

Invited Talk at Swinburne University, Centre for Advanced Internet Architectures (CAIA)

The NorNet Testbed

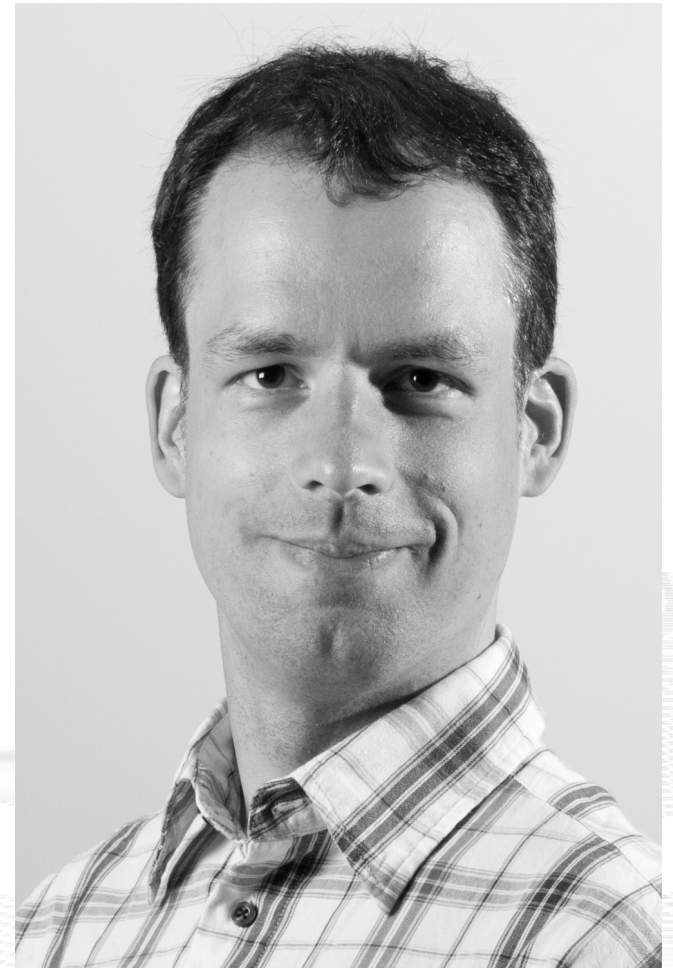
—

A Large-Scale Experiment Platform
for Real-World Experiments
with Multi-Homed Systems

Thomas Dreibholz, dreibh@simula.no

Simula Research Laboratory

28 January 2015



Contents

- 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
- Users and Research
- Conclusion

Where is Norway?



Oslo 奧斯陸

ca. 7,100 km

Beijing 北京

ca. 16,000 km

Melbourne 墨爾本

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

[**simula** . research laboratory]



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

Overview: Motivation

- Motivation
- The NorNet Testbed
 - NorNet Core
 - NorNet Edge
- Users and Research
- Conclusion

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!**



How to get a *realistic* testbed?

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 + 6 in CN, DE (2x), SE, US, KR
 - Edge: hundreds of nodes in Norway



Overview: NorNet Core

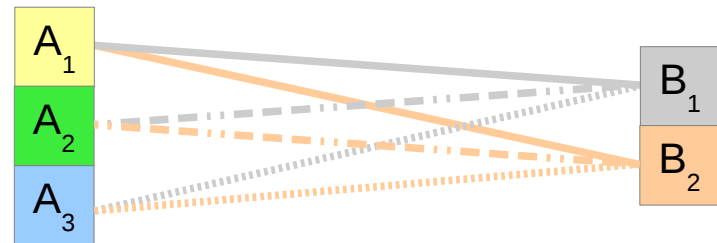
- Motivation
- The NorNet Testbed
 - NorNet Core
 - NorNet Edge
- Users and Research
- Conclusion

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:

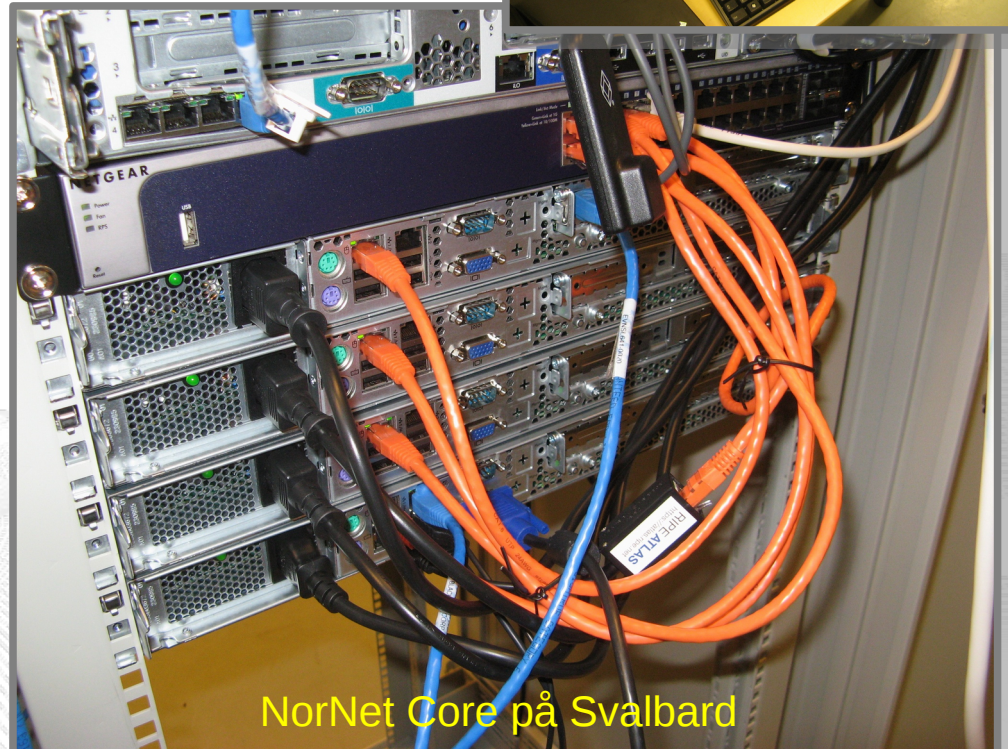
- 1x switch
- 4x server
 - 1x tunnelbox
 - 3x research systems
- At least two ISP connections
 - Research network provider
 - Other providers
- IPv4 and IPv6 (if available)

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 (January 2015)

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			

 IPv4 and IPv6

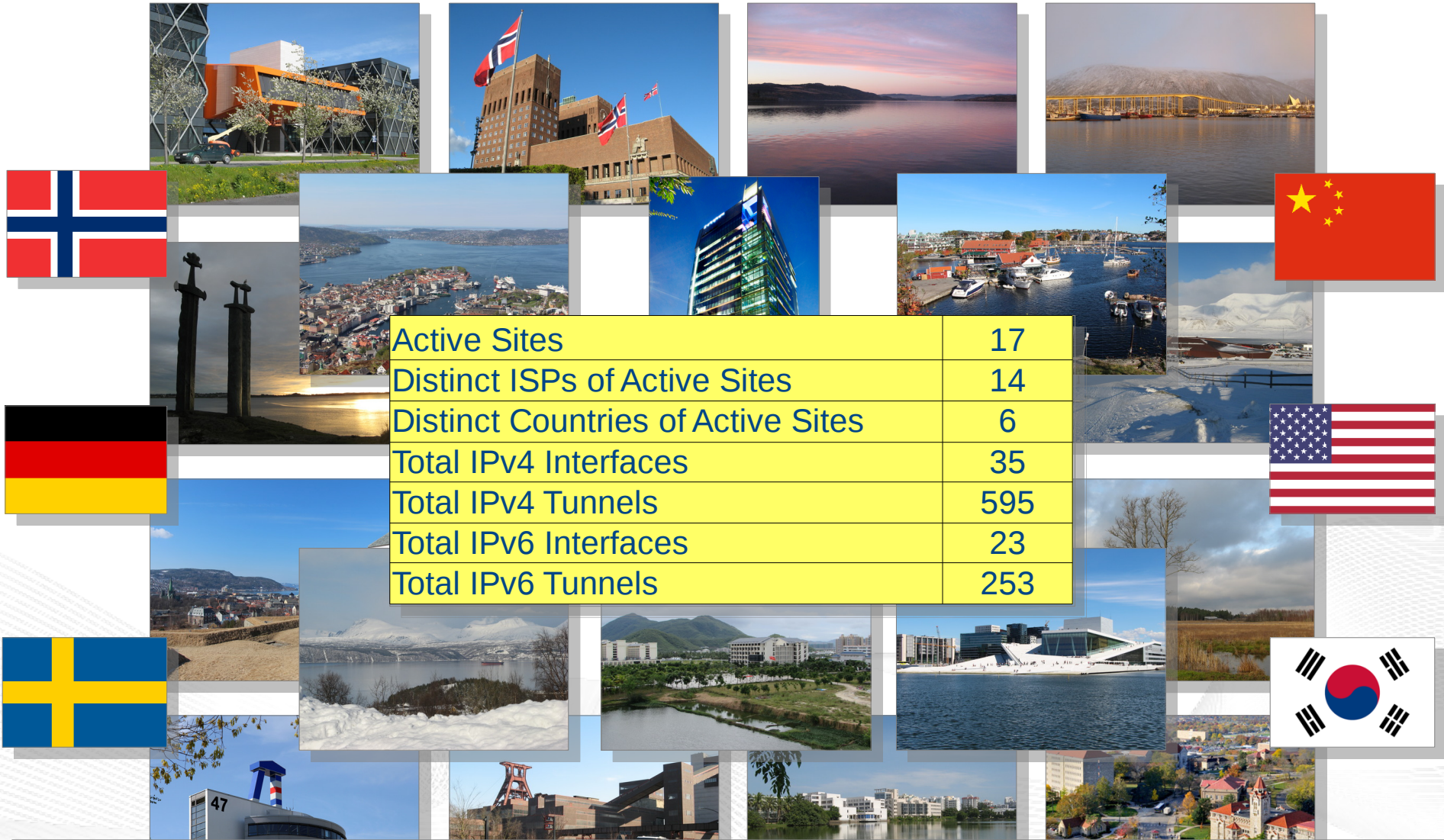
 ISP negotiation in progress

 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 (January 2015)



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	23
Total IPv6 Tunnels	253

<https://www.nntb.no/pub/nor-net-configuration/NorNetCore-Sites.html>

Remote Systems

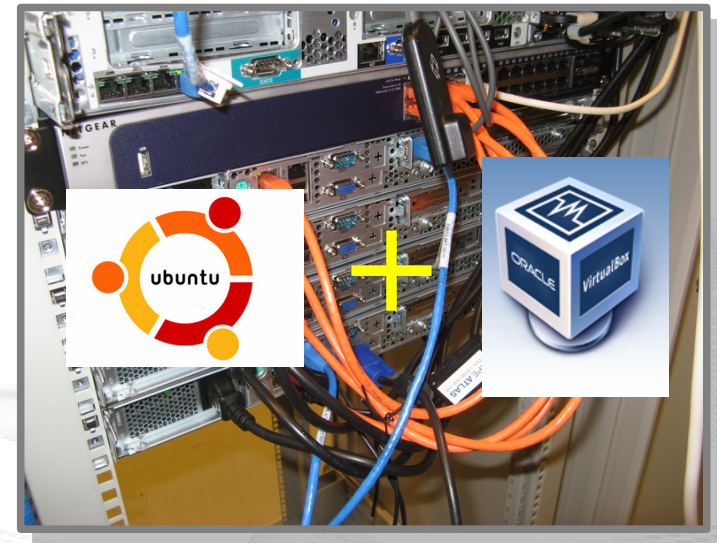
Our servers may be really remote!

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
 - NorNet Core
 - NorNet Edge
- Users and Research
- Conclusion

NorNet Edge – Wireless Network Conditions at Heterogeneous Locations



NorNet Edge needs to cover many locations!

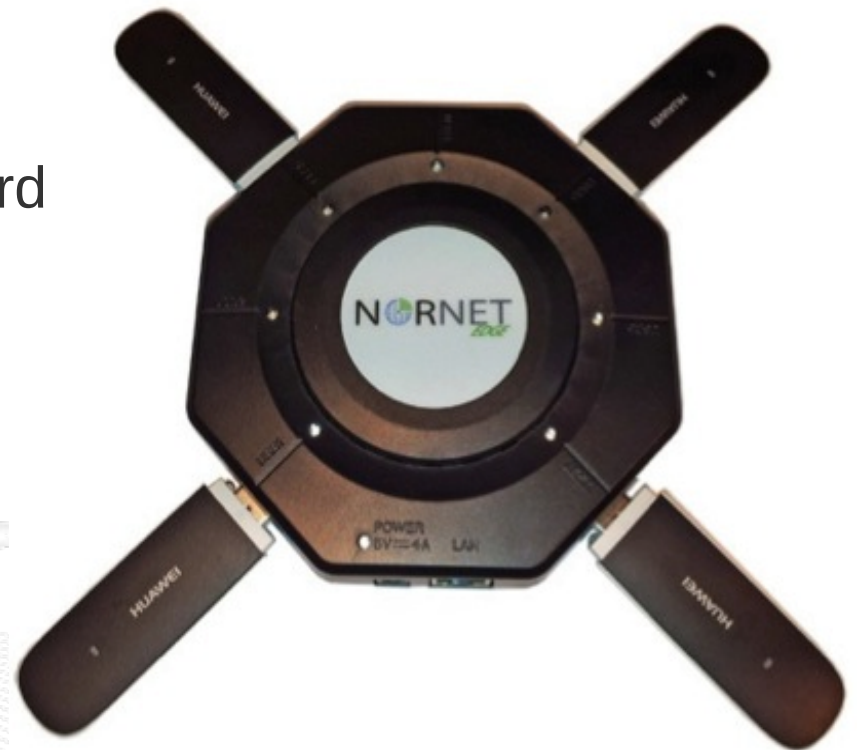


NorNet Edge Nodes

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”)



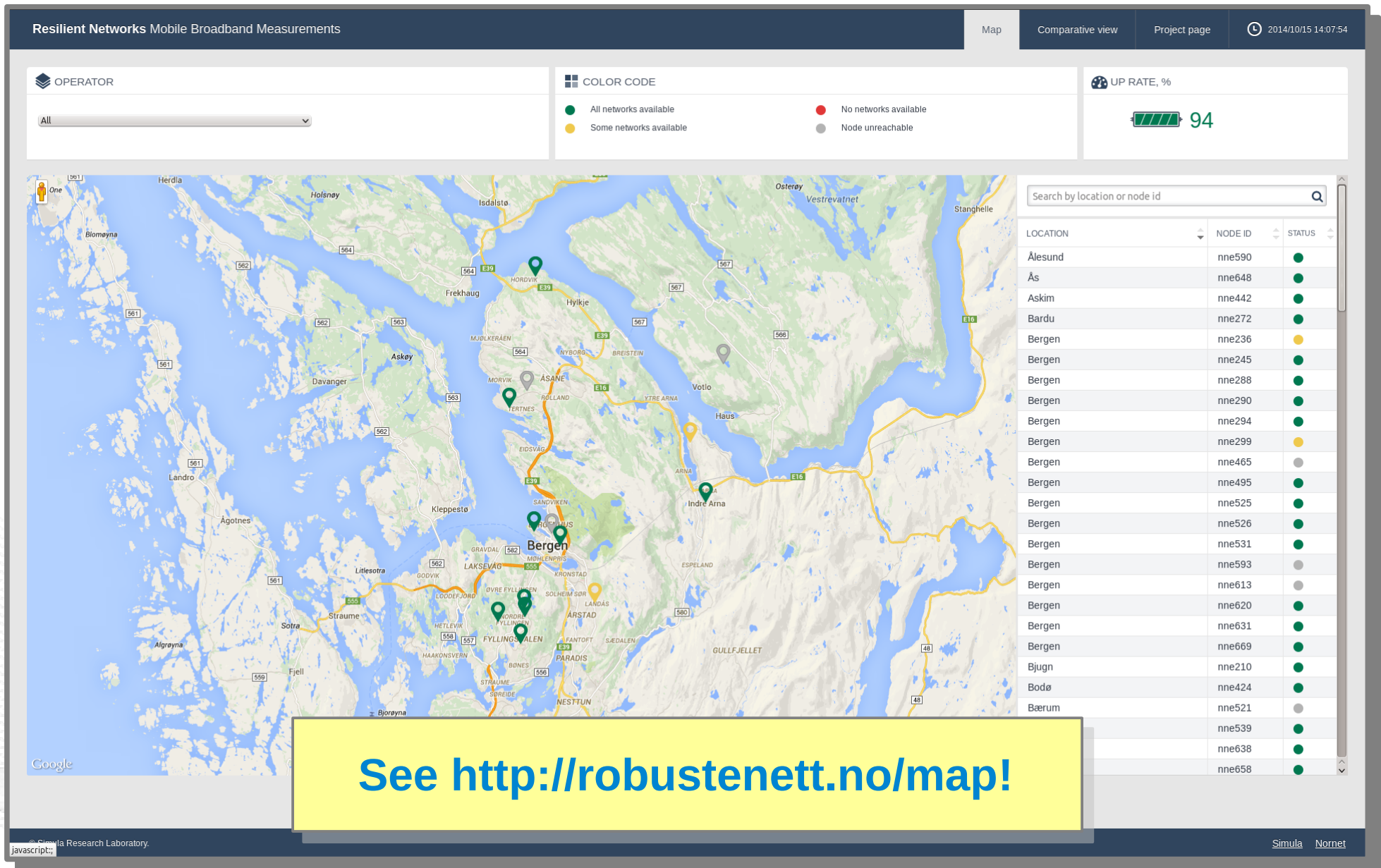
The NorNet Edge Box: Ready for Deployment

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



Live Visualisation of NorNet Edge (1)

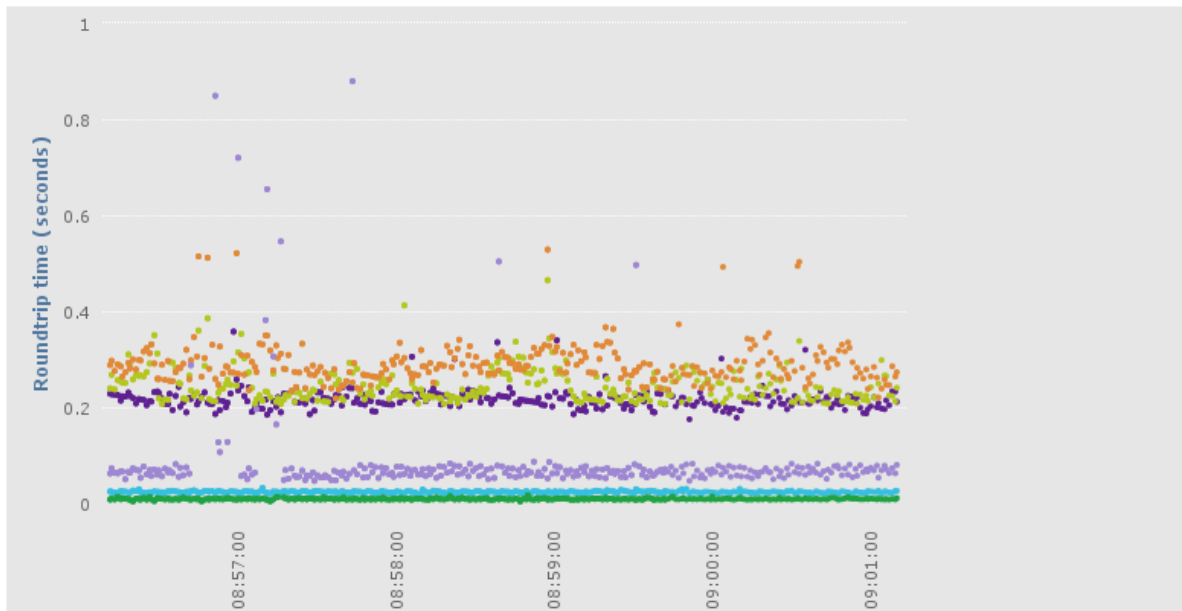


See <http://robustenett.no/map!>

Live Visualisation of NorNet Edge (2): Real-Time Data and Statistics Database

OSLO, THOMAS'S HOME (NNE497)

LATENCY PACKET LOSS



✓	ISP	STATUS	
←	Telenor	3G (WCDMA)	
←	Netcom	LTE	
←	Tele2	3G (WCDMA)	
←	Network Norway	3G (WCDMA)	
←	ICE.NET	Unknown	
←	LAN	Available	

This plot shows the round-trip time (rtt) for each connection. One 20 byte UDP packet is sent every second to our server, and we record the time it takes before it returns back to the measurement node.

Note that the rtt depends heavily on the mode of the connection. For example, a 3G connection will generally have lower delays than a 2G connection, and an HSPA+ connection will have lower delay than a WCDMA connection. The mode of a connection again depends on the traffic pattern. Hence, sending more traffic can result in a lower rtt.

[See http://robustennet.no/map!](http://robustennet.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
- The NorNet Testbed
 - NorNet Core
 - NorNet Edge
- Users and Research
- Conclusion

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!

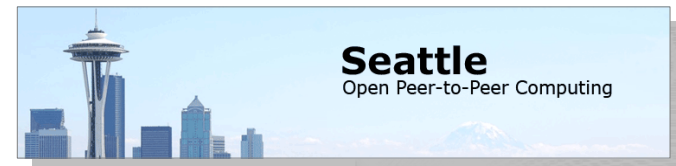
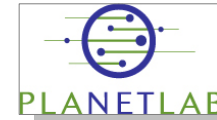
The “NorNet World Tour”

- 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: NICTA in Sydney/New South Wales and
CAIA in Melbourne/Victoria, Australia



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



Overview: Conclusion

- Motivation
- The NorNet Testbed
 - NorNet Core
 - NorNet Edge
- Users and Research
- Conclusion

Conclusion and Future Work

- The NorNet testbed is ready for experiments!
 - Do you 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 you?



And, of course, do more research!

“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?

N  RNET

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