Consumer-Oriented Integration of Smart Homes and Smart Grids

A Case for Multicast-Enabled Home Gateways?

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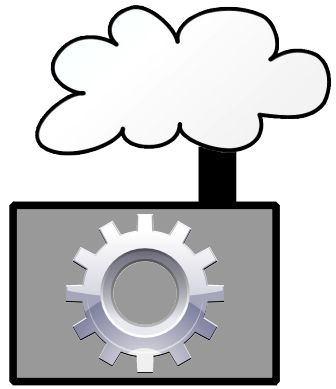
Agenda

1. Introduction & Motivation
2. Multicast-Enabled Home Gateways
3. Deployment Considerations
4. Evaluation
5. Conclusion

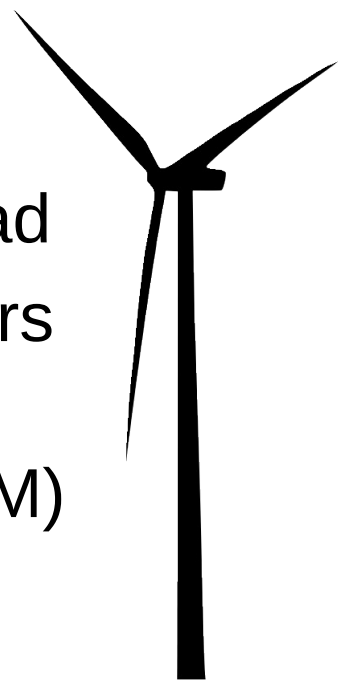
Smart Grid



measurement and control of energy consumption

- Smart Meters at customer sites,

  Advanced Metering Infrastructure (AMI)
- load management by intelligent energy consumers



lowering the base load capacity and avoiding peak load

- requires control of many energy devices (consumers and generators)
- load balancing by Demand Side Management (DSM)

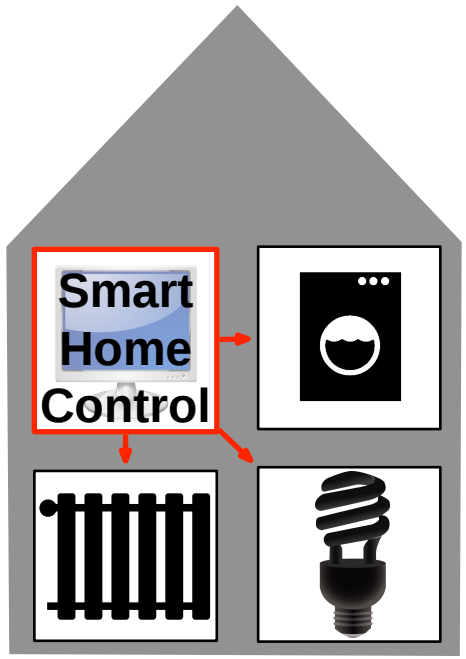
decentralized energy production

- instead of a few big power plants, many small generators
- operation of Virtual Power Plants (VPP)

Smart Home and Smart Grid

Smart Home & automation

- control various (energy) appliances in households
- increase comfort and reduce expenses
- already some deployment



Smart Grid ↔ Smart Home

- comparable motivations
- large scale ↔ small scale
- possible synergies

Yet, there is no interconnection or integration!

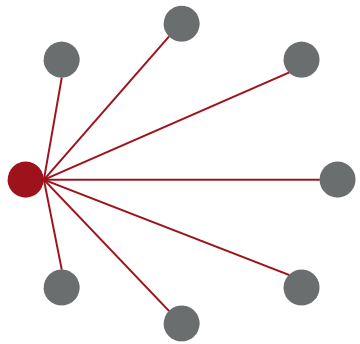
Problem Statement

- integration of Smart Homes requires communication-access to households
- dedicated communication infrastructure is expensive
- no scalable public-network infrastructure for a Smart Grid integrating Smart Homes available

Communication Patterns in a Smart Grid

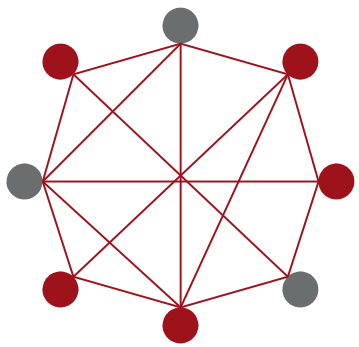
one-to-many (1:N)

- device scheduling
- energy tariff information
- AMI, DSM and VPP



many-to-many (M:N)

- cooperative execution of a task
- decentralized coordination
- DSM and VPP



- that is group communication
- not efficient trough unicast but multicast

Contribution of this Work

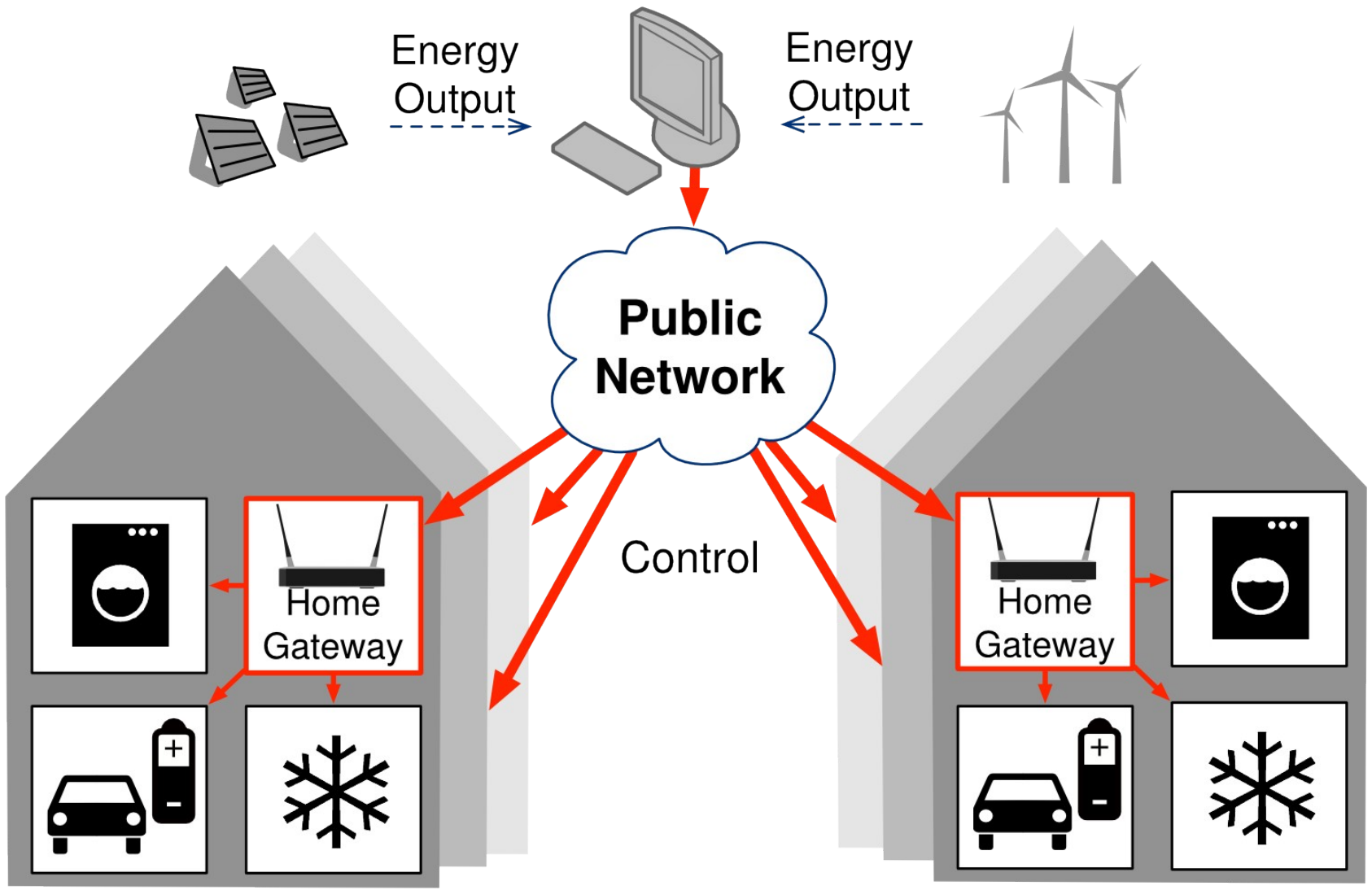
our concept

- based on consumer hardware (COTS)
- integration of Smart Home devices
- use of existing public networks, i.e. the Internet
- (hybrid) multicast-enabled home gateways
  - overcome limited IP multicast deployment

we show

- feasibility and performance measurements
- testbed in the area of Hamburg
- evaluation of consumer internet connections

Smart Grid using Home Gateways



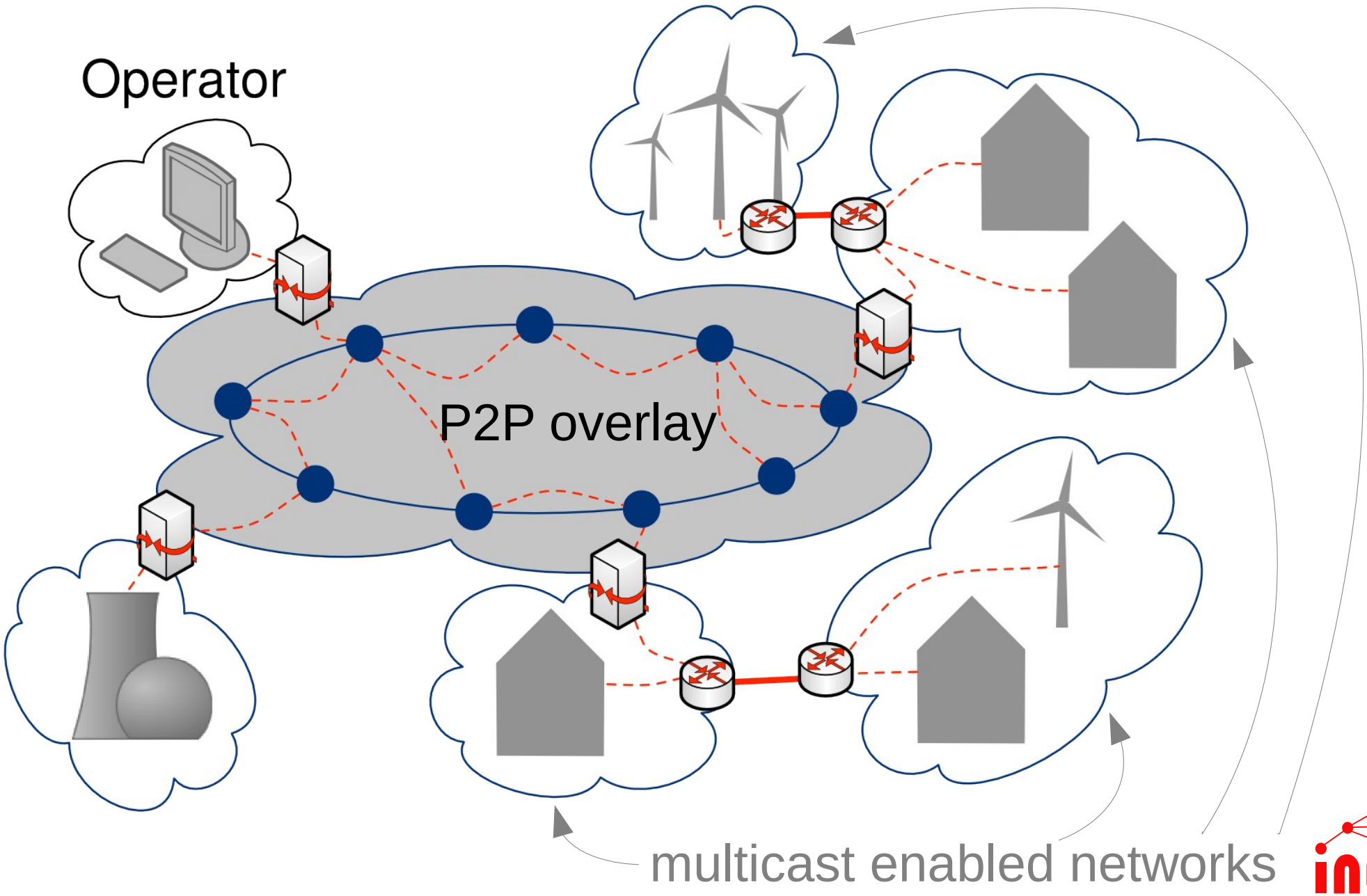
Hybrid Multicast

- overcomes lack of IP multicast deployment
- application layer multicast using p2p technologies
- native multicast where available

H∀Mcast hybrid adaptive multicast framework

- common multicast API with abstract group naming scheme
- adaptive middleware layer for technology abstraction
- Inter-Domain Multicast Gateways (IMGs)

Hybrid Multicast



Evaluation Scenario

- system performance of home gateways
- measurement study of consumer Internet connections

- home gateway
  - standard consumer WLAN router
  - MIPS processor (400 MHz)
  - 32MB RAM
  - OpenWRT Linux operating system

System Performance

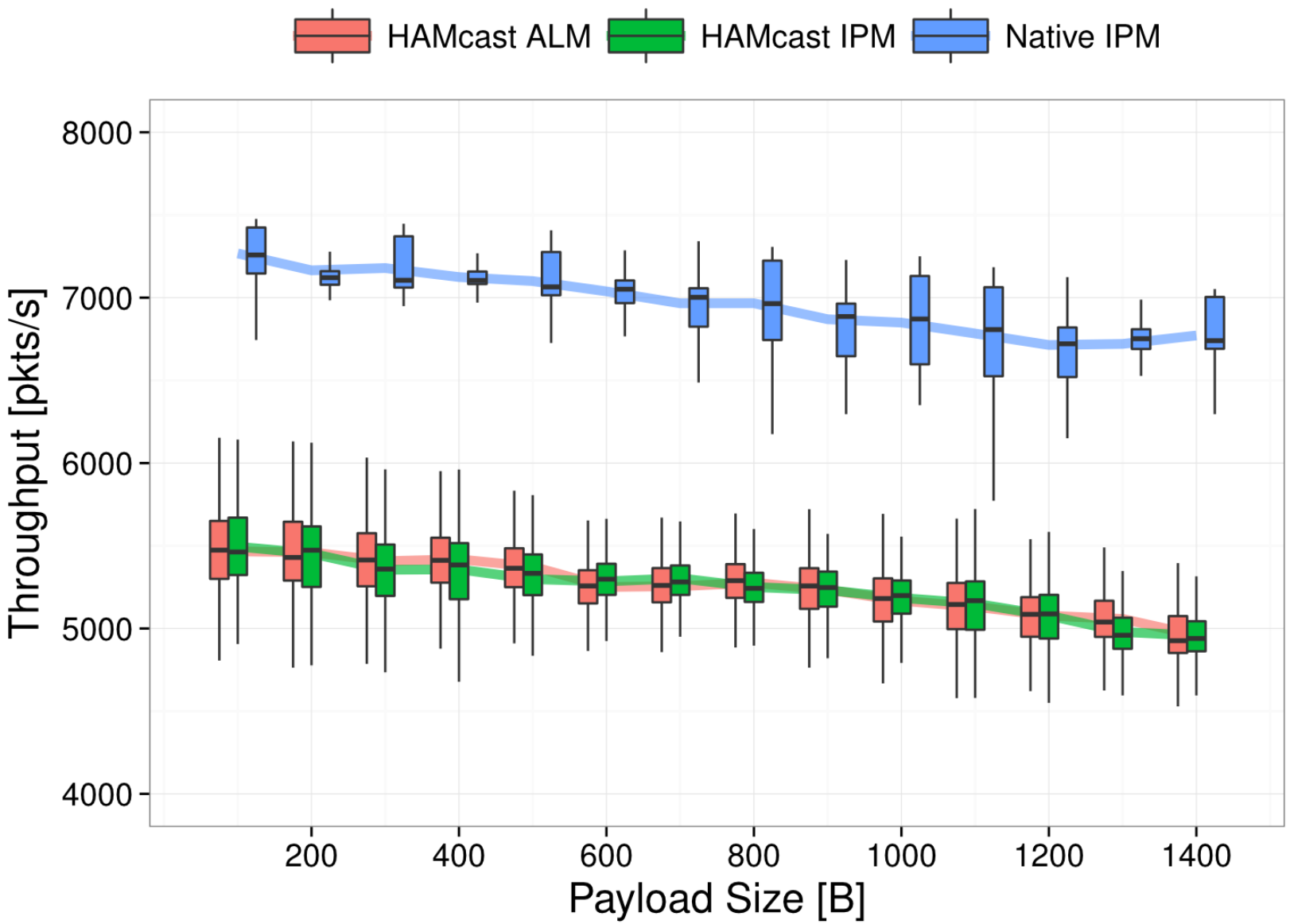
test setup

- two home gateways (sender and receiver)
- direct connection via 100 MBit/s Ethernet
- metrics: packet throughput and loss, CPU utilization
- constraints of hardware resources

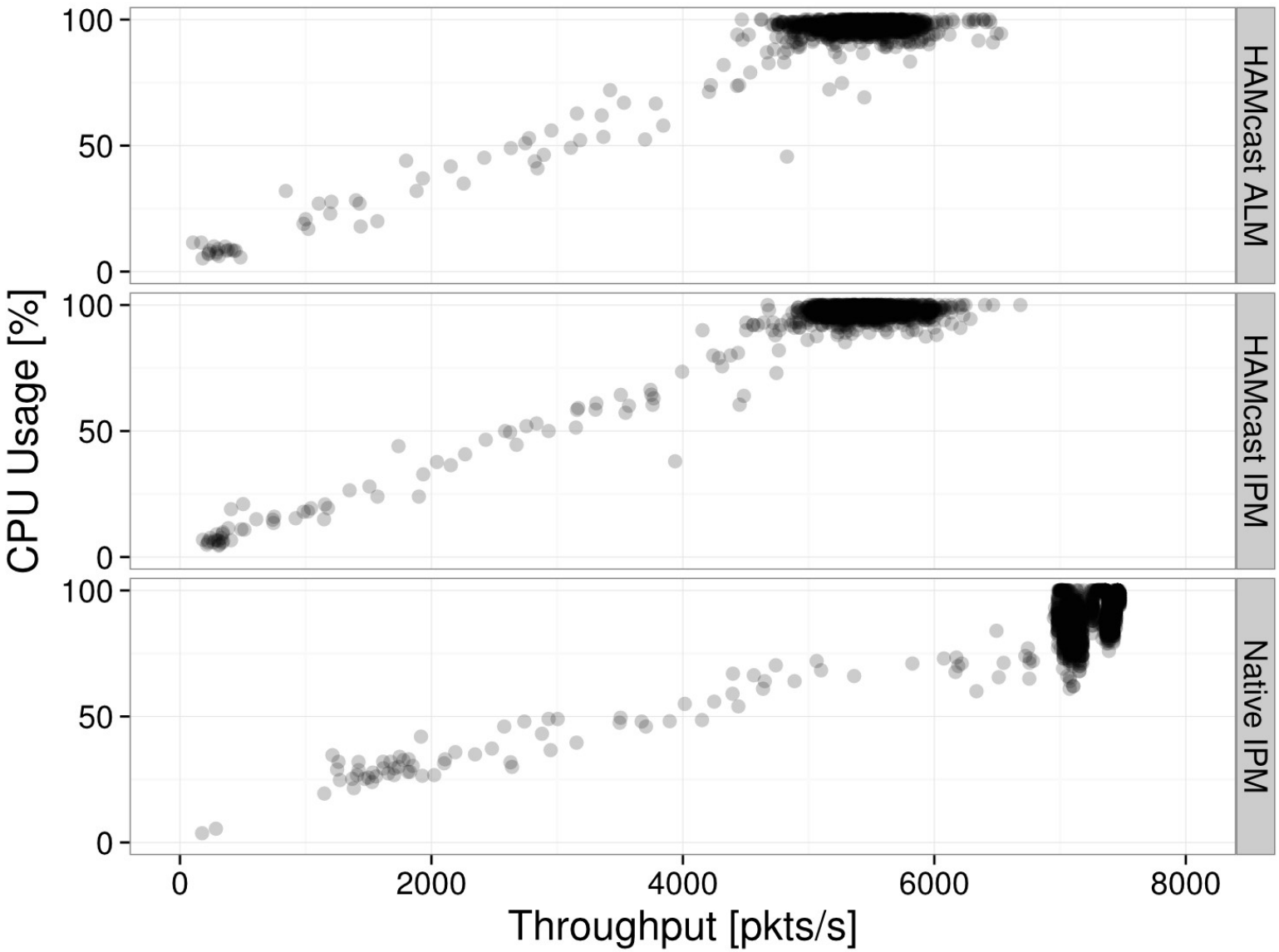
technologies under test

- native IP multicast (Native IPM) as reference
- H∀Mcast IP multicast (IPM)
- H∀Mcast application layer multicast via Scribe (ALM)

System Performance



System Performance

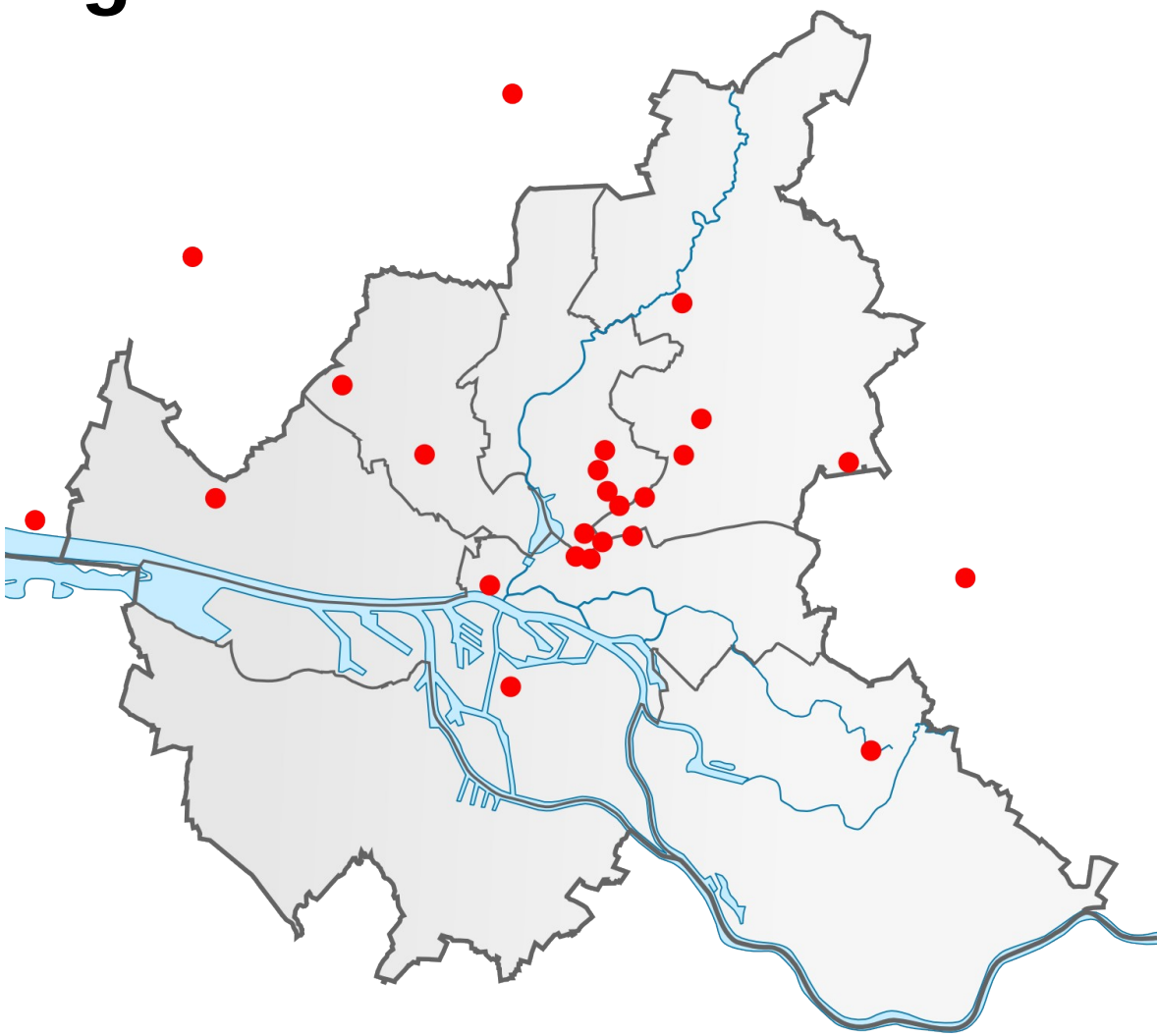


CPU performance is a limit to throughput

Hamburg testbed

test setup

- 30 nodes
- 9 Internet service providers (ISPs)
- metropolitan area of Hamburg, Germany



metric under test

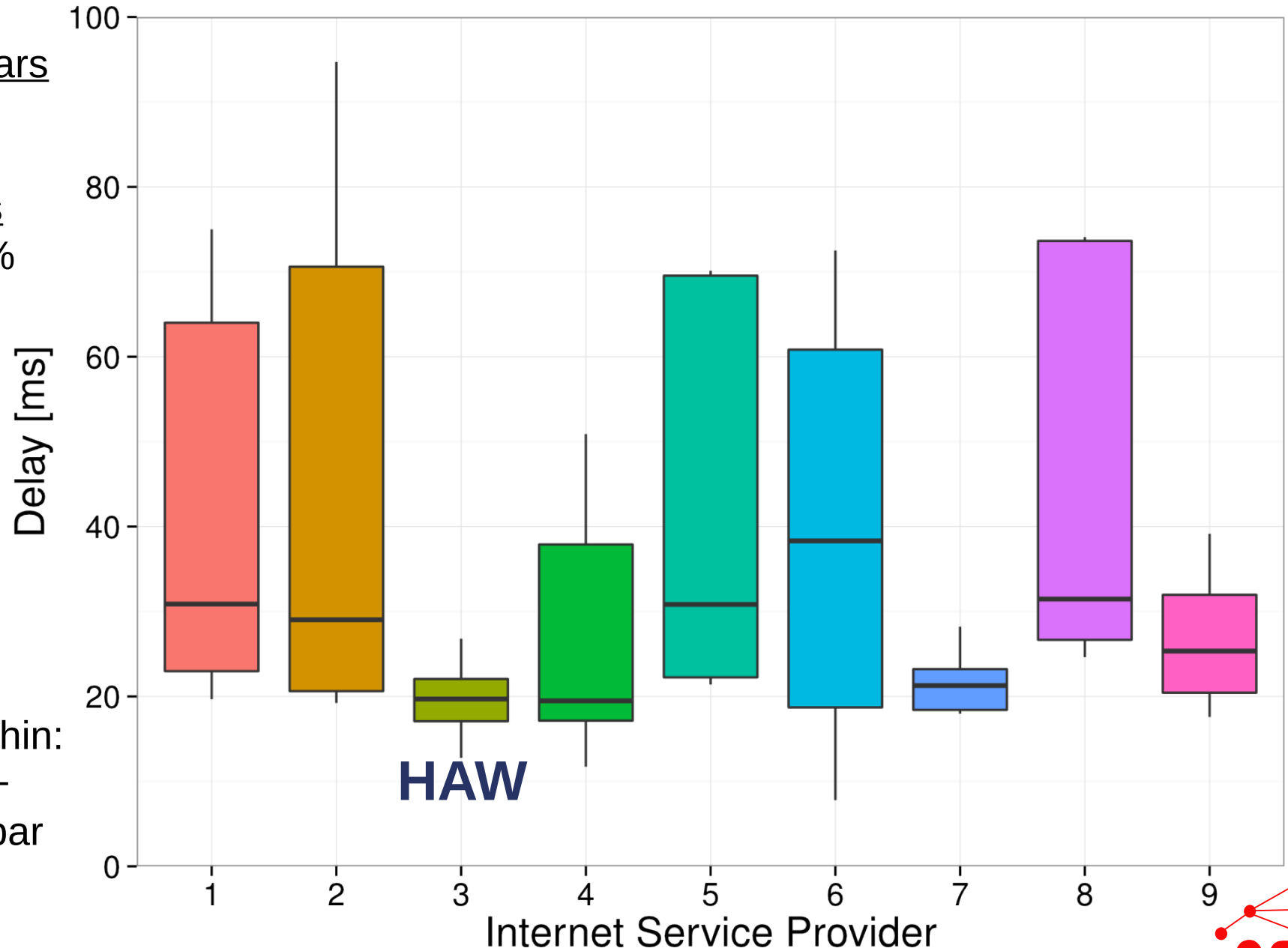
- one-way message delays

Distributed Measurement

horizontal bars
median

thick bars
25% - 75%

thin bars
last value within:
thick bar +
1.5 × thick bar



Conclusion

- results show high packet throughput on COTS
- end-to-end delays over ISP connections
  - surprisingly high for the regionally confined scenario
  - heavily depend on provider association
  - differ considerably between ISPs

- standard consumer embedded hardware more than sufficient for Smart Grid applications

  (AMI, DSM, and VPP)

Outlook

our ongoing research

- measurements and experiments in our Hamburg testbed
- analyze impacts of consumer Internet connectivity on (future) Smart Grid applications
- develop decentralized coordination schemes for energy devices
- other considerations
  - privacy, security, integrity
  - interfaces, other technologies (IEC 61850)

Questions?
Thank you!

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