Concepts and Challenges of a Green Internet

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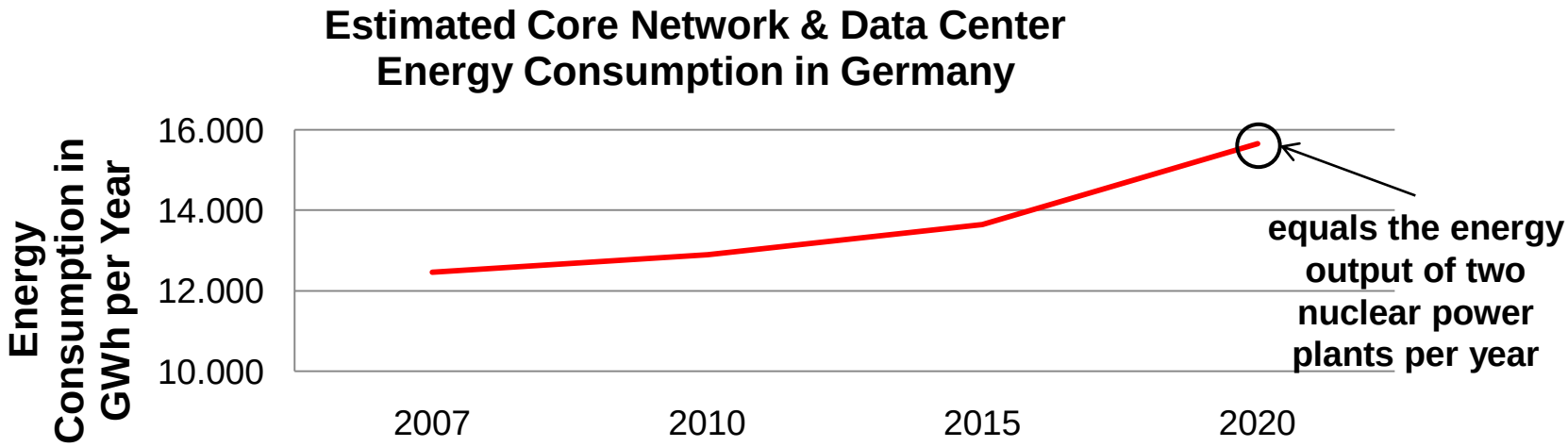
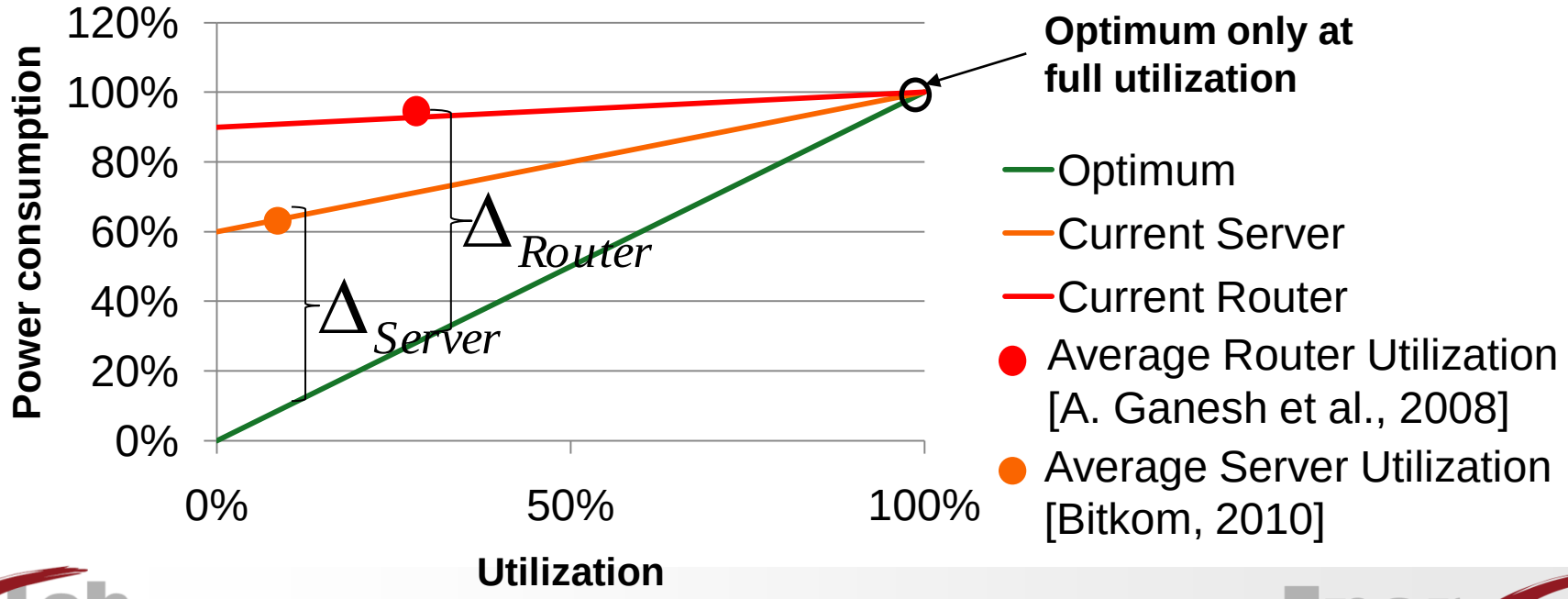
Energy Consumption in the Current Internet

- The current Internet accounts for an estimated 2% of world wide carbon emissions [Smart2020, 2008]
- Need to reduce this number
  - Economically
    - Energy costs of servers surpass acquisition costs
    - Energy prices are rising, increase of more than 50% over the last 10 years in Germany [BMWi, 2010]
  - Ecologically
    - Global warming demands for a drastic reduction of greenhouse gas emissions



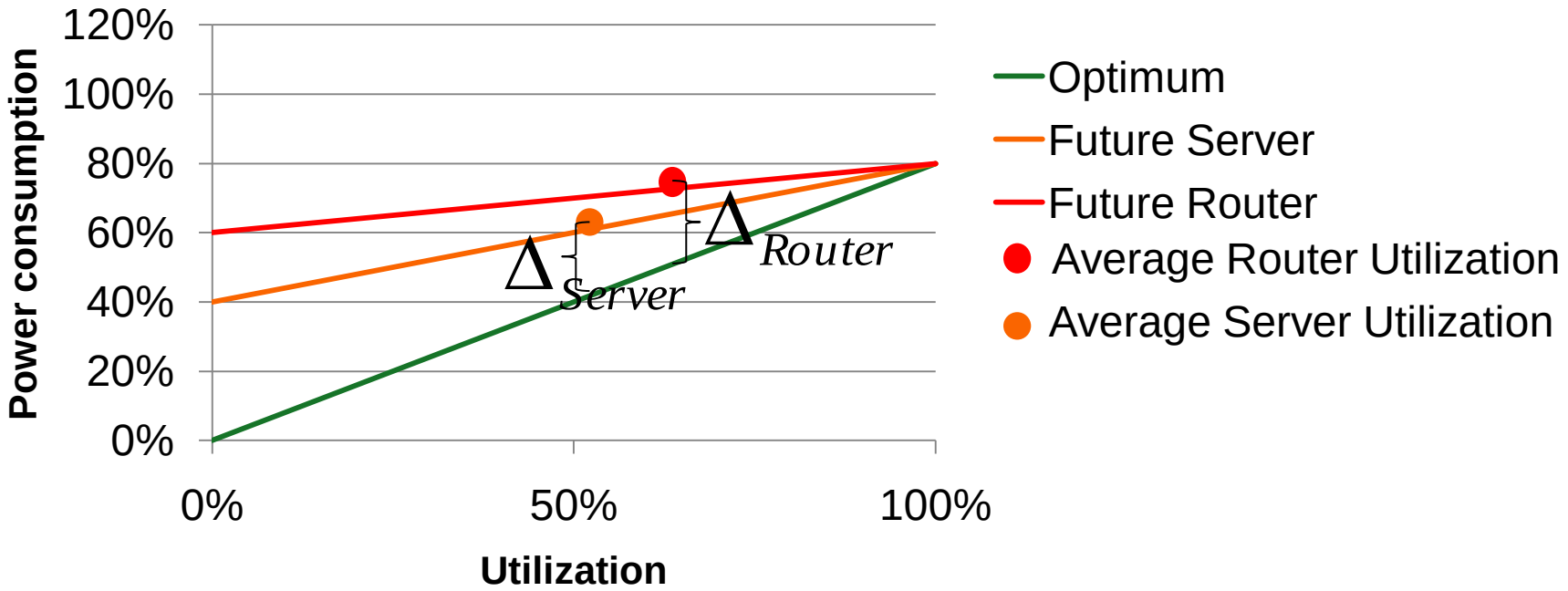
Reasons for Energy Waste

- Current Internet still relies on an architecture never designed to be energy-efficient
  - Soft-states require permanent accessibility
  - Redundancies in the protocol stack
- Current hardware is far from the goal of energy-proportional computing
  - Servers consume up to 70% of their maximum power when idle [Bitkom, 2010]
  - Routers and switches have an almost constant power consumption [Cisco Catalyst 3560 Datasheet]



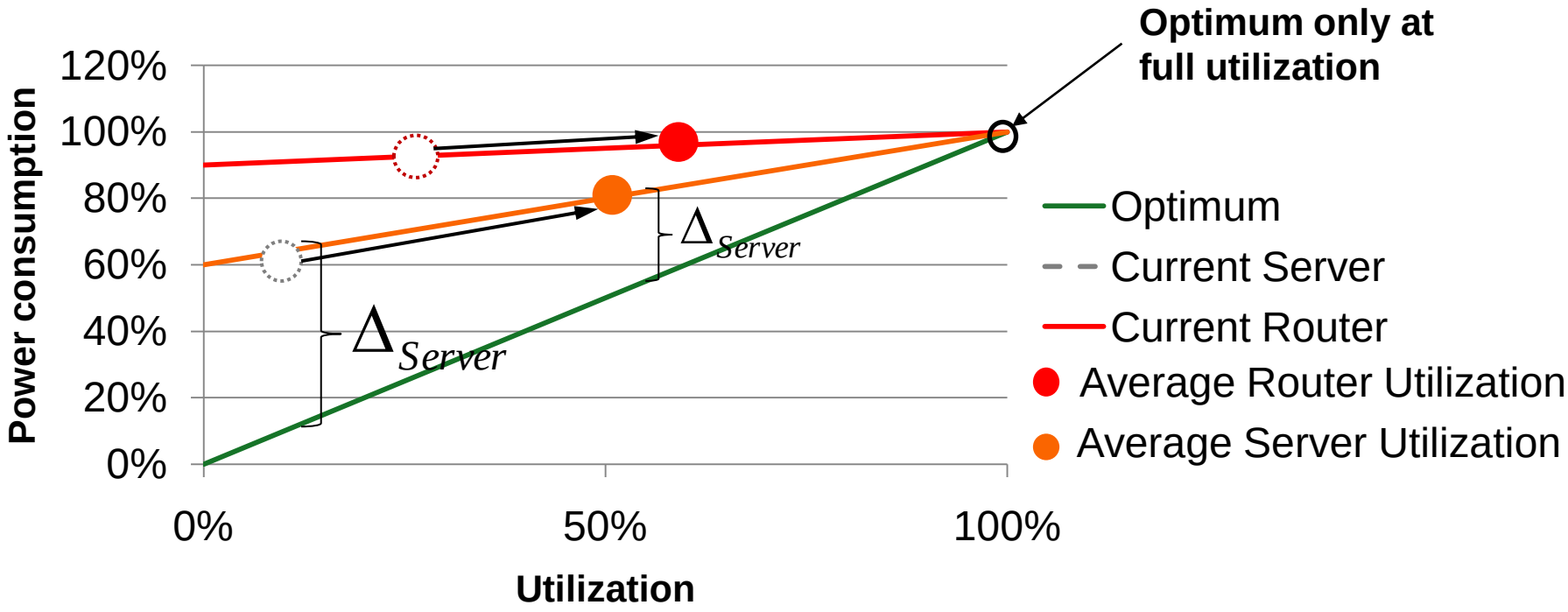
Vision of an Energy-Efficient Future Internet

- Hardware must be operated at high utilization levels
- Switches and Routers have to adopt energy saving features
- Communication protocols have to support energy-efficiency features
- Mechanisms have to be provided that allow a quick adaptation of resource availability to load level
- Networks have to support application-tailored QoS and security features



Methods and Concepts

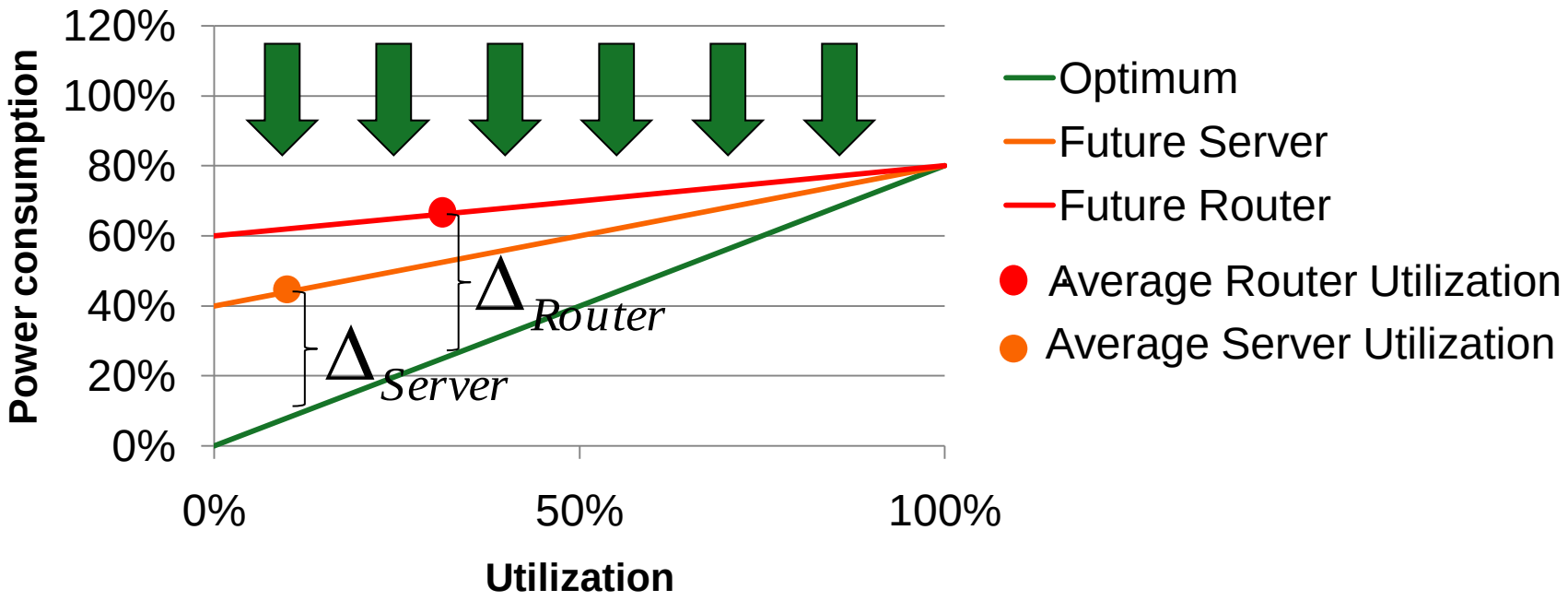
- Increasing utilization by load consolidation



- **E.g. Virtualization of servers, routers, switches and links**
  - Allows turning off underutilized parts of the physical network by consolidating the virtualized network on a subset of the physical infrastructure
  - Enables a flexible and transparent management of the infrastructure

Methods and Concepts

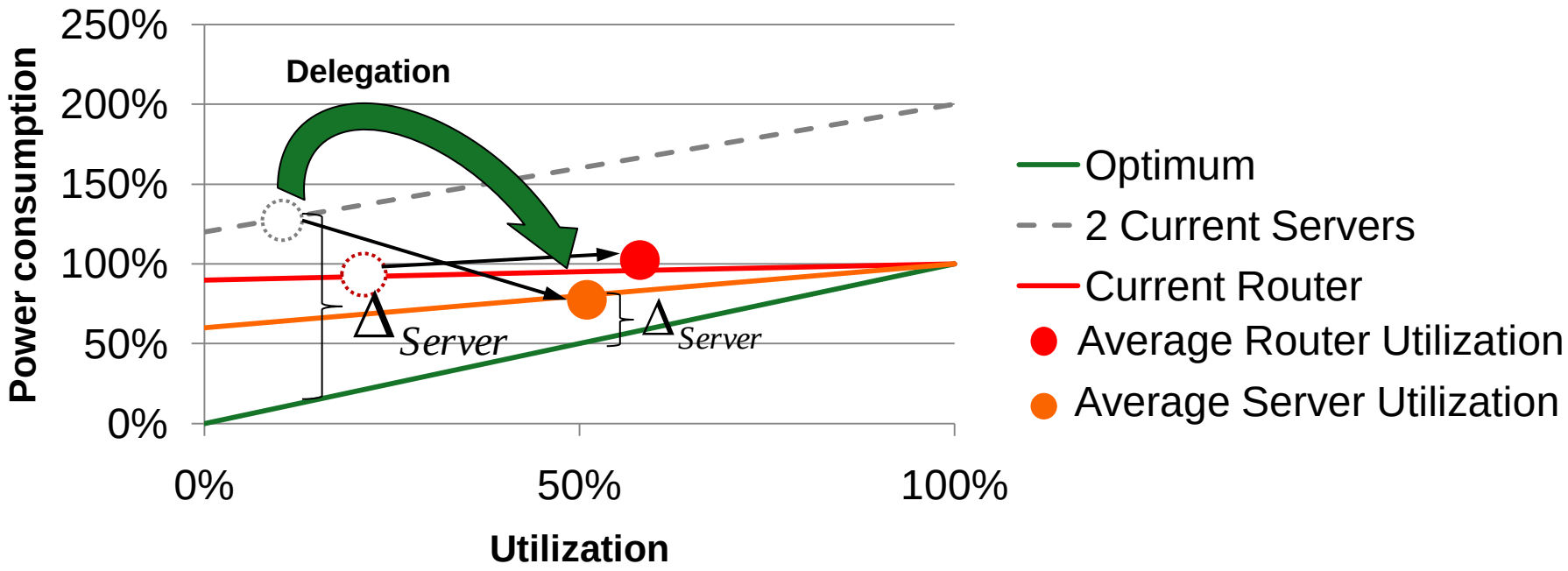
- Decreasing power consumption at low utilization levels



- ***E.g. new generation of energy-efficient and energy-aware network devices***
  - Efficient hardware components that consume less power, especially in idle state
  - Power-saving modes for routers and switches (e.g. turning off unused ports)
  - Adaptive link rate (ALR) techniques that adjust link capacities to traffic

Methods and Concepts

- Decreasing power consumption at low utilization levels

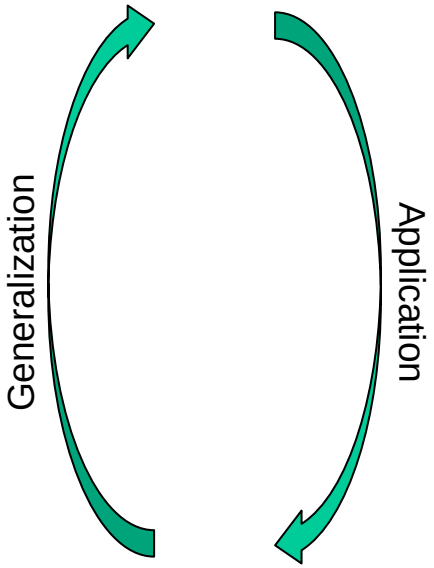


  - ***E.g. communication protocols that support energy efficiency***
    - Goal: Availability without permanent accessibility
    - Delegation of services: turn off delegating device
    - On-demand mechanisms: get rid of „soft states“
    - Out-of-band signaling: differentiation between data and control information

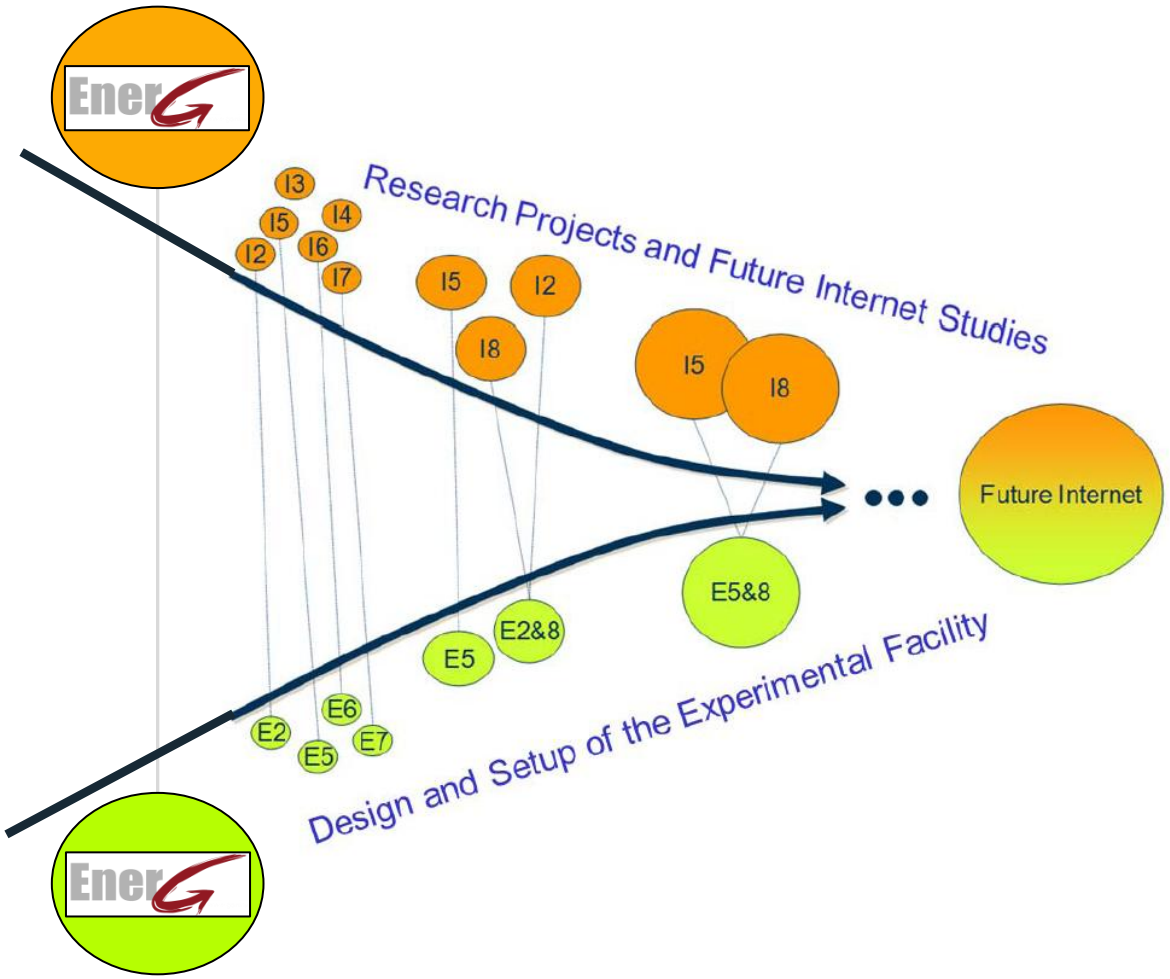
G-Lab_Ener-G

- Objectives

- Research on energy-efficient future infrastructures



- Increasing the energy efficiency of the G-Lab infrastructure



G-Lab_Ener-G

- Increasing utilization by load consolidation
  - Energy-efficient mapping of virtual nodes unto physical nodes
    - Power consumption models allow estimating the power consumption of different deployment scenarios
    - Minimization of the number of turned on physical nodes
    - Consideration of the energy consumption of migration

- Decreasing power consumption at low utilization levels
  - Energy-efficient communication protocols
    - Analysis of existing communication protocols and their extension regarding energy efficiency
    - Development of new protocols with energy efficiency support that enable the application of power saving modes

Projects on Energy Efficiency

Project	Increasing utilization by load consolidation	Decreasing power consumption at low utilization levels
G-Lab_Ener-G	- **Virtualization, consolidation** - **Near-optimal ressource allocation through power consumption models**	- **Research on energy-efficient communication protocols** - **Enabling power-saving features of hardware while considering QoS requirements**
FIT4Green	- **Load distribution in federated datacenters** - **Plugins for current datacenter automation frameworks**	---
EcoNet	- Dynamic, optimized resource allocation in terms of trade-off between energy consumption and network performance.	- **Development of novel technologies that allow the dynamic adaptation of device capacities to different loads**
Trend	- Minimizing energy requirements by considering optimal performance and resource allocation	- **Integrating energy-friendly technologies, devices, protocols and architectures into current infrastructures**

Conclusions

- Next generation networks have to be inherently energy-efficient
- Security challenges arise when consolidating workload
  - Sensitive data processing inside a cloud
  - Legal issues when migrating data across borders
- Deployment challenges
  - Current layered protocol stack imposes ‘always on’ paradigm
  - Ossification is increased by specialized hardware
  - Alternative architecture concepts?

Publications

- Gergö Lovász, Florian Niedermeier and Hermann de Meer, *Energy-Efficient Management of Physical and Virtual Resources - A Holistic Approach*. In Jean-Marc Pierson and Helmut Hlavacs, editor, Proc. of the COST Action IC0804 on Energy Efficiency in Large Scale Distributed Systems - 1st Year , page 80--83. Publisher: COST Office, 2010 ISBN: 978-2-917490-10-5
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- Andreas Berl and Hermann De Meer, *A Virtualized Energy-Efficient Office Environment.* Proc. of the 1st ACM SIGCOMM Int'l Conf. On Energy-Efficient Computing and Networking (e-Energy 2010) , p. 11--20. Publisher: ACM, 2010, ISBN: 978-1-4503-0042-1
- Andreas Berl, Andreas Fischer und Hermann de Meer, *Virtualisierung im Future Internet - Virtualisierungmethoden und Anwendungen.* Informatik-Spektrum, 33(2):186--194 2010 ISSN: 0170-6012 (Print); 1432-122X (Online)
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- Michel Steichen, Bernd Reuther and Gergö Lovász, *Methods and Approaches for Energy Saving in the Context of Ener-G* (Poster). Presented at the 1st ACM SIGCOMM Int'l Conf. On Energy-Efficient Computing and Networking (e-Energy 2010), Passau, 2010