Invited Talk at Tsinghua University

The NorNet Testbed
at Tsinghua University
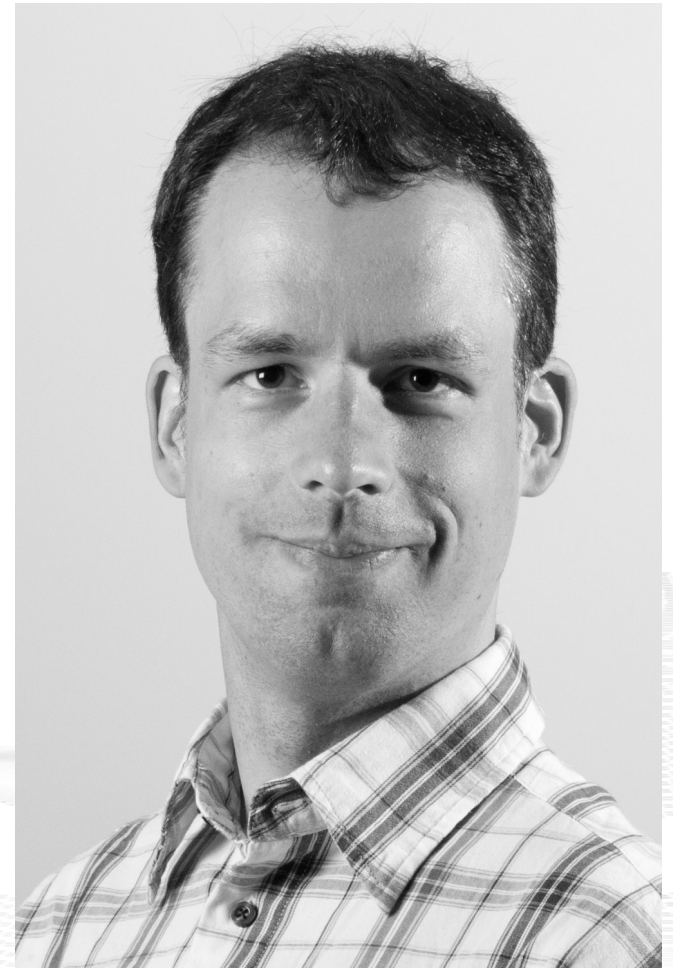–
A Large-Scale Experiment Platform
for Real-World Experiments
with Multi-Homed Systems

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Simula Research Laboratory

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- About Norway and the Simula Research Laboratory

- Motivation

- The NorNet Testbed

  - NorNet Core

  - NorNet Edge

- Users and Research

- Conclusion

Overview:
About Norway and the Simula Research Laboratory

- **About Norway and the Simula Research Laboratory**

- Motivation

- The NorNet Testbed

  – NorNet Core

  – NorNet Edge

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- Conclusion

# Where is Norway?

Oslo 奥斯陆

ca. 7,100 km

Beijing 北京

Svalbard — Kvitøya, Nordaustlandet, Spitsbergen, Ny-Ålesund, Pyramiden, Longyearbyen, Barentsburg, Bellsund, Edgeøya, Hopen, Kongsøya, Svenskøya, Barentsøya

Norwegian Sea

Arctic Circle

SWEDEN

FINLAND

Gulf of Bothnia

Baltic Sea

ESTON

Gulf of Riga

Skagerrak

Facts about Norway

Capital:	Oslo
Size:	ca. 385,000 km^2
Population:	ca. 5,150,000
Internet TLD:	.no

The Kingdom of Norway (Kongeriket Norge)

King Harald V
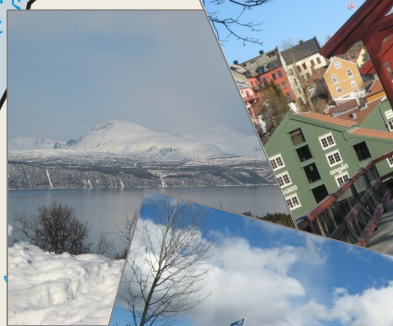
The Simula Research Laboratory

- Located in Fornebu
  - Just outside of Oslo
  - In the IT Fornebu complex
- Public limited company
  - 100% owned by Norwegian government
  - Strong connection to Universitetet i Oslo
  - Ca. 160 people from all over the world
- Research groups
  - Scientific Computing
  - Software Engineering
  - **Network and Distributed Systems**
- Norway's leading place for computer science research

Visit https://www.simula.no for further information!

Overview:
Motivation

Motivation: Robust Networks

- More and more applications rely on ubiquitous Internet access!

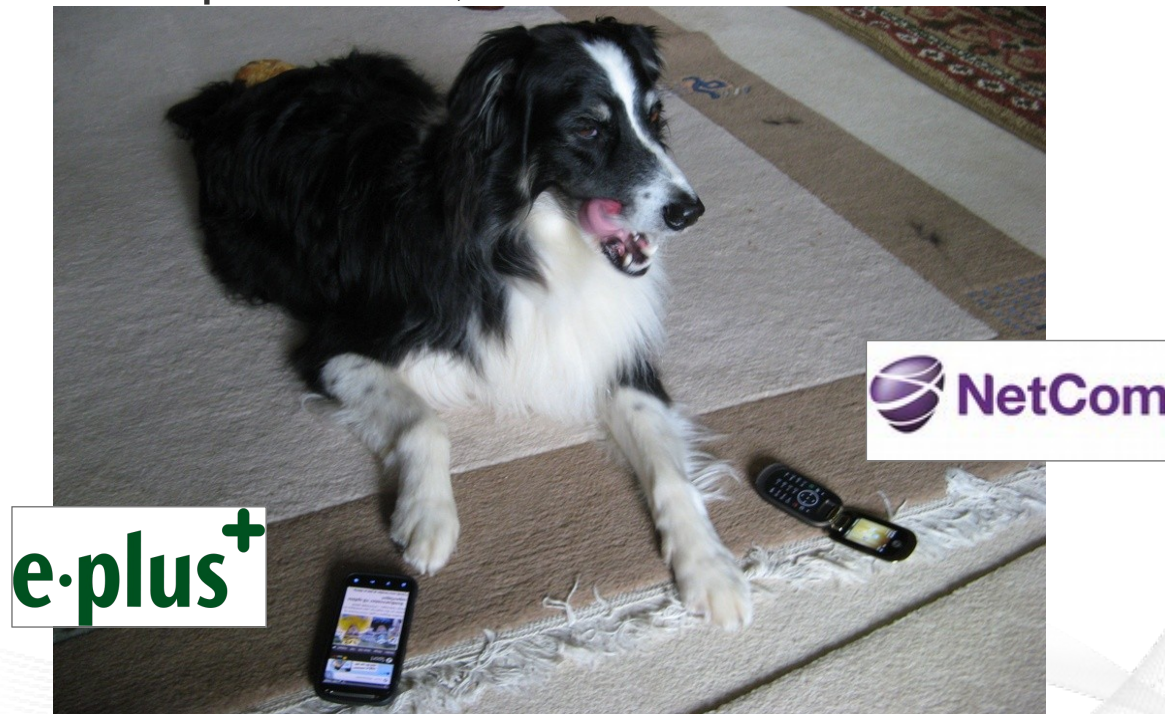- However, our current networks are not as robust as they should be ...

How to make networks more robust?

Resilience by Redundancy

Multi-Homing

- Connections to multiple Internet Service Providers (ISP)

- Idea: if one ISP has problems, another connection still works

Is resilience really improved? What about multi-path transport?

Idea: A Testbed for Multi-Homed Systems

Research in realistic setups is necessary!

- A multi-homed Internet testbed would be useful

  - Something like PlanetLab?

  - Perhaps with better node availability?

  - Support for mobile access (e.g. 2G/3G/4G/CDMA) as well as wired?

- **NorNet** – A research testbed for multi-homed systems!

  - Lead by the Simula Research Laboratory in Fornebu, Norway

  - Supported by Forskningsrådet

N☉RNET

https://www.nntb.no

Overview:
The NorNet Project

- **Motivation**

- **The NorNet Testbed**

  – NorNet Core

  – NorNet Edge

- Users and Research

- Conclusion

Goals of the NorNet Project

- Building up a **realistic** multi-homing testbed

- Wired and wireless

  – Wired → "NorNet Core"

  – Wireless → "NorNet Edge"

- **Perform research with the testbed!**

<div style="text-align:center; border: solid; background: #ffffcc;">

How to get a _realistic_ testbed?

</div>

Idea: Distribution of NorNet over whole Norway

- **Challenging topology:**
    - Large distances
    - A few "big" cities, many large rural areas
    - Svalbard:
        - Interesting location
        - Many polar research institutions
- Deployment:
    - Core: 11 sites in Norway + 5 in CN, DE (2x), SE, US
   - Edge: hundreds of nodes in Norway

Overview:
NorNet Core

- Motivation

- The NorNet Testbed

    - NorNet Core

    - NorNet Edge

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- Conclusion

Idea for NorNet Core: Tunnelling

- Researchers require control over used ISP interfaces

  - Which outgoing (local site) interface

  - Which incoming (remote site) interface

- Idea: Tunnels among sites

  - Router at site A: IPs A_1, A_2, A_3

  - Router at site B: IPs B_1, B_2

  - IP tunnel for each combination:
    $A_1 \leftrightarrow B_1$, $A_1 \leftrightarrow B_2$, $A_2 \leftrightarrow B_1$, $A_2 \leftrightarrow B_2$, $A_3 \leftrightarrow B_1$, $A_3 \leftrightarrow B_2$

  - Fully-connected tunnel mesh among NorNet Core sites

  - Each site's router (called **tunnelbox**) maintains the tunnels

    - Static tunnels

    - NorNet-internal addressing and routing over tunnels
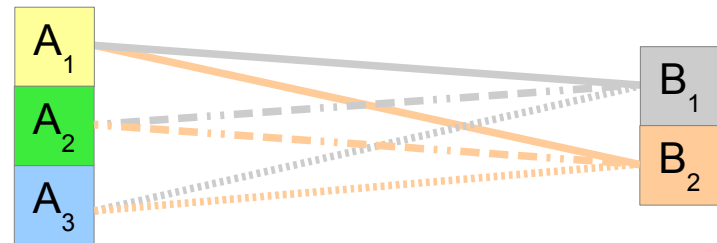
Address Assignment

- NorNet-internal address spaces:

  – Private NorNet-internal IPv4 "/8" address space (NAT to outside)

  – Public NorNet-internal IPv6 "/48" address space

- Systematic address assignment:

  – IPv4: 10.*<Provider ID>*.*<Site ID>*.*<Node ID>*/24 per site

  – IPv6: 2001:700:4100:*<PP><SS>*::*<NN>*/64
    (*PP*=Provider ID; *SS*=Site ID; NN=Node ID)

- NorNet-internal DNS setup including reverse lookup

Make it as easy as possible to keep the overview!

A NorNet Core Site Deployment

A usual NorNet Core site:

- 1x switch

- 4x server

  - 1x tunnelbox

  - 3x research systems

- At least two ISP connections

  - Research network provider

  - Other providers

- IPv4 and IPv6 (if available)

Additional researcher-provided sites:

- Varying configurations

- VM setups, powerful servers, "retro-style" PCs ...

Longyearbyen 78.2°N,15.6°E

NorNet Core på Svalbard

Site Deployment Status
(October 2014)

No.	Site	ISP 1	ISP 2	ISP 3	ISP 4
1	Simula Research Laboratory	Uninett	Kvantel	Telenor	PowerTech
2	Universitetet i Oslo	Uninett	Broadnet	PowerTech	
3	Høgskolen i Gjøvik	Uninett	PowerTech		
4	Universitetet i Tromsø	Uninett	Telenor	PowerTech	
5	Universitetet i Stavanger	Uninett	Altibox	PowerTech	
6	Universitetet i Bergen	Uninett	BKK		
7	Universitetet i Agder	Uninett	PowerTech	–	
8	Universitetet på Svalbard	Uninett	Telenor		
9	Universitetet i Trondheim	Uninett	PowerTech		
10	Høgskolen i Narvik	Uninett	Broadnet	PowerTech	
11	Høgskolen i Oslo og Akershus	Uninett	–		
12	Karlstads Universitet	SUNET			
13	Universität Kaiserslautern	DFN			
14	Universität Duisburg-Essen	DFN	Versatel		
15	Hainan University	CERNET	China Unicom		
16	The University of Kansas	KanREN			
17	Bell Labs Korea	KREONET			
18	Qiongzhou University	CERNET	China Telecom		

Legend:
- IPv4 and IPv6
- ISP negotiation in progress
- IPv4 only (ISP without IPv6 support ☹)
- IPv4 only (site's network without IPv6 support)

https://www.nntb.no/pub/nornet-configuration/NorNetCore-Sites.html

Some Site Statistics (October 2014)

Active Sites	17
Distinct ISPs of Active Sites	14
Distinct Countries of Active Sites	6
Total IPv4 Interfaces	35
Total IPv4 Tunnels	595
Total IPv6 Interfaces	22
Total IPv6 Tunnels	231
Inactive Sites	1

https://www.nntb.no/pub/nornet-configuration/NorNetCore-Sites.html

Remote Systems

Our servers may be really <u>remote</u>!

The "road" to Longyearbyen på Svalbard, 78.2°N

Virtualisation

> ## *"Anything that can go wrong, will go wrong."*
> **[Murphy's law]**

- Experimentation software is experimental

- How to avoid software issues making a remote machine unusable?

- Idea: virtualisation

    - Lightweight, stable software setup:
      Ubuntu Server 12.04 LTS

    - VirtualBox 4.3

    - Other software runs in VirtualBox VMs:

        - Tunnelbox VM on physical server #1

        - 2 LXC-based research node VMs
          on physical servers #2 to #4

    - In case of problem: manual/automatic restart or reinstall of VM
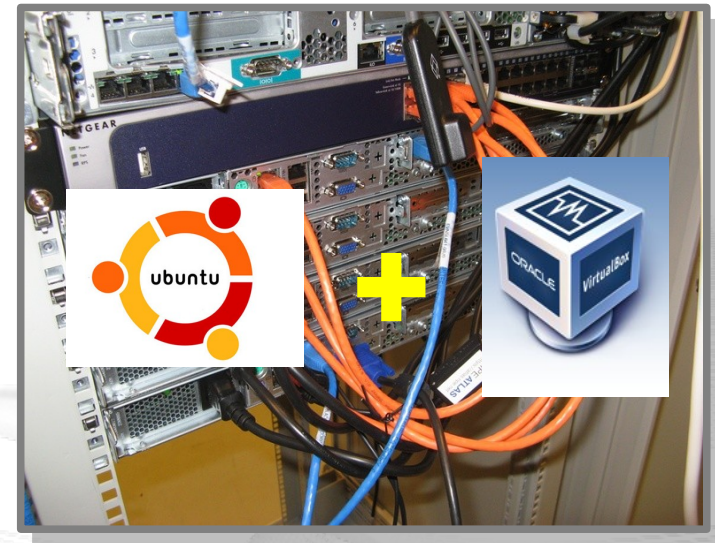
PlanetLab-based Software for Experiments

- Key idea:
    - Researchers should get virtual machines for their experiments
    - Like **PlanetLab** …
    - … but with multi-homing and IPv6, of course
- *PlanetLab* software:
    - Different "stable" distributions: *PlanetLab*, *OneLab*, etc.
    - Current implementation: based on *Linux VServers*
        - Not in mainline kernel
        - Patched kernel, makes upgrades difficult
    - The future: **Linux Containers** (LXC)
        - Active development by *PlanetLab*/*OneLab*
        - We are involved in developing and testing the LXC software

Experiments with Special Requirements

**Special requirements for your experiment? Ask!**

- **NorNet Core can satisfy special setup requirements for experiments!**

- Example: VMs with **custom operating system**

    – For example: custom Linux, **FreeBSD**, AROS, ...

    – Currently still requires manual setup, automation as future work

- Other example: VoIP **SIP honeypot**

    – Security project at University of Duisburg-Essen (UDE)

    – Tunnelboxes tunnel SIP traffic to a central honeypot server at UDE site

    – Analysis of SIP attacks tried on the tunnelbox addresses at different sites
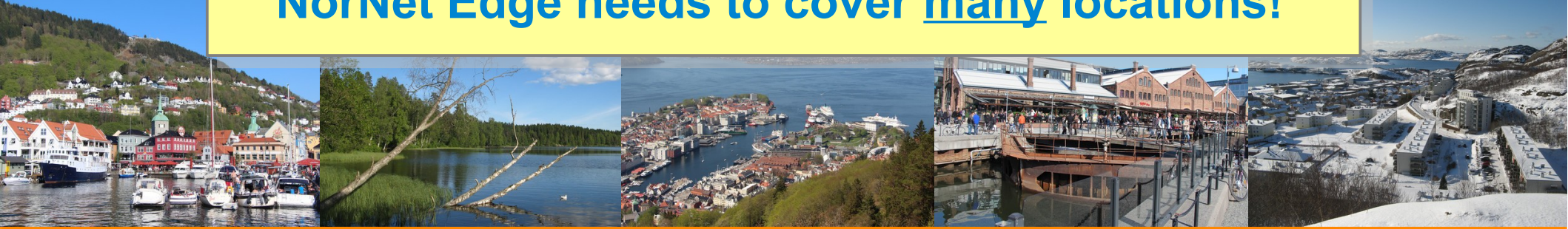
UNIVERSITÄT
DUISBURG
ESSEN

Overview:
NorNet Edge

- **Motivation**

- **The NorNet Testbed**

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NorNet Edge –
Wireless Network Conditions at Heterogeneous Locations
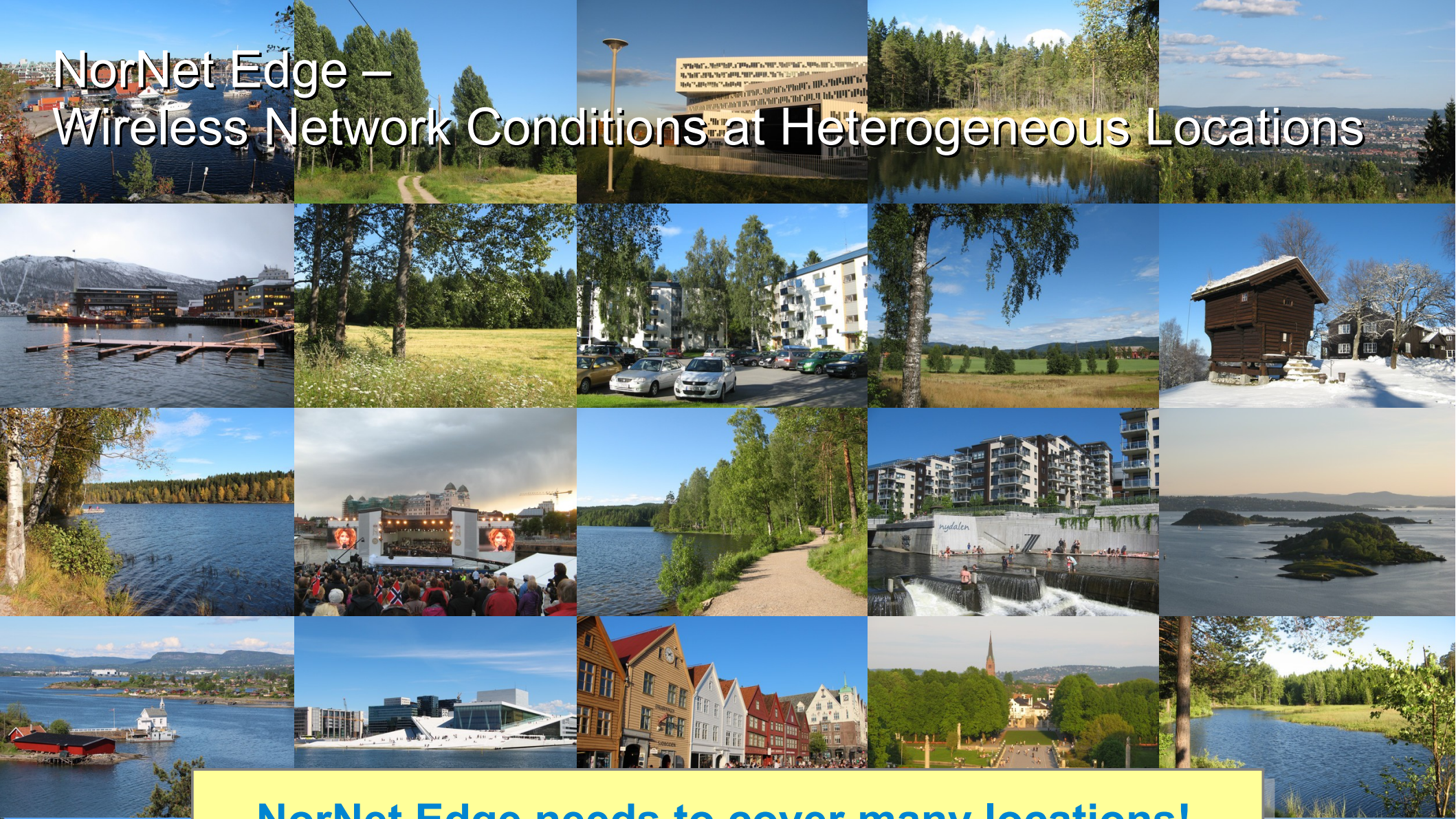
NorNet Edge needs to cover <u>many</u> locations!

[simula . research laboratory]   - by thinking constantly about it

NorNet Edge Nodes

Solution: embedded systems instead of servers!

Ufoboard:

- Custom-made for NorNet

- Based on off-the-shelf smartphone board (Samsung Galaxy S)

- 1 GHz ARM Cortex-A8 CPU

- 512 MiB RAM

- 16-32 GB disk (SD card)

- 7 USB ports + Ethernet port

- Debian Linux 7.6 ("Wheezy")

The NorNet Edge Box: Ready for Deployment

Box contents:

- Ufoboard

- Up to 4x USB UMTS or LTE:

    – Telenor, NetCom,

    – Network Norway, Tele2

- 1x ICE CDMA mobile broadband

- 1x Ethernet

- 1x WLAN (optional)

- Power supplies

- Handbook

NorNet Edge på Kringsjå, Oslo
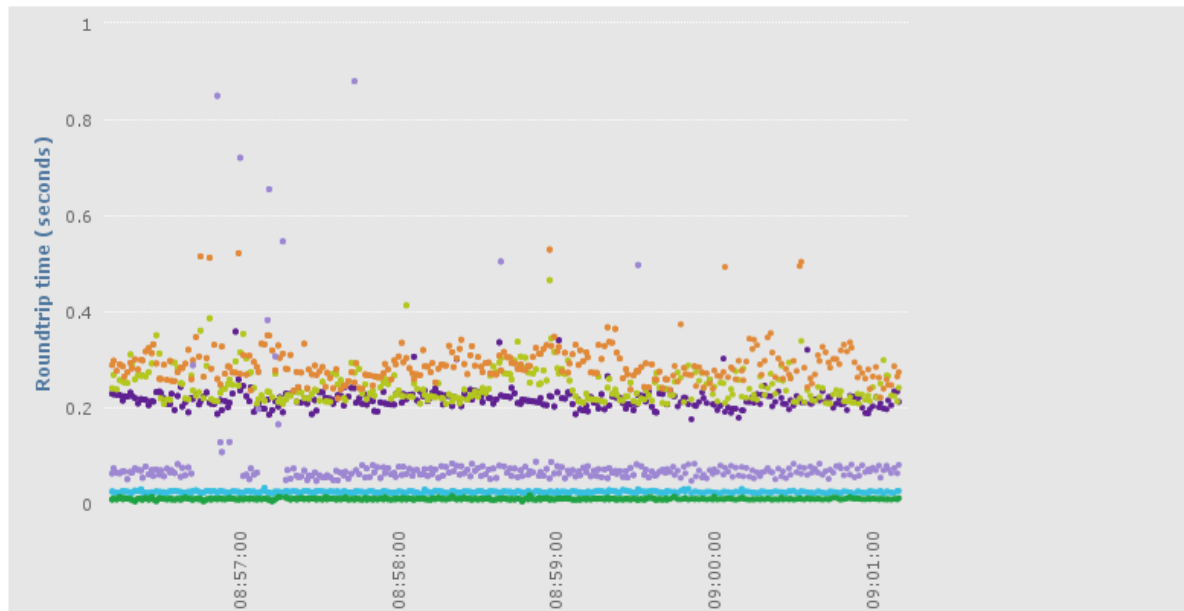
NorNet
http://www.nntb.no

Live Visualisation of NorNet Edge (1)

See http://robustenett.no/map!
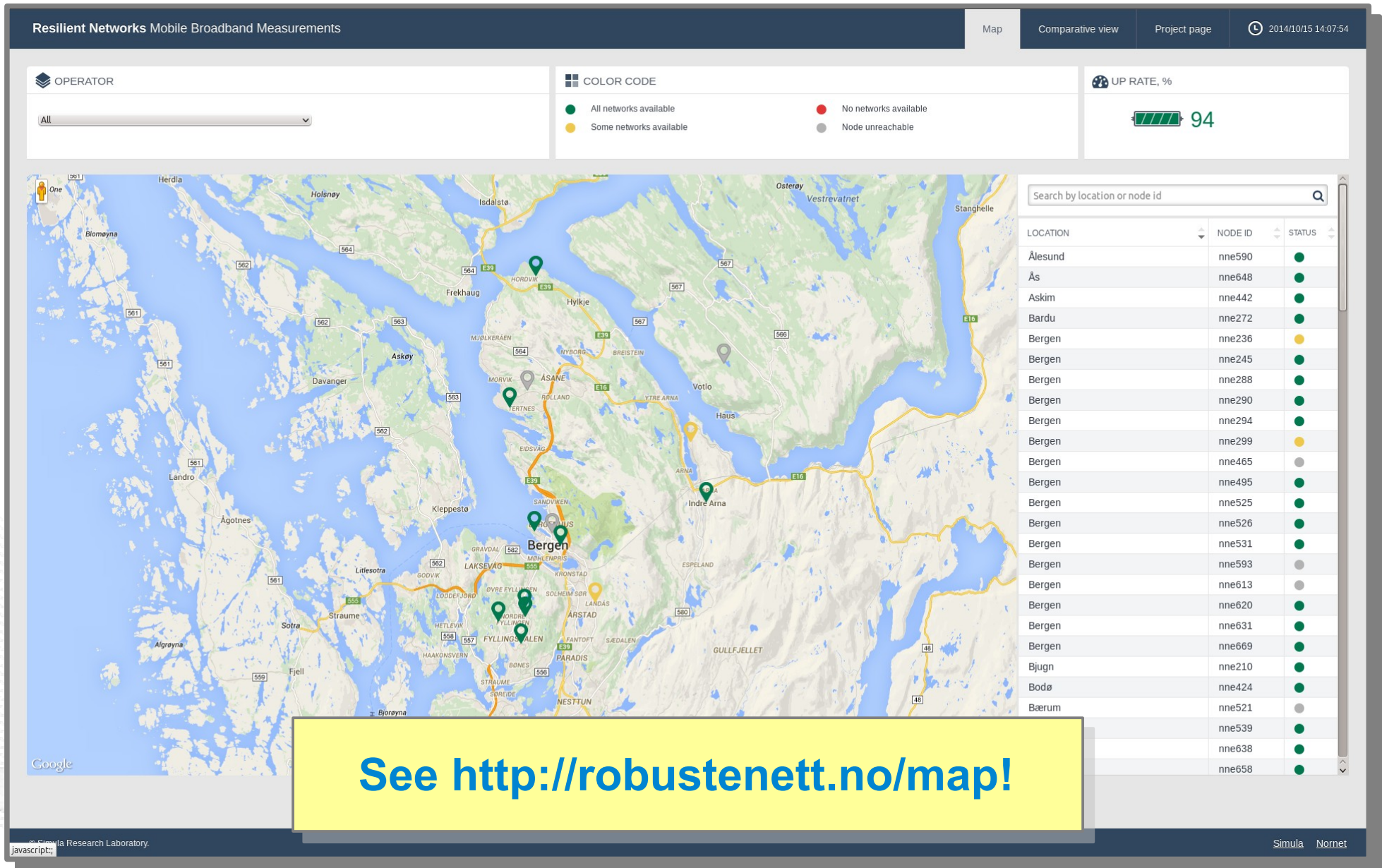
Live Visualisation of NorNet Edge (2): Real-Time Data and Statistics Database

See http://robustenett.no/map!

Software for NorNet Edge Experiments

- Currently:

  - Uses get exclusive access to selected nodes

  - SSH login

  - Nodes are just normal Linux machines
    (ARM-based, memory size restrictions)

  - Data amount restriction:
    ISP connections have a monthly restriction on full-speed data
    (1 GiB to a few GiB). After that: speed limit to max. 64 Kbit/s!

  - Mostly manual user management

- Future:

  - Improved, mostly automatic user management

Overview:
Users and Research

- **Motivation**

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- **Users and Research**

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Users and Research

> ***"The road to hell is paved with unused testbeds."***
> **[James P. G. Sterbenz]**

- We already got some users!

- Examples:

  - Shared Bottleneck Detection (UiO+Simula)

  - VoIP Misuse Detection (UDE)

  - Multi-Path Transport (Simula, UDE, UiO, HU, etc.)

  - Balia Congestion Control (Bell Labs in South Korea)

  - IPv4/IPv6 Performance Comparison (Simula)

  - ...

List to be extended!

See https://www.nntb.no/projects/ for further projects using NorNet!

Next step: get even more users!

The "NorNet World Tour 2014"

- 01/2014: Centre for Advanced Internet Architectures (CAIA) at Swinburne University Melbourne, Victoria/Australia

- 05/2014: Polytechnic School of Engineering at New York University (NYU) Brooklyn, New York/U.S.A.

- 05/2014: PlanetLab Consortium at Princeton University Princeton, New Jersey/U.S.A.

- 05/2014: University of British Columbia (UBC) Vancouver, British Columbia/Canada

- 09/2014: Kungliga Tekniska högskolan (KTH Royal Institute of Technology) Stockholm/Sweden

- 10/2014: Academics, Industry and Government of the Hainan Province Haikou, Hainan/China

- 10/2014: Tsinghua University Beijing/China

- 12/2014: NorNet demo presentation at the IEEE GLOBECOM Austin, Texas/U.S.A.

- 01/2015: … [pla [planned]/Austr

Interested in a NorNet presentation? Just ask!

Collaborations

- PlanetLab/OneLab

  - Development and testing of the research software

  - URLs: https://www.planet-lab.org, https://www.onelab.eu

- RIPE Atlas

  - Connectivity and reachability measurements

  - URL: https://atlas.ripe.net

  - Node deployed at site in Longyearbyen

- Seattle

  - Open Peer-to-Peer Computing, project at NYU

  - URL: https://seattle.poly.edu

  - Running inside NorNet Core slice

- ToMaTo

  - Topology Management Tool

  - URL: http://tomato-lab.org

  - Part of the G-Lab testbed
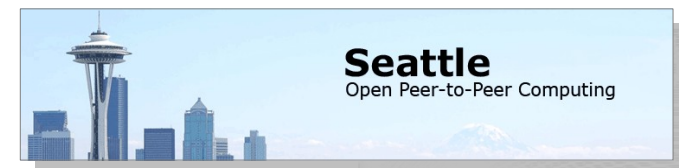
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Conclusion and Future Work

- The NorNet testbed is ready for experiments!

  - Do <u>you</u> have experiment ideas? → Talk to us!

- Future work:

  - Extend NorNet Core

    - More multi-homing, i.e. further ISPs, IPv6
    - Additional sites

  - Extend NorNet Edge

    - Cover additional countries:
      Funding granted for Sweden, Spain and Italy!
    - Node upgrades (UMTS → LTE, WLAN, subscriptions, …)

  - Improve and refine management software

  - Get more users, may be <u>you</u>?

And, of course, do more <u>research</u>!

"NorNet wants to be a building block of the railroad to heaven" ...

… and not be another unused testbed that paves the road to hell!

Any Questions?

NORNET

Visit https://www.nntb.no for further information!