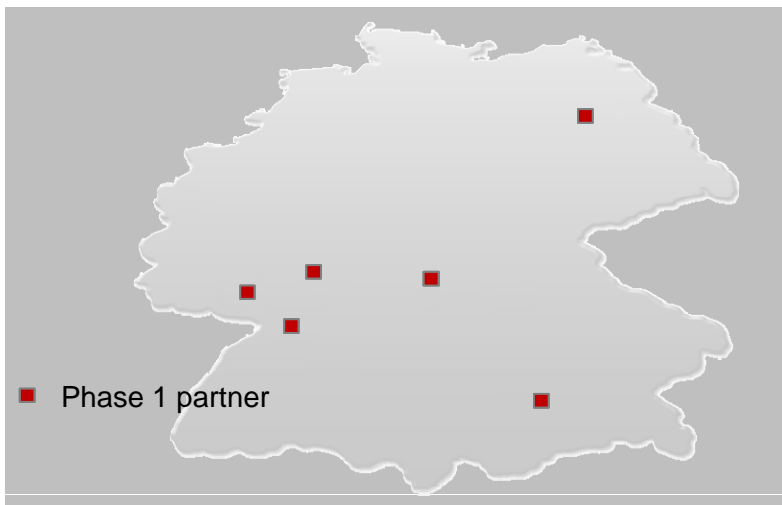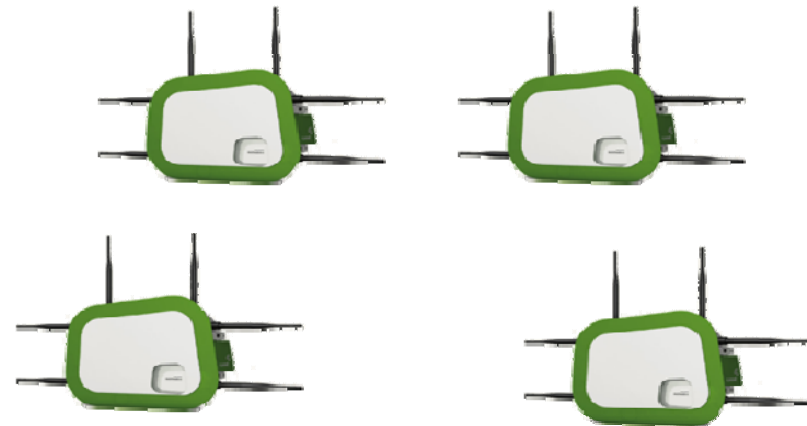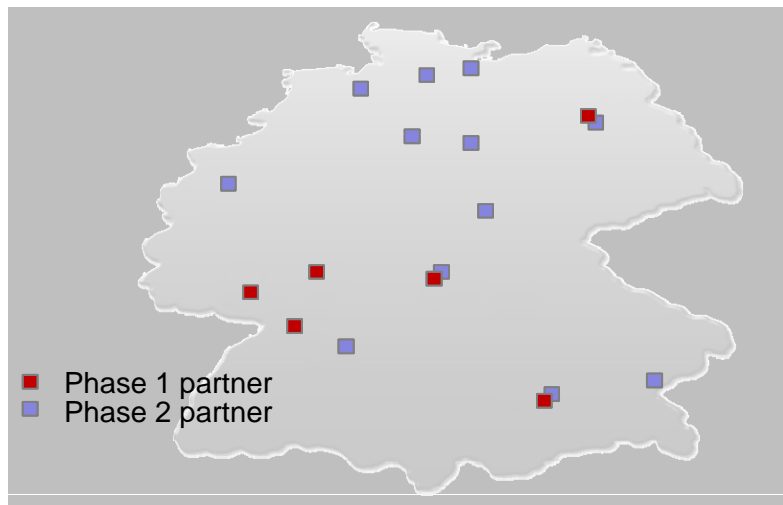
G-Lab Experimental Facility 2008

▶ Homogeneous hardware

▶ 6 Sites

▶ Minimum of 25 nodes per site

▶ Central in Kaiserslautern

▶ Around 170 nodes

▶ Started with PlanetLab like nodes

■ Phase 1 partner

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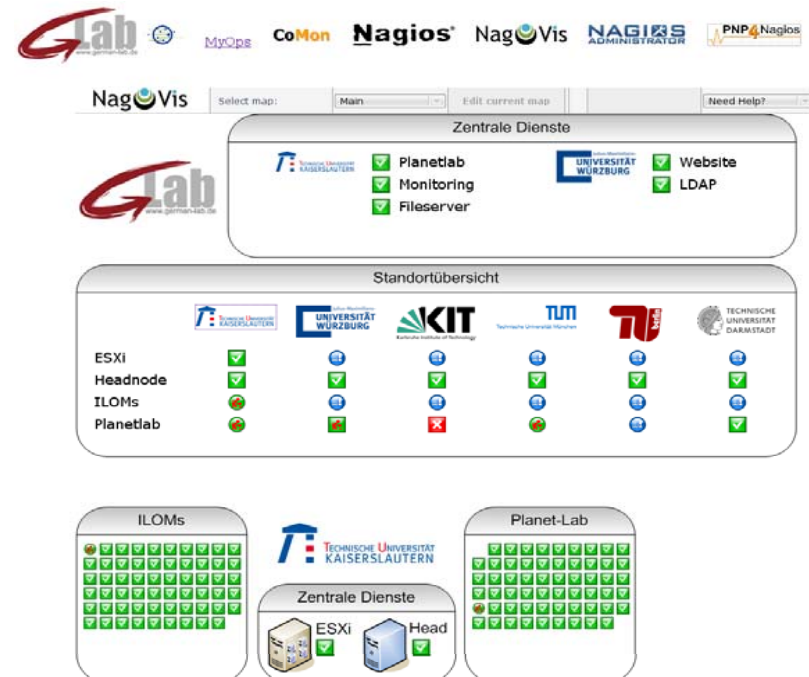*Institute of Computer Science*
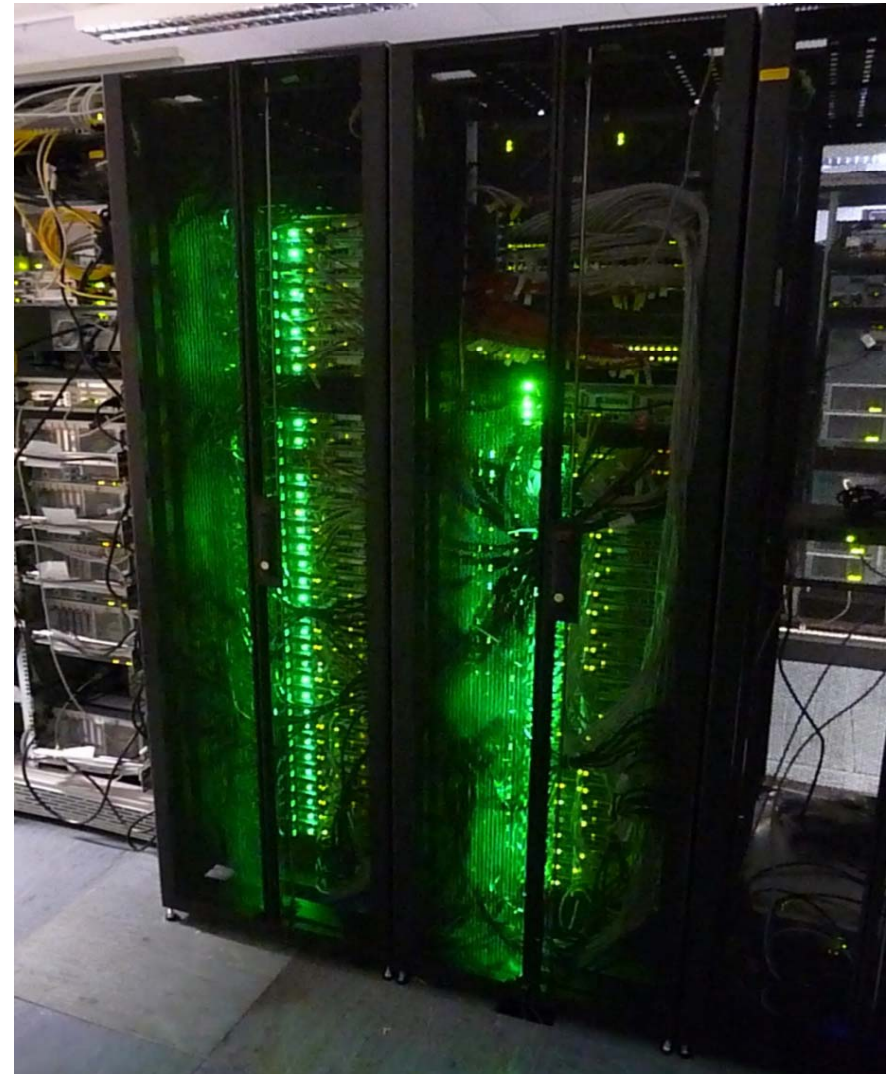
G-Lab Experimental Facility 2009

- ▶ 10 Sites
- ▶ Central in Kaiserslautern
- ▶ Net nodes
- ▶ Sensor nodes
- ▶ Mesh nodes

- ▶ PlanetLab nodes
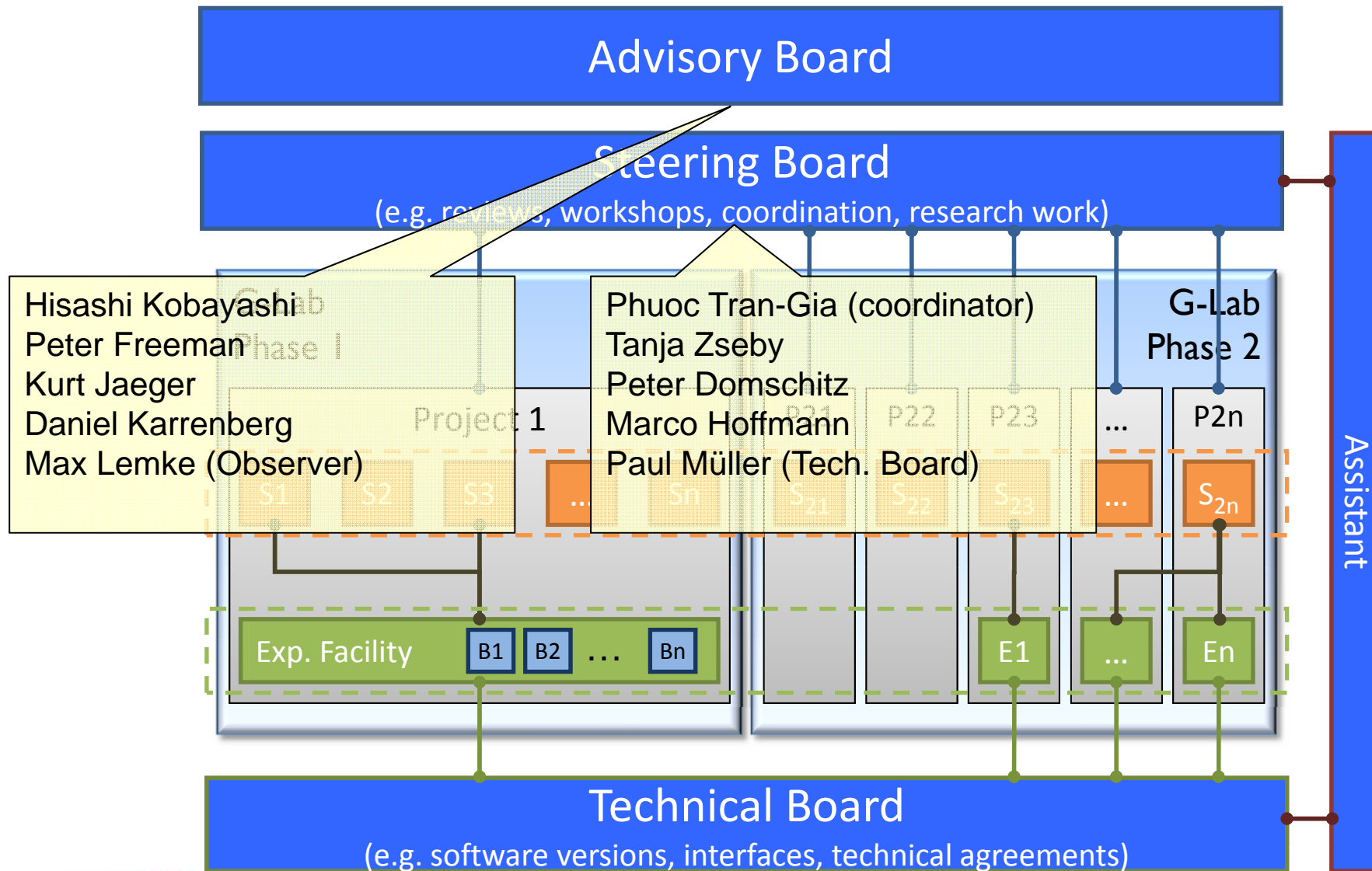- ▶ Multi-hop IPv6 based on Contiki OS

- ■ Phase 1 partner
- ■ Phase 2 partner

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G-Lab Experimental Facility 2010

► All nodes: managed over ILOM

► Power supply: power consumption can be queried remotely

► Predefined boot images
  ▪ Planet-Lab
  ▪ Hypervisor virtualization (Proxmox)
  ▪ Custom boot image

► G-Lab **Topology Management Tool** (**ToMaTo**)

► Emulab

► Multi-hop IPv6 based on Contiki OS

► OpenFlow

► Energy-efficient node management

► Enhanced monitoring capabilities

G-Lab Structure

Advisory Board

Steering Board
(e.g. reviews, workshops, coordination, research work)

Hisashi Kobayashi
Peter Freeman
Kurt Jaeger
Daniel Karrenberg
Max Lemke (Observer)

Phuoc Tran-Gia (coordinator)
Tanja Zseby
Peter Domschitz
Marco Hoffmann
Paul Müller (Tech. Board)

G-Lab Phase I

G-Lab Phase 2

Project 1

P21 P22 P23 ... P2n

S1 S2 S3 ... Sn

S_{21} S_{22} S_{23} ... S_{2n}

Exp. Facility B1 B2 ... Bn

E1 ... En

Assistant

Technical Board
(e.g. software versions, interfaces, technical agreements)

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G-Lab Phase 2

► **COMCON (Control and Management of Coexisting Networks)**
- Nokia Siemens Networks — *Industry*
- DoCoMo Eurolabs — *Industry*
- Infosim — *SME*
- University of Stuttgart — *University*
- University of Würzburg — *University*

> *Provider and operator-grade management and control of virtualized networks*

► **VirtuRAMA (Virtual Routers: Architecture, Management, Applications)**
- Thomson — *Industry*
- Lamdanet — *SME*
- University of Hannover — *University*
- Technical University Darmstadt — *University*

> *Facilitated setup and management of virtualized network components*

► **FoG (Forwarding on Gates)**
- Technical University Illmenau — *University*

> *Future Internet architecture with forward plane based on functional blocks*

► **NETCOMP (Network-Computing for the Service Internet of the Future)**
- Alcatel-Lucent — *Industry*
- University of Bremen — *University*

> *Efficient utilization of network-connected computing resources*

► **CICS (Convergence of Internet and Cellular Systems)**
- Qualcomm — *Industry*

> *Develop architectures and protocols to support mobility and QoS*

G-Lab Phase 2

▶ **HAMcast (Hybrid Adaptive Mobile Multicast)**
- HAW Hamburg — *University*
- The unbelievable Machine Co. — *SME*

Robust service access allowing group applications to run over every technology

▶ **Deep (Deepening G-Lab for Cross-Layer Composition)**
- Fraunhofer Fokus — *Research Institute*
- Technical Univ. Kaiserslautern — *University*
- Technical Univ. Berlin — *University*
- University of Duisburg/Essen — *University*

Innovative composition-approaches for cooperation between network and services with the focus on security

▶ **Real-World G-Lab**
- Coalesenses — *SME*
- University of Lübeck — *University*
- FH Lübeck — *University*
- University of Braunschweig — *University*
- FU Berlin — *University*

Development of various technologies to enable the "Internet of Things"

▶ **Ener-G (Energy Efficiency in G-Lab)**
- AKT Infosys — *SME*
- University of Passau — *University*
- TU Kaiserslautern — *University*

Exploration of energy-efficient operation of the Future Internet and extension of G-Lab with aspects of energy efficiency
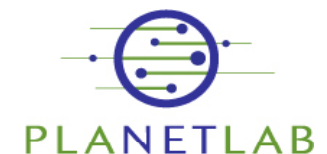
Memorandum of Understanding

- ▶ Goal
  - federation of experimental platforms
  - exchange of software
  - cross-promotion and joint research
  - exchange of students

- ▶ MoU of G-Lab and OneLab 2
  - Status: **signed**

- ▶ MoU of G-Lab and PlanetLab Japan
  - Status: **signed**

- ▶ MoU of G-Lab and GENI
  - Status: **signed**

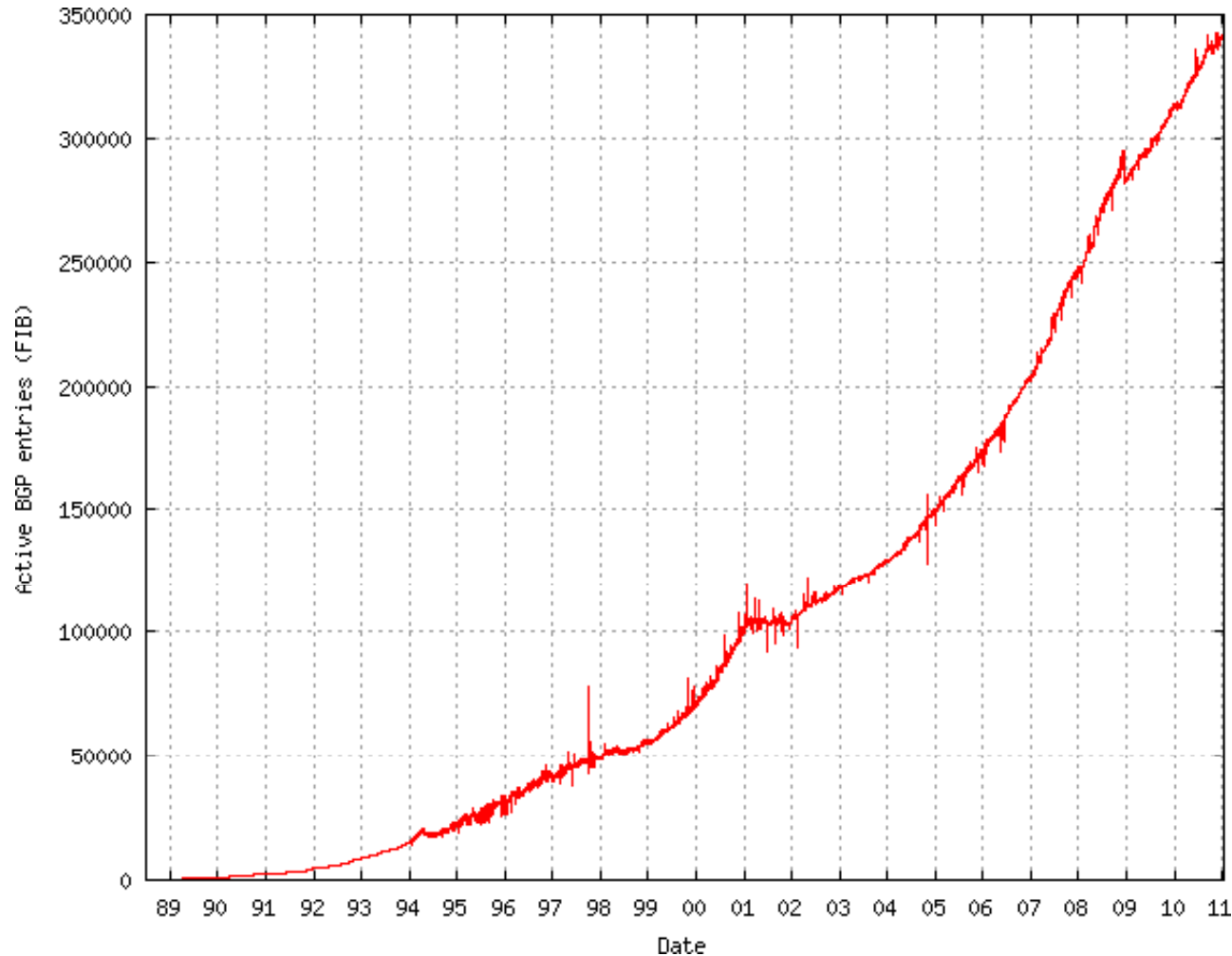- ▶ MoU of G-Lab and PlanetLab US
  - Status: **signed**

Julius-Maximilians-
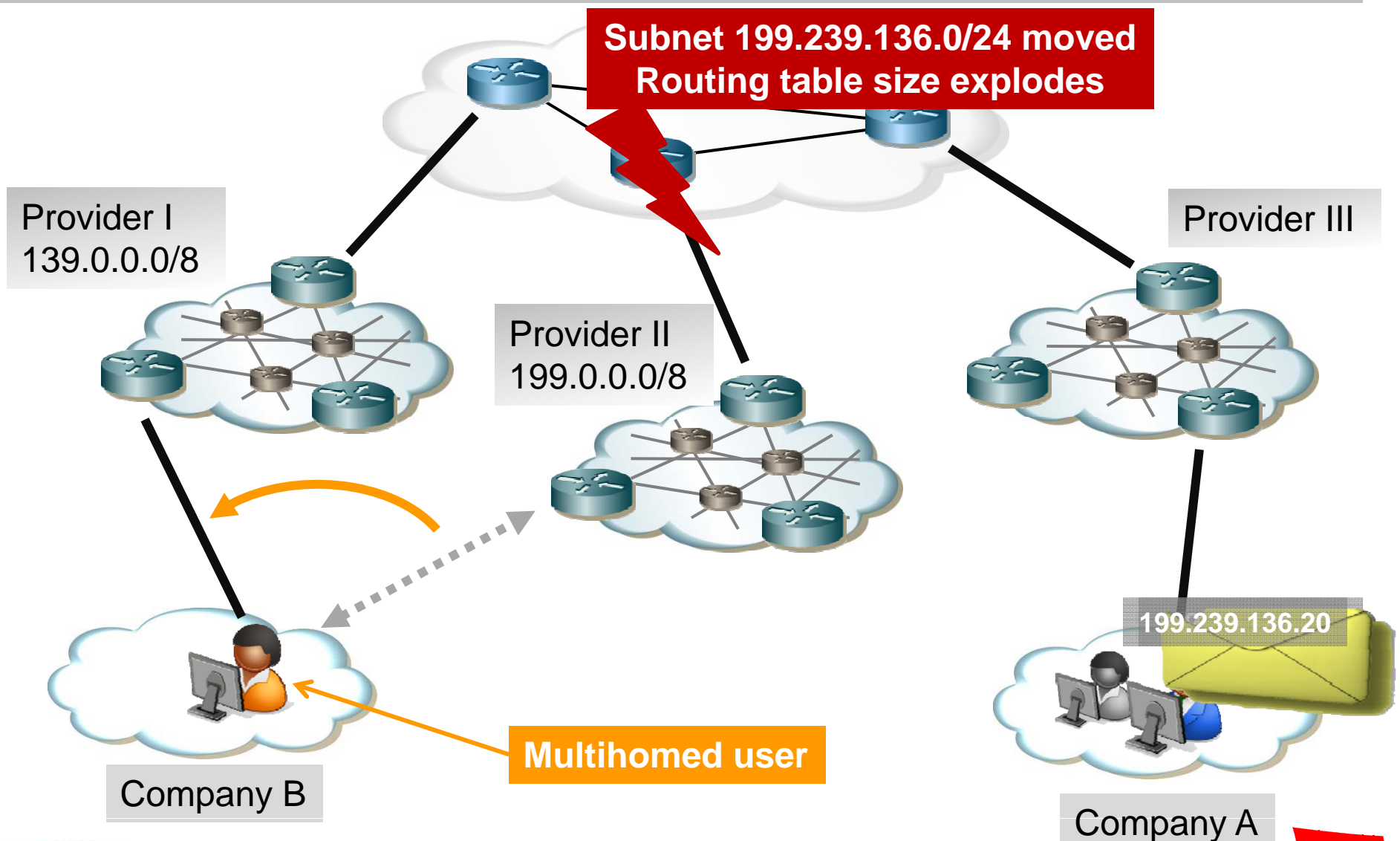UNIVERSITÄT
WÜRZBURG

Institute of Computer Science
University of Würzburg
Prof. Phuoc Tran-Gia

Example: Project
Future Internet Mapping System FIRMS

Lab
www.german-lab.de

Federal Ministry
of Education
and Research

Why do we need a new Internet routing?

▶ BGP table sizes seen at one router (07.1988 – 01.2011)

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Current Internet Routing

Subnet 199.239.136.0/24 moved
Routing table size explodes

Provider I
139.0.0.0/8

Provider III

Provider II
199.0.0.0/8

199.239.136.20

Multihomed user

Company B

Company A

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ID-Locator Separation

Provider I
139.0.0.0/8

199.239.136.20

Provider II
199.0.0.0/8

Provider III

Provider I

Mapping service

199.239.136.20

Company B

Company A

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Test cases and Federation of Experimental Facilities

Test Interfaces (TI)

Test cases (TC)

FIRMS

TC
TC
...
TC
TC

Omnet++

TI
TI
TI
TI

Test-Bed Provider (TBP)

Federation Control

TI
TI
TI
TI

Test-Bed Provider (TBP)

Federated Test Facility

▶ **Federated test case**
- Extend scale for mapping system

- More diversity regarding network properties

- G-Lab serves as stable distribution network
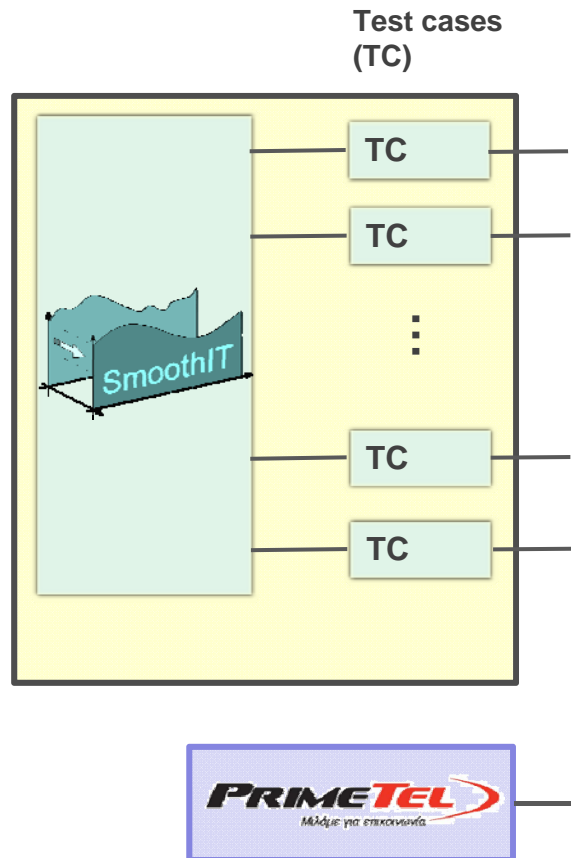
- MBs and MRs located in other testbeds

FIRMS Implementation in G-Lab

Demo:

Euroview 2010
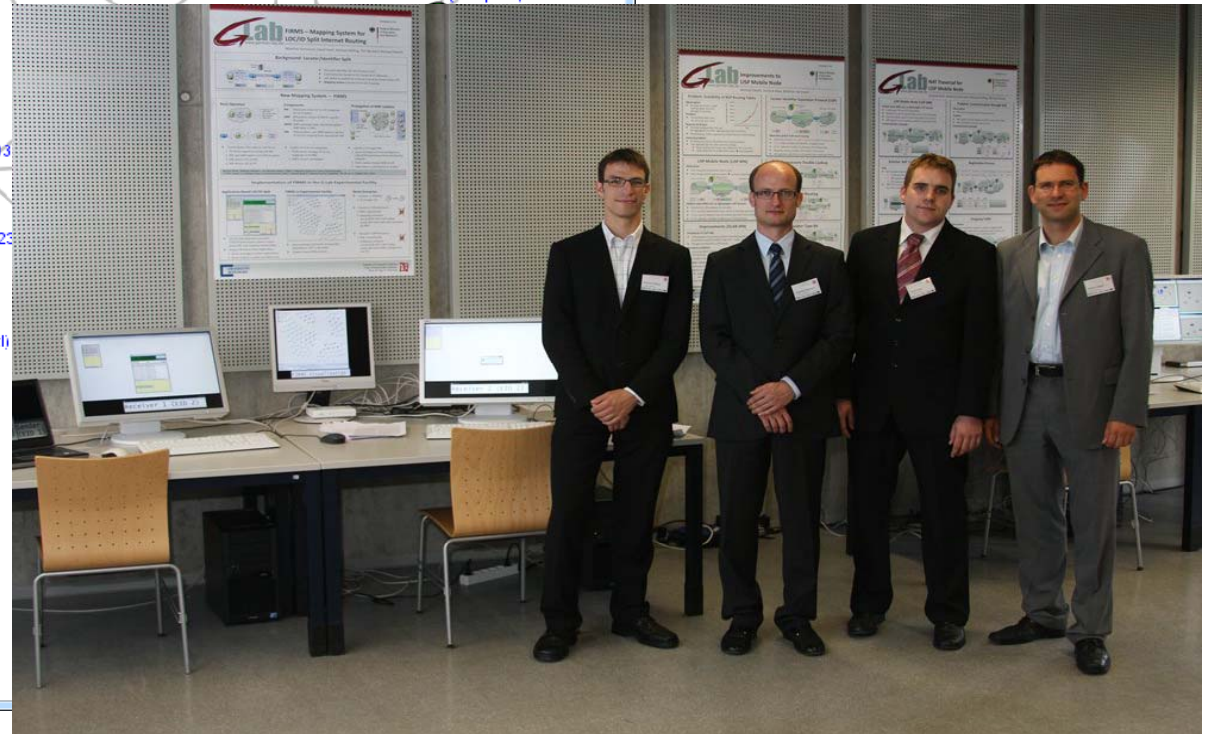
Example
Project SmoothIT (FP7)

www.german-lab.de

Federal Ministry
of Education
and Research

Test cases and Federation of Experimental Facilities

Test cases (TC)

▶ **Problem statement**

- ▪ Inter-AS traffic increases ISP costs
- ▪ Highest percentage → P2P traffic

▶ **Idea**

- ▪ Location-aware P2P client
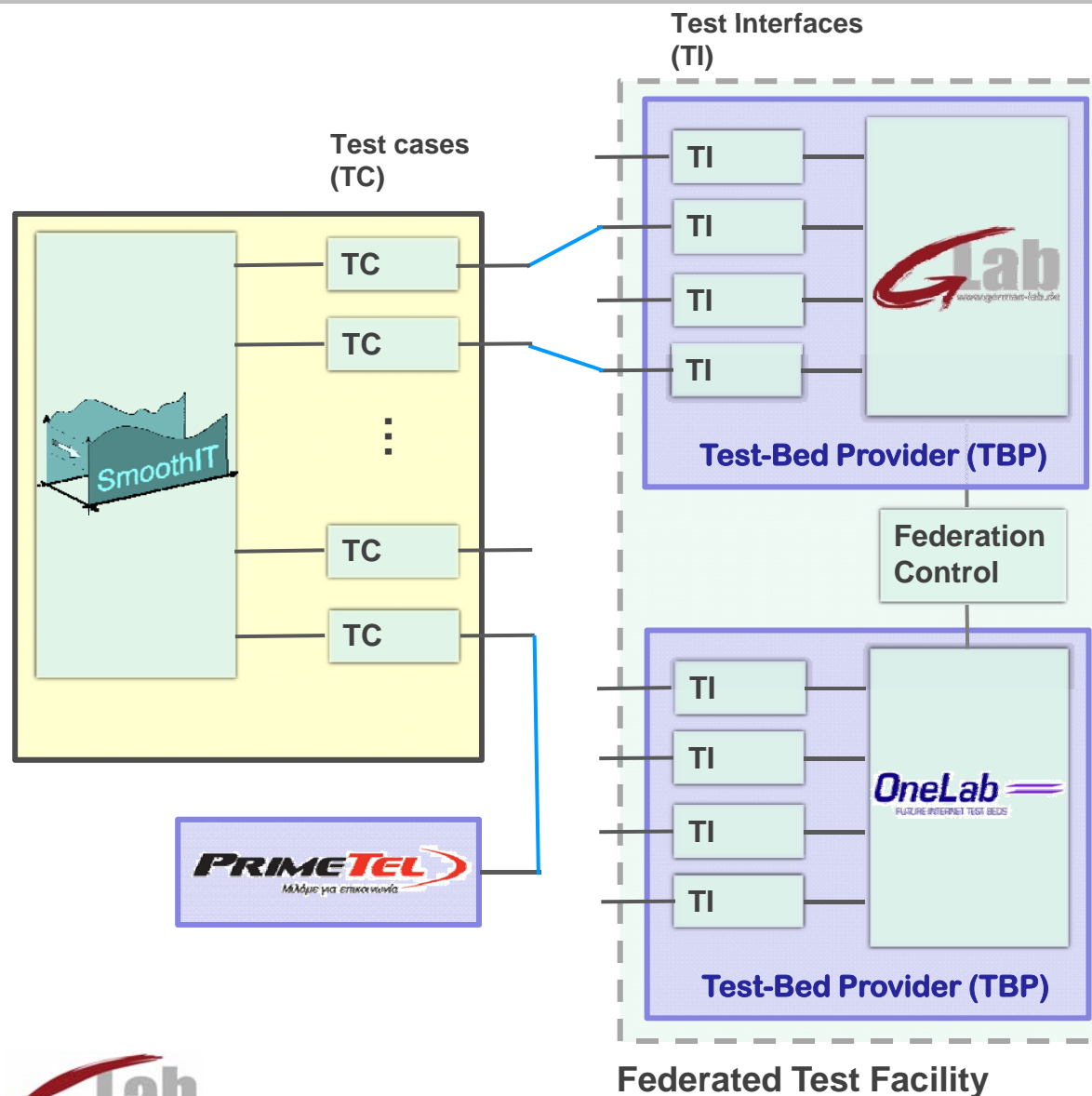- ▪ Prefer peers from same AS

▶ **First experiments**

- ▪ Local tests at PrimeTel with real users

Test cases and Federation of Experimental Facilities
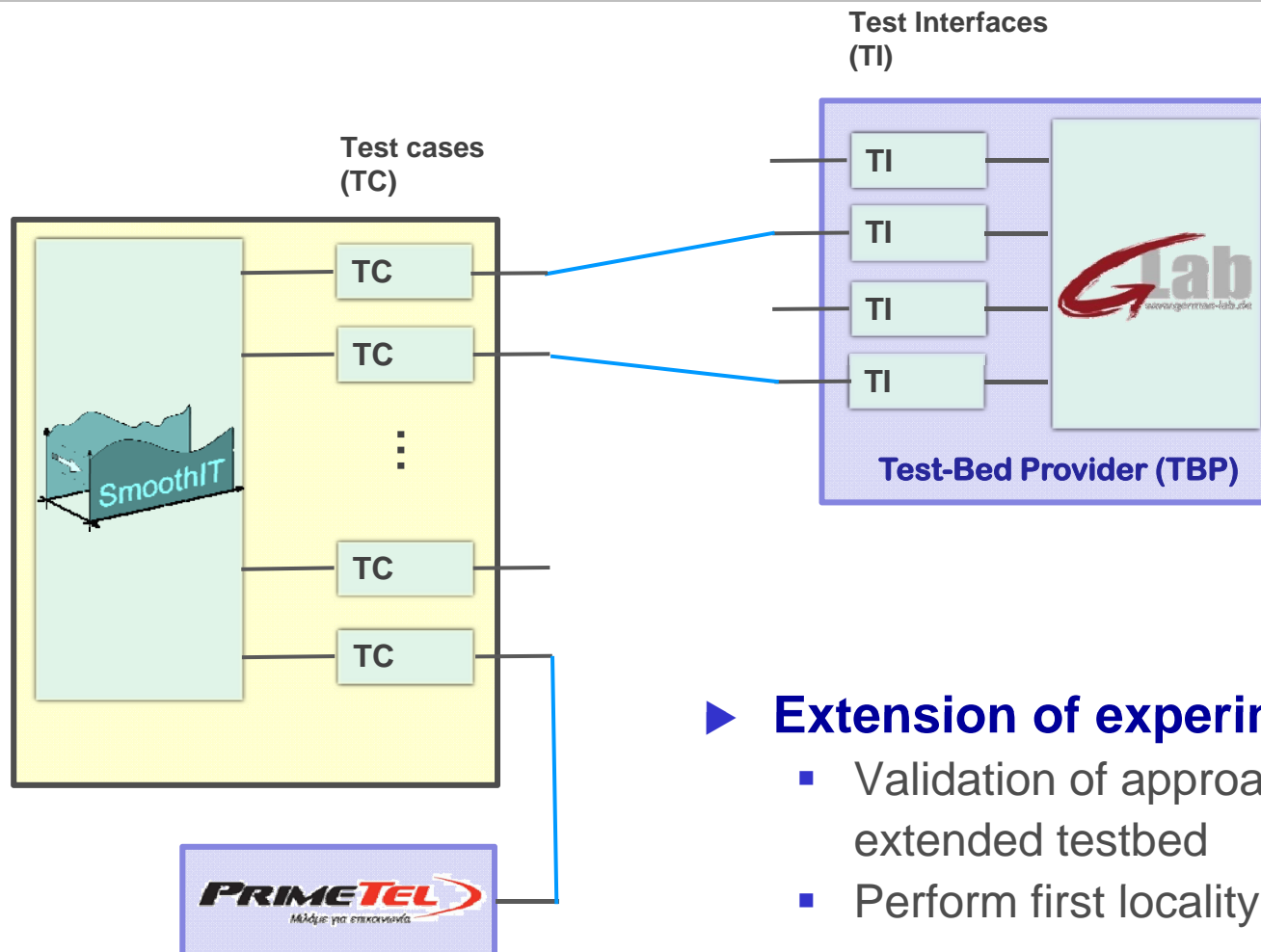
Extension of experiments
- Validation of approach within extended testbed
- Perform first locality tests

# Test cases and Federation of Experimental Facilities

Test Interfaces (TI)

Test cases (TC)

SmoothIT

TC
TC
...
TC
TC

PRIMETEL
Μιλάμε για επικοινωνία

TI
TI
TI
TI

G-Lab
www.german-lab.de

Test-Bed Provider (TBP)

Federation Control

TI
TI
TI
TI

OneLab
FUTURE INTERNET TEST BEDS

Test-Bed Provider (TBP)

Federated Test Facility

▶ **Final evaluation**

- Large-scale testing

- Multiple ASes (e.g. G-Lab and OneLab)

▶ **Outcome**

- Problem identification

- Optimize simulation and analytical models

Federated Test case Scenario
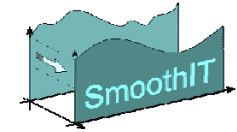
▶ **Test case objective**

- Percentage of inter-AS traffic
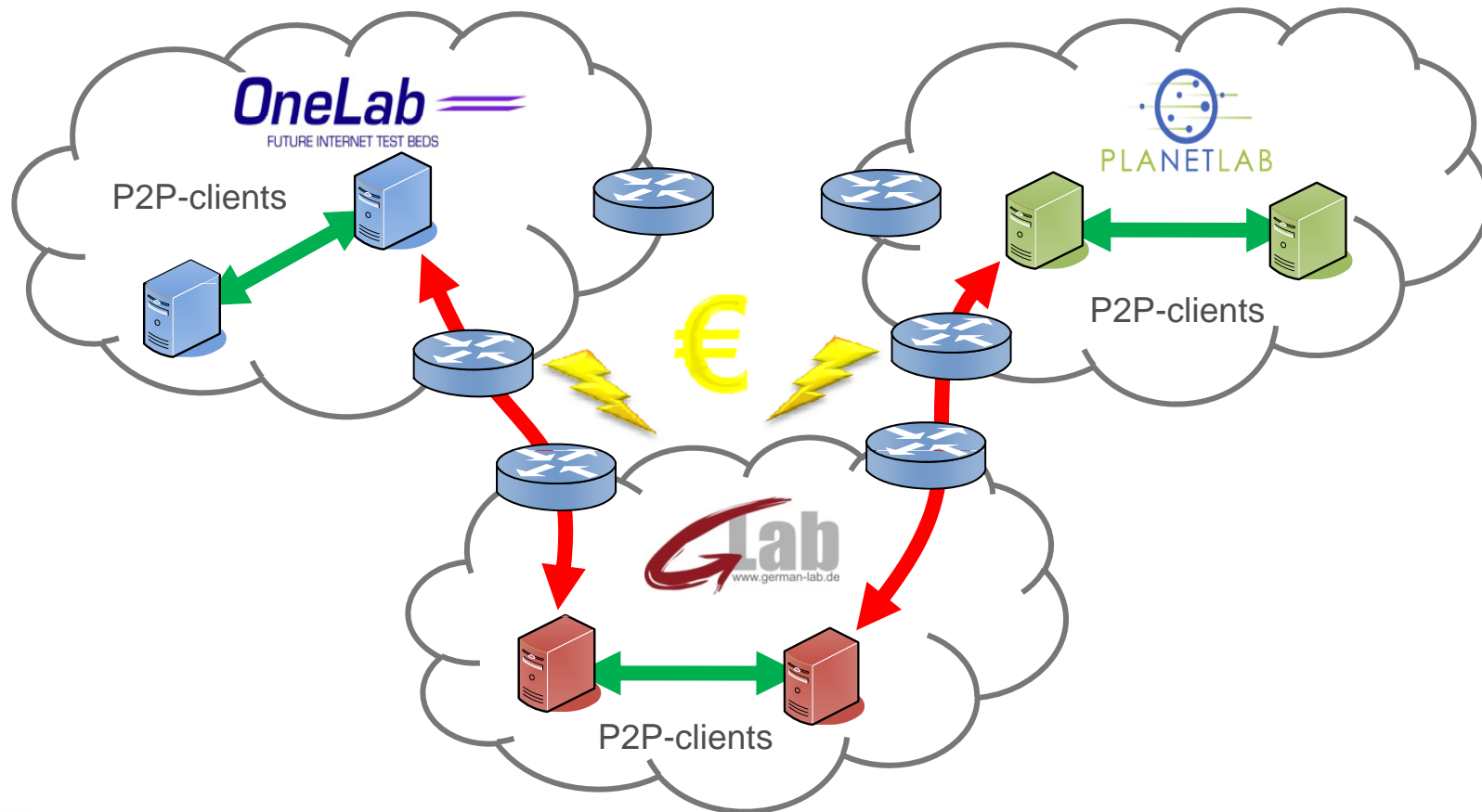
Pathways to Next Generation Networks

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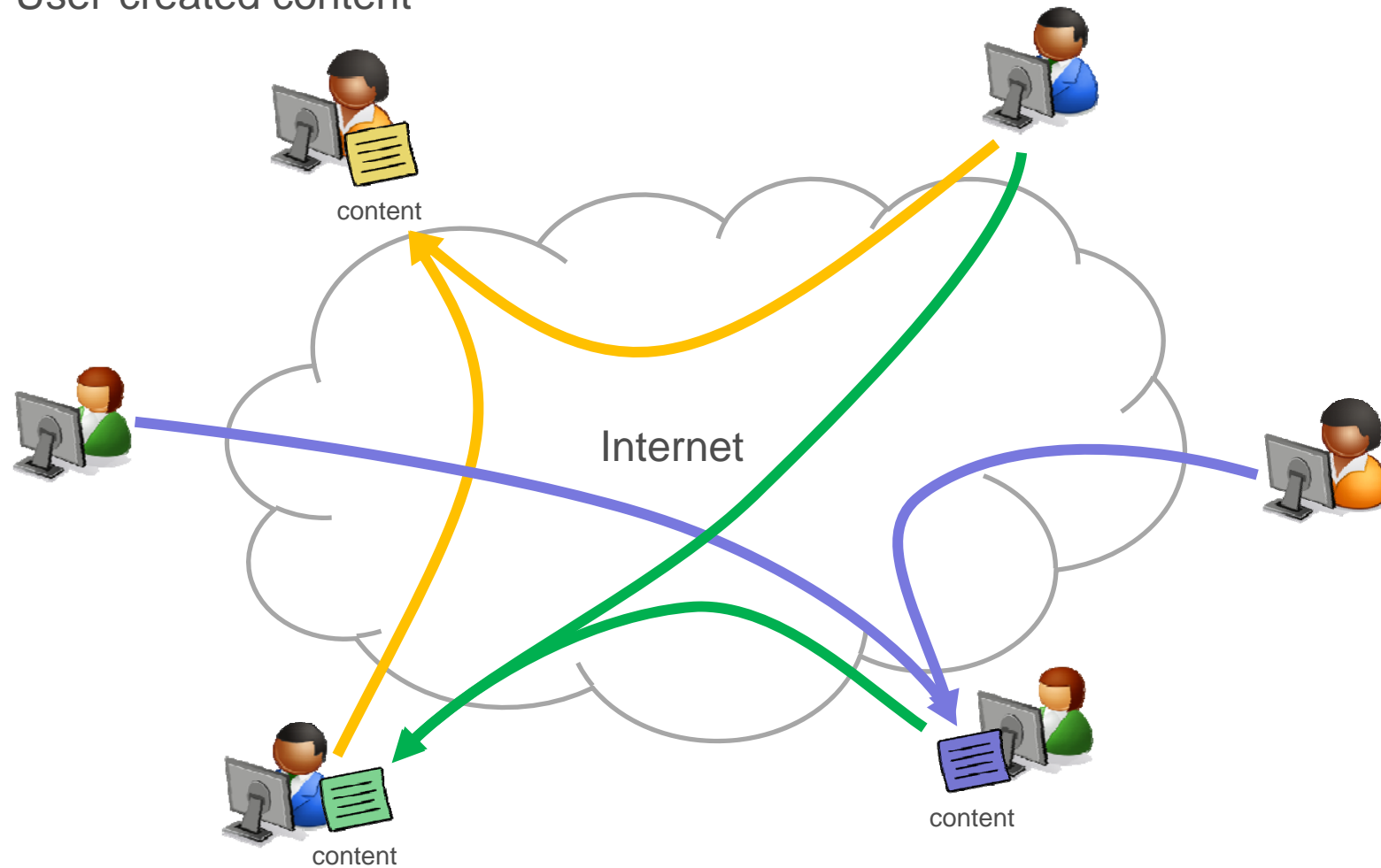
► **The G-Lab Experimental Facilities**

- Concept and project structure
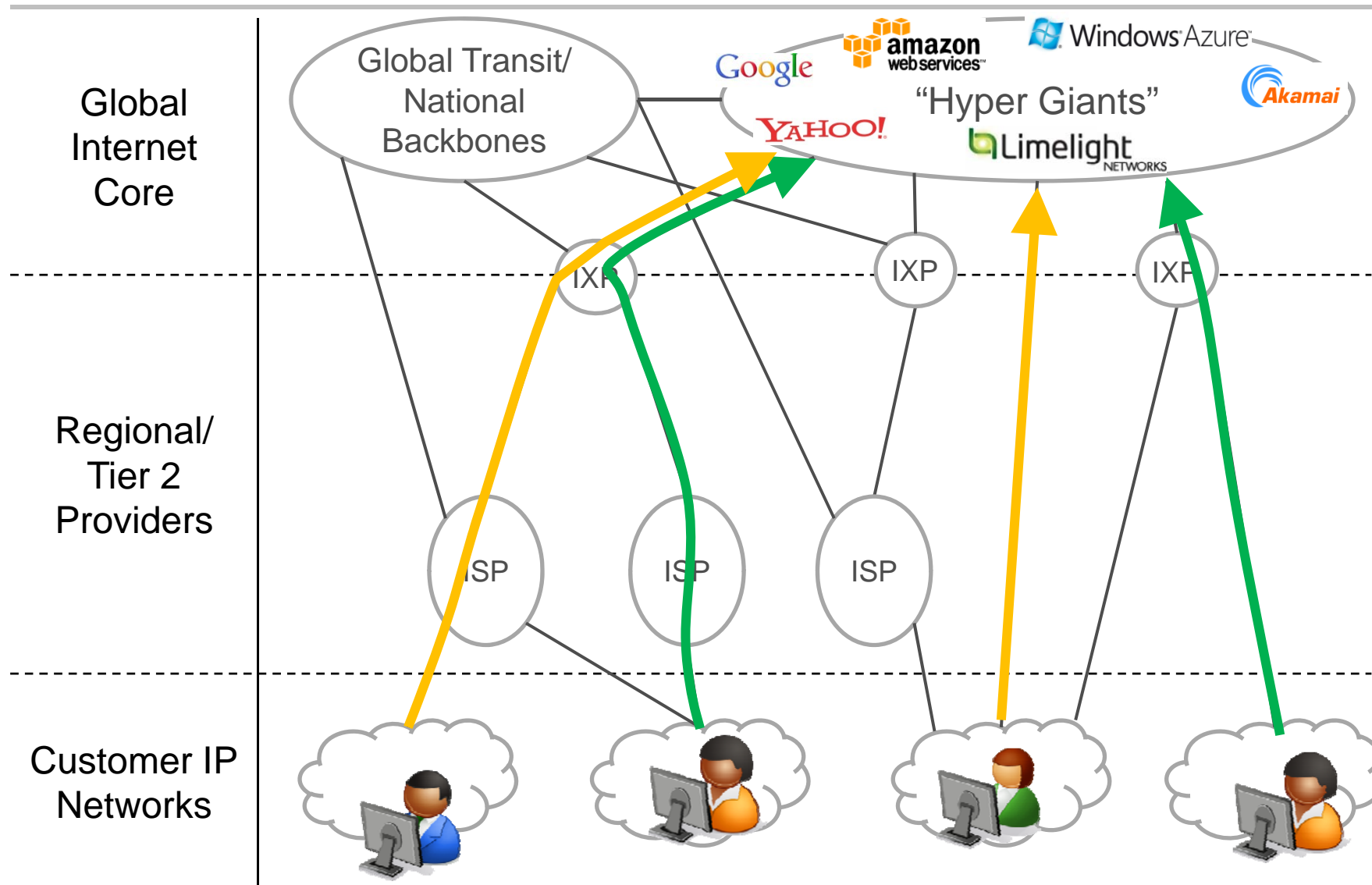- Some exemplary results

► **Future network: quo vadis?**

- Emerging trends
- One network or polymorphic networks

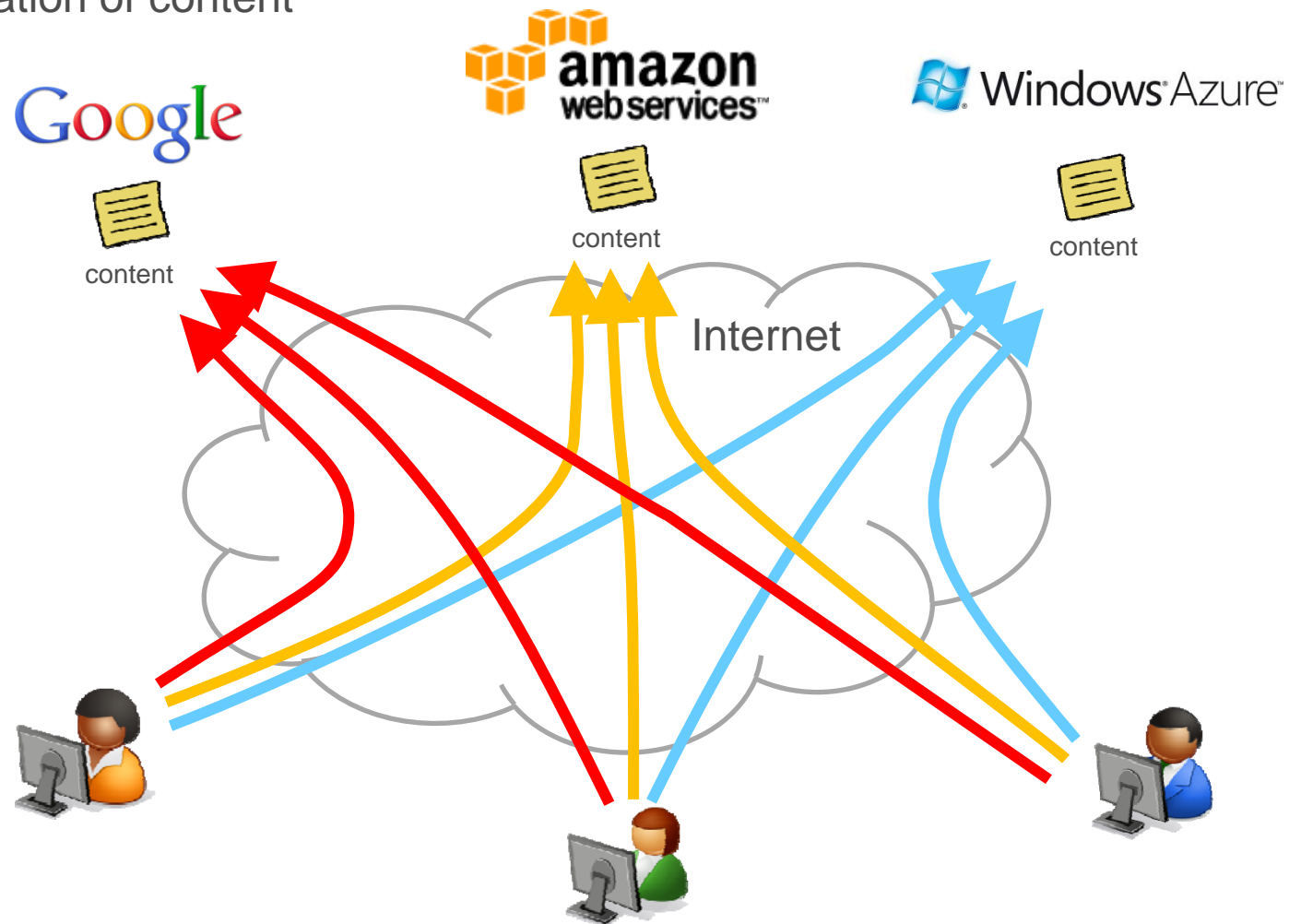# Classical Idea of Content Distribution
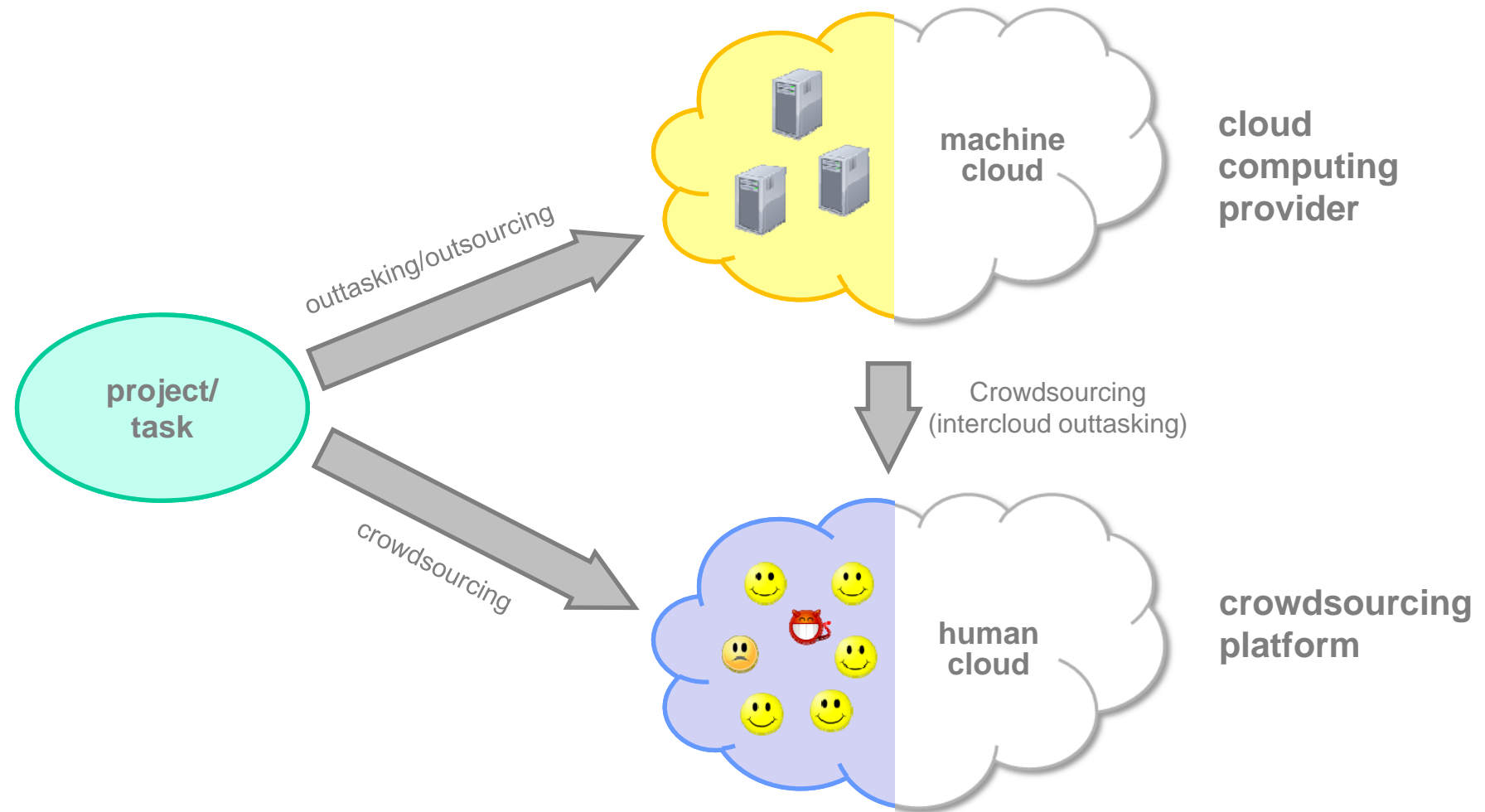
▶ User-created content

content

Internet

content

content

Concentration of Content

Global Internet Core

Global Transit/ National Backbones

Google
YAHOO!
amazon web services
Windows Azure
"Hyper Giants"
Limelight NETWORKS
Akamai

IXP   IXP   IXP

Regional/ Tier 2 Providers

ISP   ISP   ISP

Customer IP Networks

Concentration of Content

▶ Concentration of content

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Human cloud vs machine cloud

Network-aware Application Design
or
Application-aware Network Design

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Network & Application: a never-ending tussle

▶ **A never-ending tussle: Applications & Networks**

- Research orientation: Applications or Networks
- Can we design advance applications without knowing the underlying network?
- Can we design future networks without caring about possible application?

▶ **Application-aware Network Design**

- Network design should be adaptive towards application
- Inter-application control and network design necessary
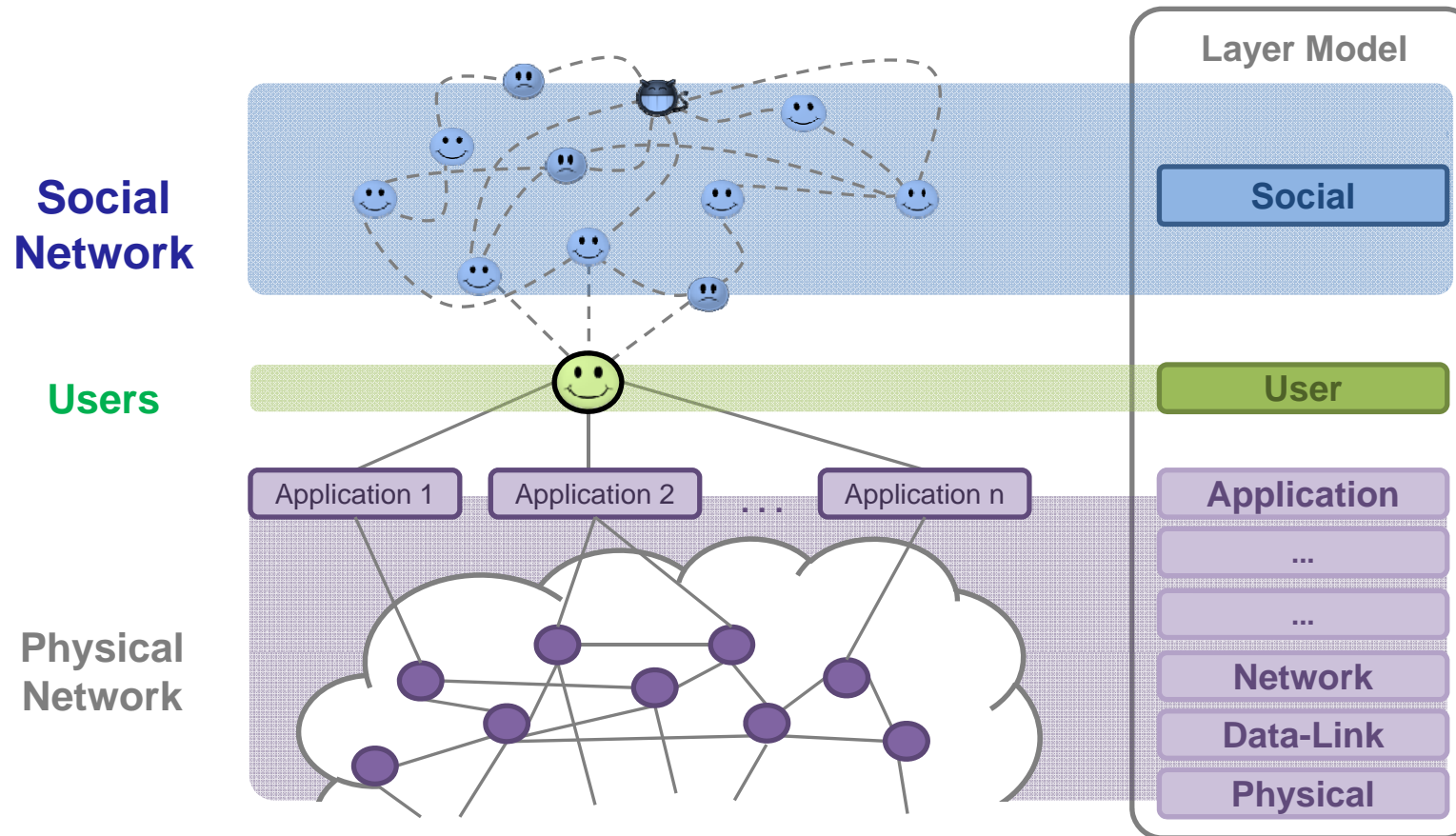- Composing a network for a QoE-aware application

▶ **Network-aware Application Design**

- Application design has to take network features into account
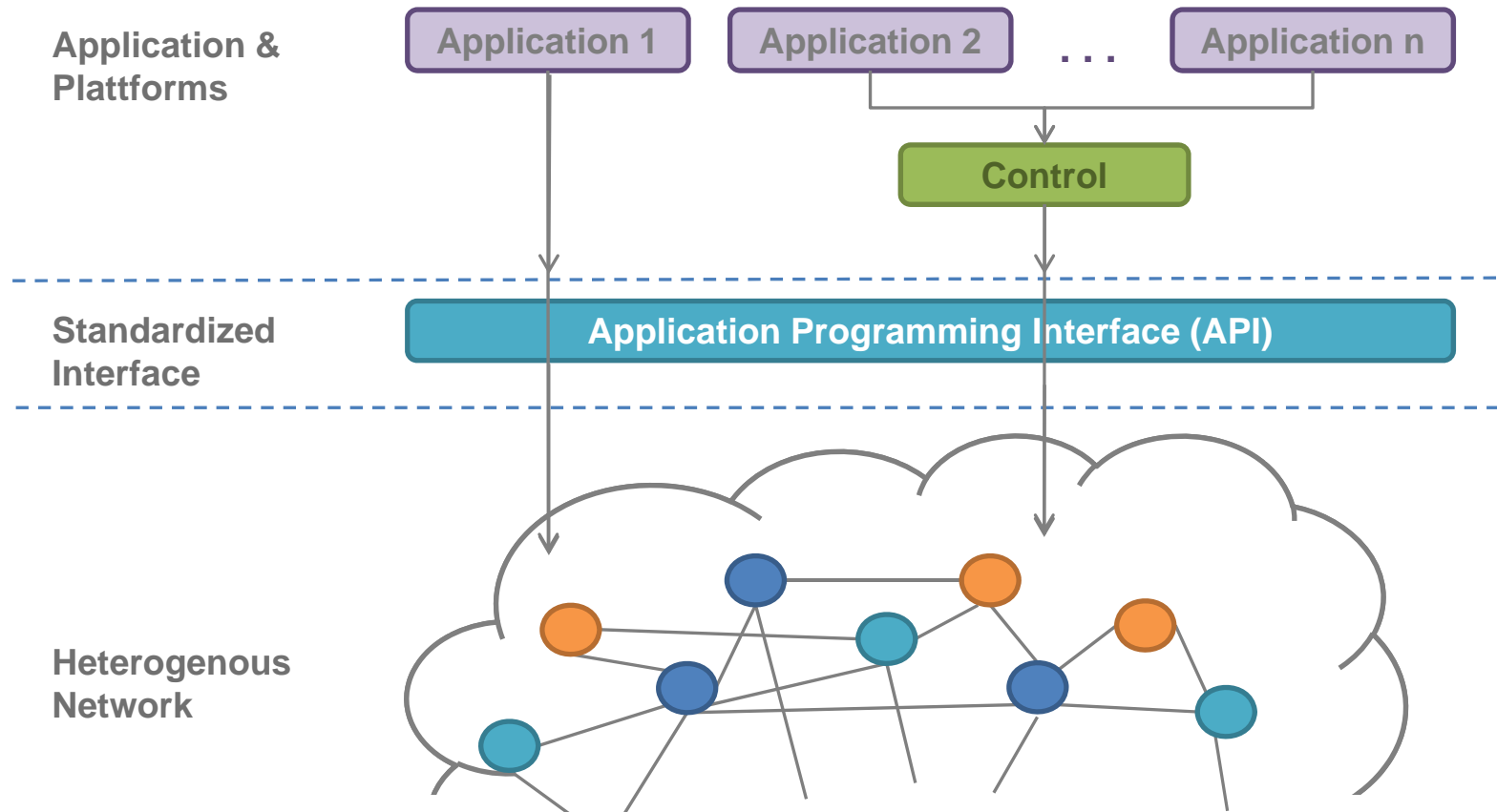- Performance problems with network-agnostic applications

# Network-aware application design: appl.-layer flow control

YouToube Video

Voice over IP

O... ...istribution

Bandwidth

Application layer flow control

Network aware application design
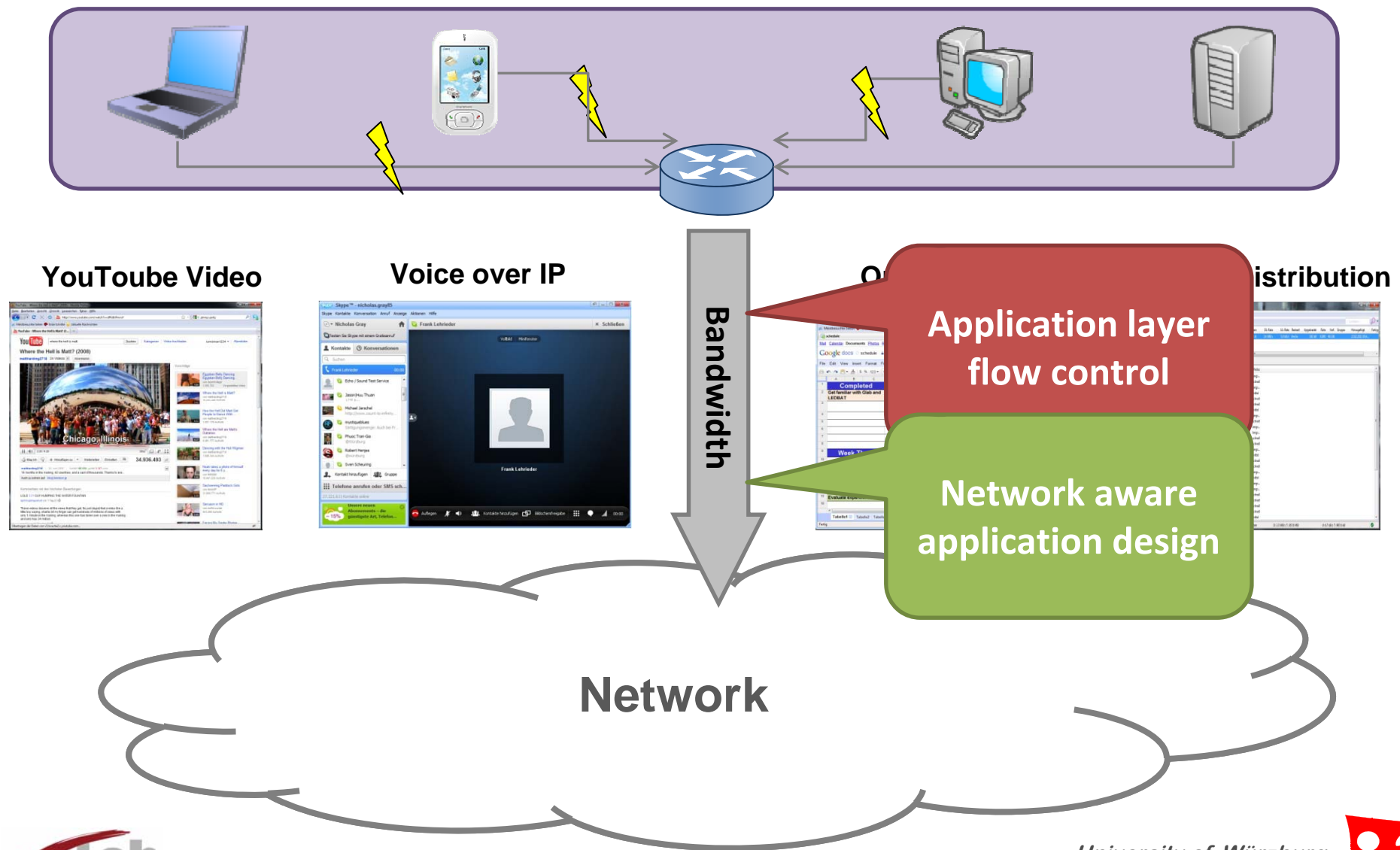
Network

Emerging protocol architecture

Network, control and applications

Application & Plattforms

Application 1   Application 2   . . .   Application n

Control

Standardized Interface

Application Programming Interface (API)

Heterogenous Network

Applications & Networks

application-
aware
network
design

network-
aware
application
design

Application
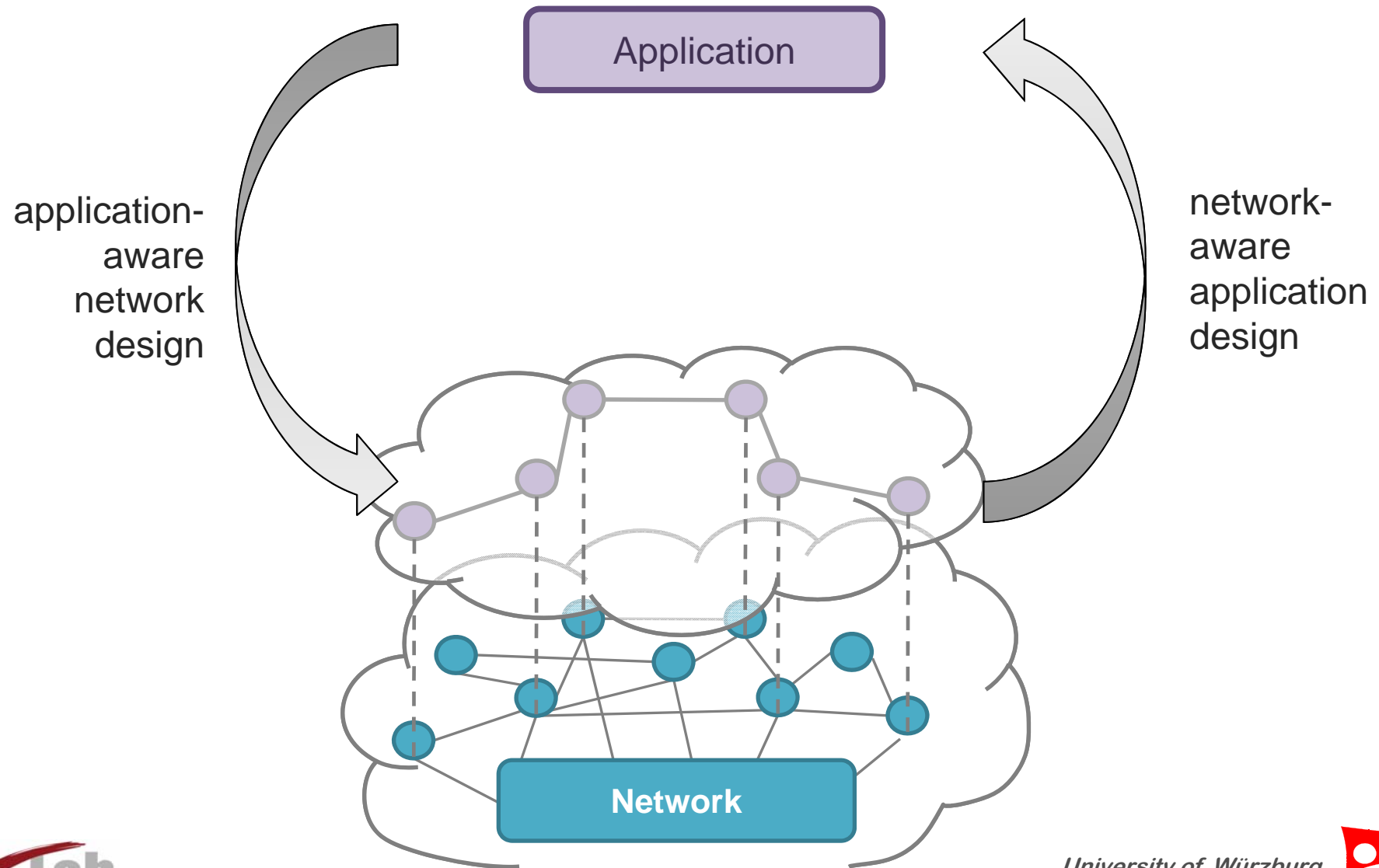
Network

Moving towards Next Generation Networks

Today   5 years   10 years
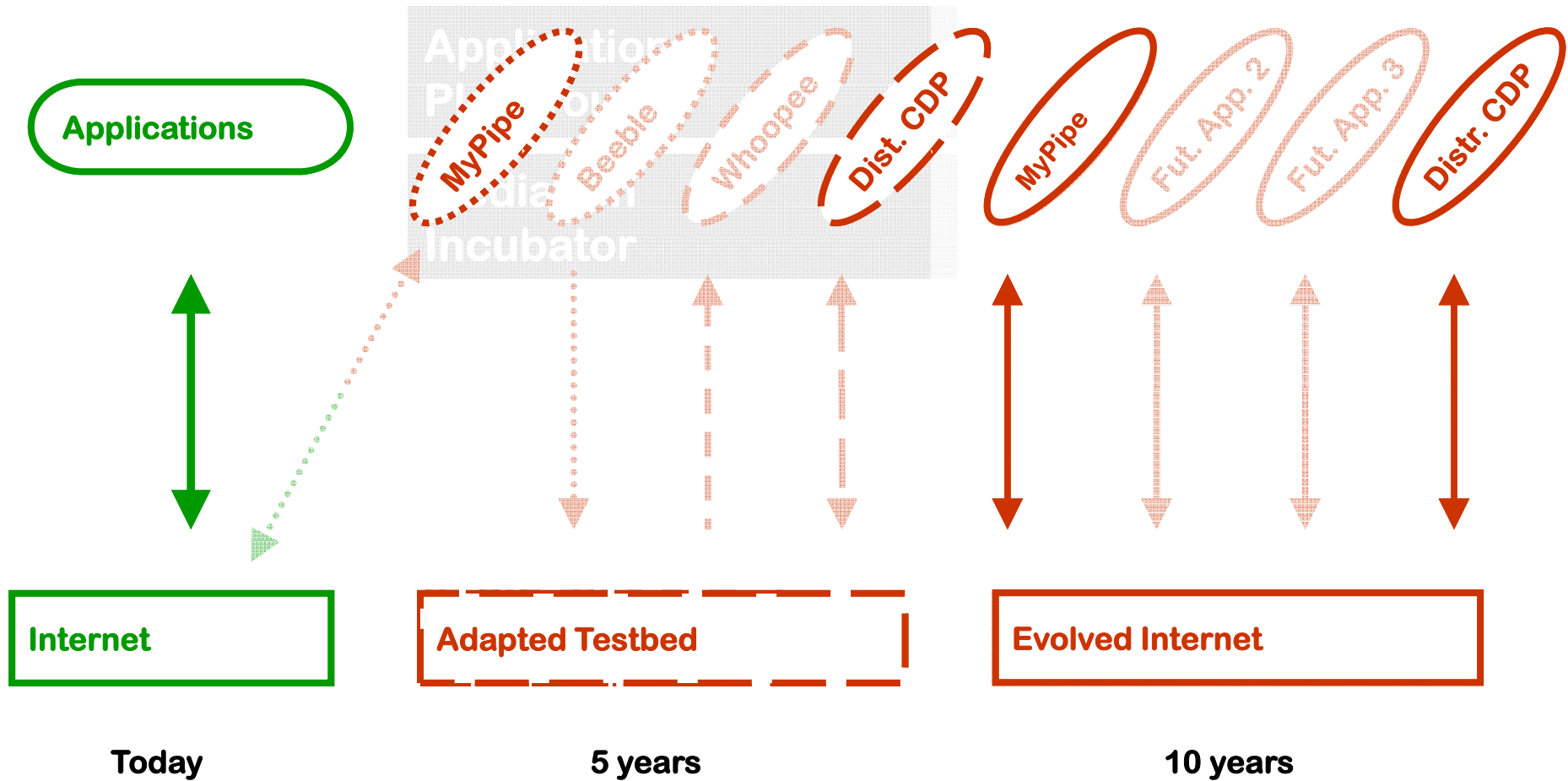
Euroview2011: 01-02.08.2011

http://www3.informatik.uni-wuerzburg.de/euroview/2011/

Bing

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Favoriten Vorgeschlagene Sites ▾ Web Slice-Katalog ▾

Lehrstuhl für Informatik III: Euroview

Se̱ite ▾ Sicherheit ▾ Extras ▾

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Lehrstuhl für Informatik III
Kommunikationsnetze

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GENERAL   STAFF   RESEARCH   TEACHING   PUBLICATIONS   EVENTS   INTERN

SUCHE

EuroView

EuroView 2011
EuroView 2010
EuroView 2009
EuroView 2008
EuroView 2007
EuroView 2006
EuroView 2005
EuroView 2004
EuroView 2001
EuroView 2000

euronf NETWORK OF EXCELLENCE

ITG INFORMATIONSTECHNISCHE GESELLSCHAFT IM VDE

G-Lab www.german-lab.de

i3

11th Würzburg Workshop on IP:
Joint ITG, ITC, and Euro-NF Workshop
"Visions of Future Generation Networks"
(EuroView2011)

Co-located with Official G-Lab Status Meeting

August 1st - August 2nd 2011
Würzburg, Germany
http://www.euroview2011.com

Quick Navigation

> Fakultät für Mathematik und Informatik
> Institut für Informatik
> Fachschaft Mathe/Info
> Lageplan
> Rechenzentrum & IT-Dienste
> CIP-Pool der Fakultät
> Adressverzeichnis elMuT

Quick Links

> Vorlesungen im SS 2011
> Vorlesungen im WS 2010/11
> Vorlesungsverzeichnis der Fakultät
> Dokumente zu Bachelor/Master
> ERASMUS
> WueCampus
> SB@Home

The workshop's tradition and intention are to foster the communication among researchers from industry, universities, and other research institutes. To that end, technical talks about current research, invited sessions, and invited talks by outstanding experts will be presented.

The workshop is the continuation of a series of successful events previously held in Wuerzburg. A summary and the results from the user survey of last year's workshop are available for download.

The Call for Presentation (CfP) and more details on EuroView2011 can be found at http://www.euroview2011.com.

Details on registration and submission can be found at http://www.euroview2011.com/details.

LEHRSTUHL FÜR INFORMATIK III, AM HUBLAND, 97074 WÜRZBURG, TEL. +49-(0)-931-31-86631 , FAX +49-(0)-931-31-86632

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당신의 친절한 관심에 감사드립니다
Thank you for your kind attention!