On Performance and Robustness of Internet-Based Smart Grid Communication: A Case Study for Germany

Sebastian Meiling, Thomas C. Schmidt, and Till Steinbach
{smeiling, t.schmidt, steinbach}@ieee.org

iNET RG, Department of Computer Science
Hamburg University of Applied Sciences

November, 4th 2015 — IEEE SmartGridComm

iNET

Hochschule für Angewandte Wissenschaften Hamburg
Hamburg University of Applied Sciences

Outline

1. Motivation and Problem Statement
2. Internet Topology of the Energy Sector
3. Properties of Customer Access Networks
4. Conclusion and Outlook

Motivation

Internet-based SmartGridComm

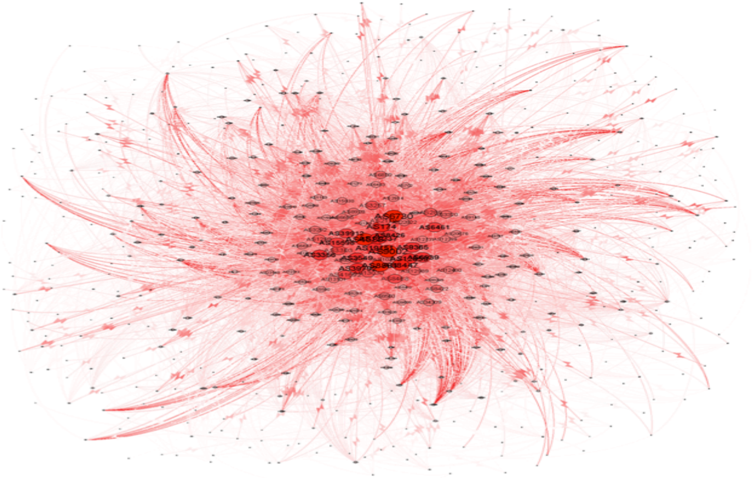
- Smart Grid applications require out-of-band communication:
  - bi-directional data flow utilizing network technologies
  - contrary to in-band control of *classic* power grids
- The Internet is a promiment deployment canditate:
  - proofed scalability and self-healing capabilities
  - cost efficient for large scale deployments
- Today, most countries consider Power Grids and the Internet as critical parts of their national infrastructure

Problem statement

Challenges of Internet-based SmartGridComm

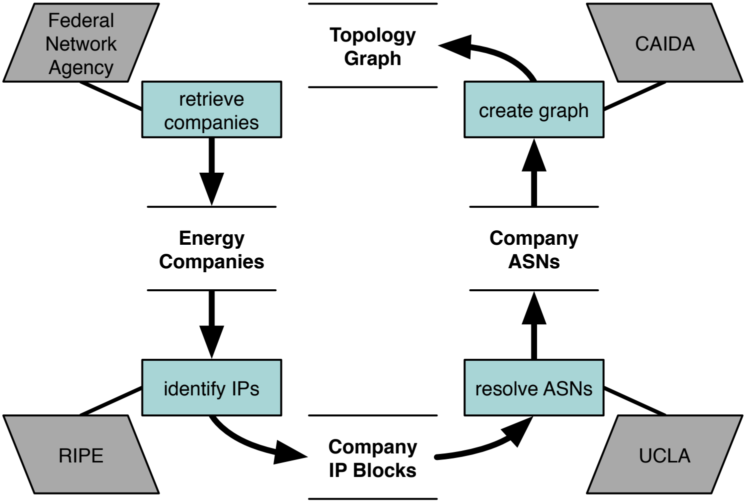
- Power grids developed along national borders
- Internet infrastructure globally distributed
- Coupling power grids with the Internet introduces new threats
- Power outage lead to network outages, causing further power failures
- Performance and robustness of energy-related Internet infrastructure
  - company networks, customer networks, inter-connectivity
  - match requirements of Smart Grid applications

Internet Topology of the Energy Sector



Passive Measurement

Workflow



Numerical Findings

Overview on retrieved Data

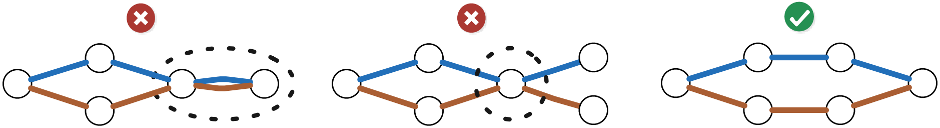
	# companies	# with IPs	# IP blocks	# AS
Electric Utility	463	218	459	88
Grid Operators	889	432	762	112
Energy Sector	1354	652	1050	128

- Around 50 % of the German energy sector are individually *visible*
- Coverage of utility companies with > 90 % share in the market

Assessing Robustness

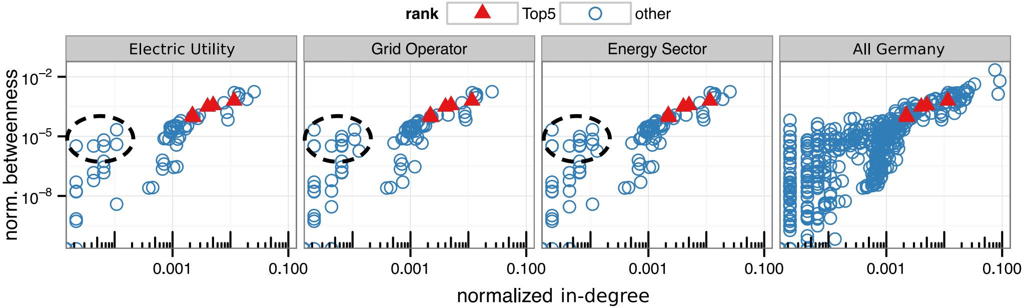
Methodology and Background

- Quantify failure resistance of networks and inter connectivity
- Links or peerings per network (AS) : degree
- Significance of AS for connectivity : betweenness
- Distinct paths between networks : disjoint paths



Network Robustness

Betweenness and degree

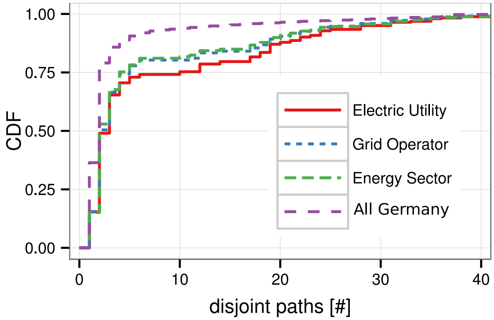


- High ranking network exhibit high betweenness and degree
- Weakness: regional ISP and specialized IT services with low degree

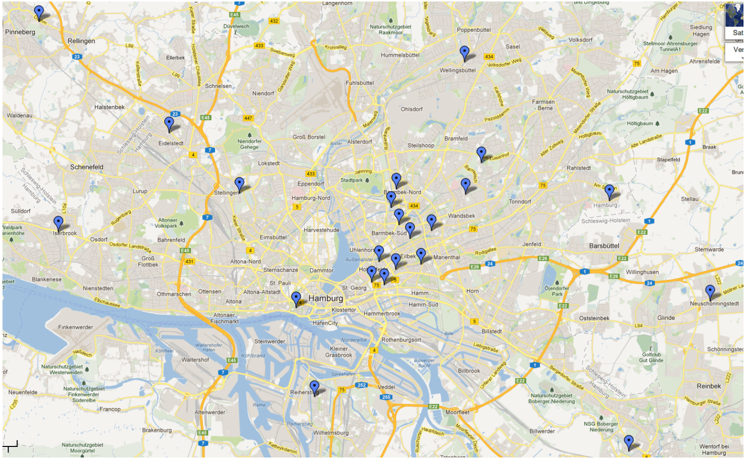
Connectivity Robustness

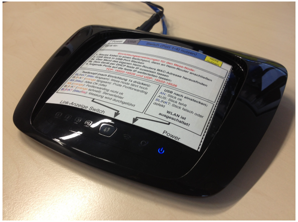
Disjoint paths

- Energy sector exhibits more disjoint paths than national average
- 80 % > 1 path, 20 % > 10 paths
- Overall denser connectivity and higher robustness



Properties of Access Networks





Active Measurement

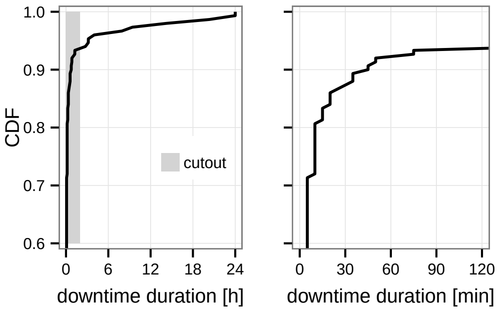
Methodology

- Assume Internet-based SmartGridComm at households
- Use-cases: metering, monitoring, demand response, VPP
- Deployed 30 probes in metropolitan area of Hamburg
- 9 different ISPs, varying bandwidths, and technologies
- Long-term active measurements, aimed at minimal impact
- Analysis of availability, responsiveness, and connectivity

Availability

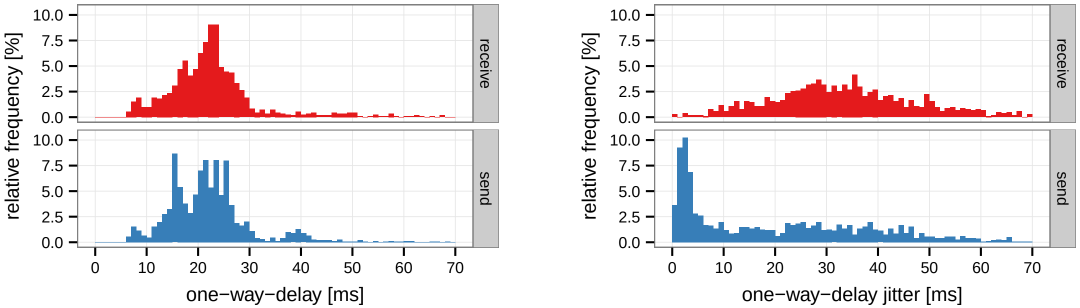
Length of downtimes

- Periodic updates by each probe
- Random and unrelated failures
- Often only single probe effected
- Overall 90 % downtimes below 1h
- Mean availability per day > 99 %



Responsiveness

Delay and Jitter

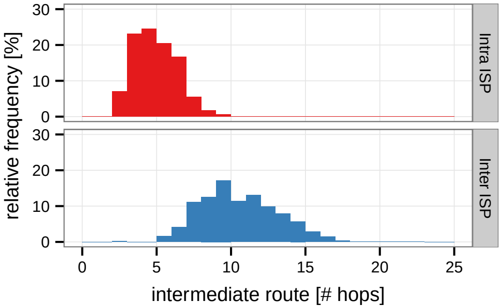


- One-way delay to assess delay asymmetries during send and receive
- Mean delays at receiver: 22 ms, and sender 20 ms, lower bound ≈ 6ms
- Lower jitter at sender, broad jitter distribution at receiver

Data Flow

Path characteristics

- Paths between all probes
- Intra ISP paths much shorter
- Inter ISP paths mostly via DE-CIX
- smaller ISPs tend to foreign IXPs
- Impacts performance & security



Conclusion and Outlook

- Top-down and bottom-up assessment of communication infrastructure
- Analysis of failure resistance and properties of customer network
- Denser connectivity & higher robustness of energy-related networks
- Suitable availability (> 99 %) and responsiveness of customer network

- Extend analysis to other countries and on continental scale
- Investigate dedicated attack vectors and countermeasures

Thank you for your attention.
Questions?

iNET RG www.inet.haw-hamburg.de

Peeroskop peeroskop.realmv6.org

RPKI rpki.realmv6.org

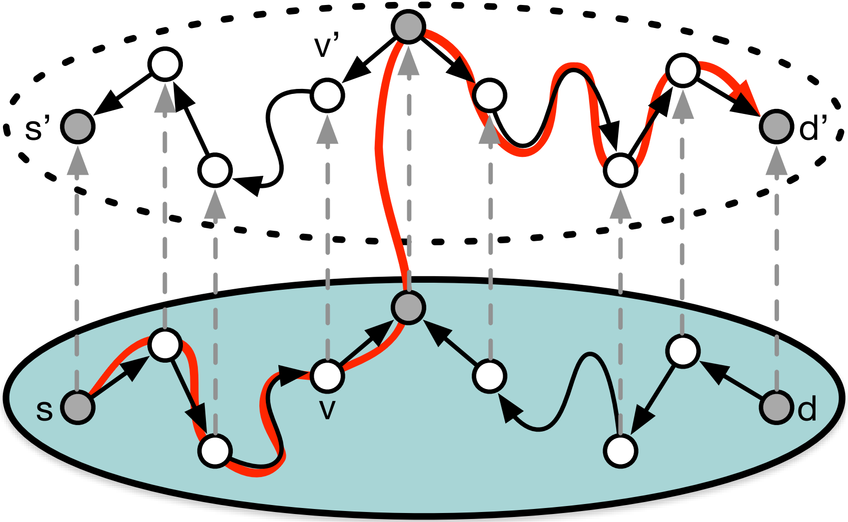
Requirements for Smart Grids

by U.S. Department of Energy in [1]

Smart Grid application	ideal latency [ms]		
real-time metering	12	to	20
real-time monitoring	20	to	200
demand response	500	to	2000
in-home applications	2000	to	15000

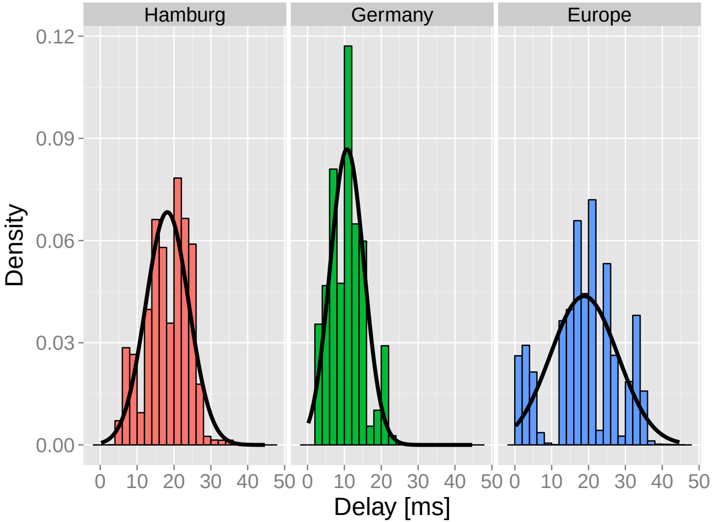
Evaluate disjoint paths

Transforming a ToR graph



Comparing Unicast OWD

Local, national, and continental



References

U.S. Department of Energy, “Communication Requirements of Smart Grid Technologies,” http://energy.gov/gc/downloads/communications-requirements-smart-grid-technologies, Oct. 2010.

S. Meiling, T. C. Schmidt, and T. Steinbach, “On Performance and Robustness of Internet-Based Smart Grid Communication: A Case Study for Germany,” in *6th IEEE Int. Conf. on Smart Grid Communications (SmartGridComm’15)*. Piscataway, NJ, USA: IEEE Press, Nov. 2015, pp. 300–305.

S. Meiling, T. Steinbach, T. C. Schmidt, and M. Wählisch, “A Scalable Communication Infrastructure for Smart Grid Applications using Multicast over Public Networks,” in *Proc. of ACM Symposium on Applied Computing (SAC’13), Poster Session*. New York: ACM, March 2013.

S. Meiling, T. Steinbach, M. Duge, and T. C. Schmidt, “Consumer-Oriented Integration of Smart Homes and Smart Grids: A Case for Multicast-Enabled Home Gateways?” in *3rd IEEE Int. Conf. on Consumer Electronics - Berlin (ICCE-Berlin’13)*. Piscataway, NJ, USA: IEEE Press, Sep. 2013, pp. 279–283.

S. Meiling, T. C. Schmidt, and M. Wählisch, “Large-Scale Measurement and Analysis of One-Way Delay in Hybrid Multicast Networks,” in *37th Annual IEEE Conf. on Local Computer Networks (LCN’12)*. Piscataway, NJ, USA: IEEE Press, Oct. 2012.