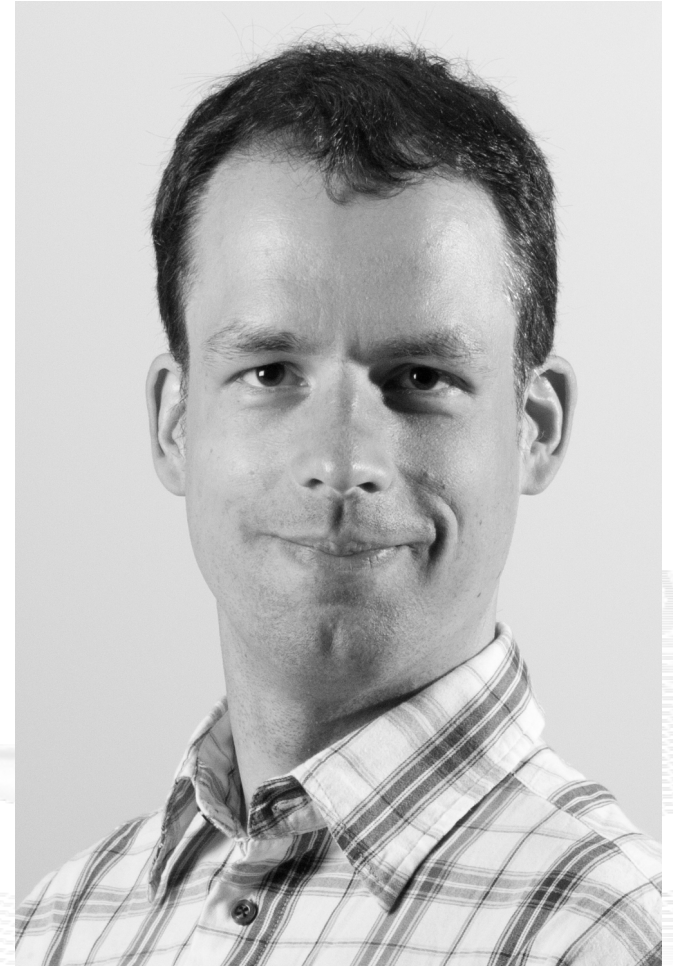


## The NorNet Experimentation Platform for Multi-Homed Systems

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**Simula Research Laboratory**

**17 September 2015**



# Contents

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

# Overview: Motivation

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# Resilience by Redundancy

## Multi-Homing

- Connections to multiple Internet Service Providers (ISP)
- Idea: if one ISP has problems, another connection still works



**Research in a realistic Internet testbed is necessary!**

# Overview: The NorNet Project

- Motivation
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# 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 and 9 in abroad
  - Edge: hundreds of nodes in Norway



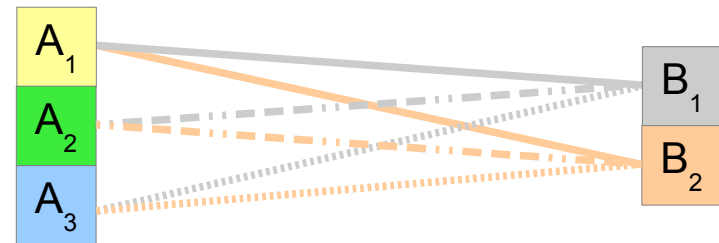
# Overview: NorNet Core

- Motivation
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# 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

# NorNet Core Site Deployment Status (September 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 海南大学	CERNET	China Unicom		
16	The University of Kansas	KanREN			
17	Korea University 고려대학교	KREONET			
18	National ICT Australia (NICTA)	AARNet			
19	Univ. Federal de São Carlos	RNP			
20	HAW Hamburg	DFN			

 IPv4 and IPv6

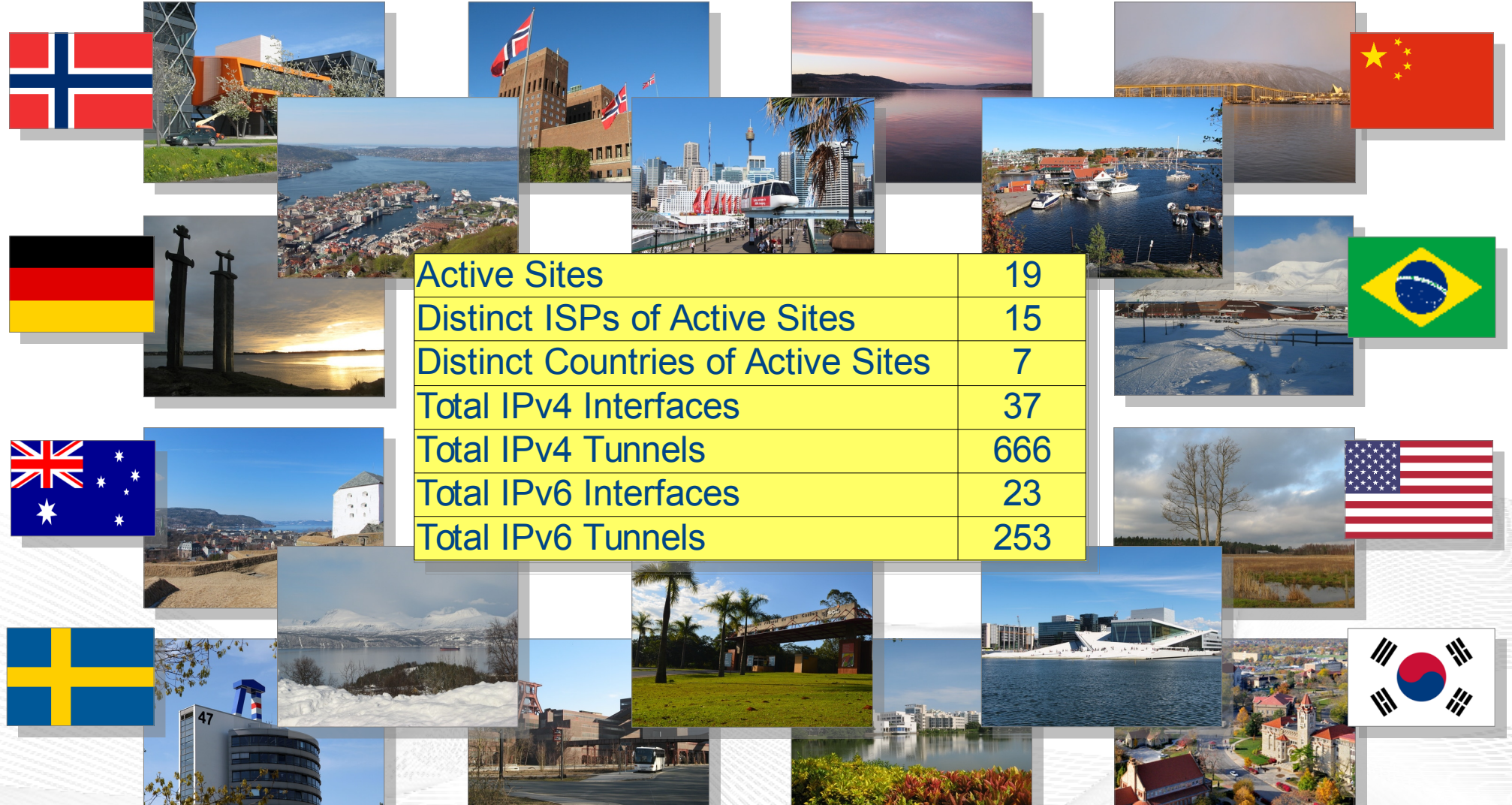
 ISP negotiation in progress

 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 (September 2015)



Active Sites	19
Distinct ISPs of Active Sites	15
Distinct Countries of Active Sites	7
Total IPv4 Interfaces	37
Total IPv4 Tunnels	666
Total IPv6 Interfaces	23
Total IPv6 Tunnels	253

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

# Remote Systems

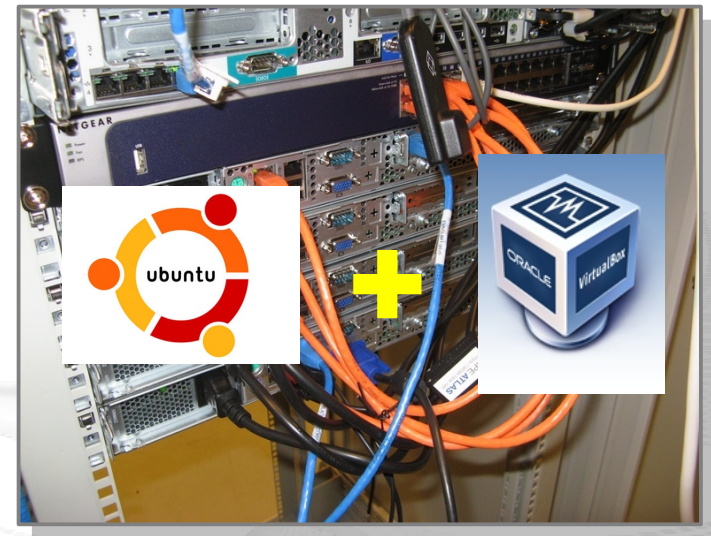
**Our servers may be really remote!**

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



# Research Software Status

- Basic research node software:
  - Based on PlanetLab/OneLab, with NorNet customisations
    - Kernel 3.14 with Linux MPTCP 0.89.4 → soon 0.89.5 (or already 0.90?)
    - Production nodes: still Fedora Core 18
    - Experimental builds for Fedora Core 21 and 22 (see <http://benlmond.nntb.no> for nightly builds)
- Custom VMs for special requirements
  - MPTCP tests with custom kernels
  - FreeBSD experiments → CMT-SCTP and FreeBSD MPTCP from CAIA
- Virtualisation:
  - VirtualBox 4.3 (with VNC patch) or VMware
  - Some test systems already run KVM → enhanced flexibility



# Overview: NorNet Edge

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# 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)

Resilient Networks Mobile Broadband Measurements

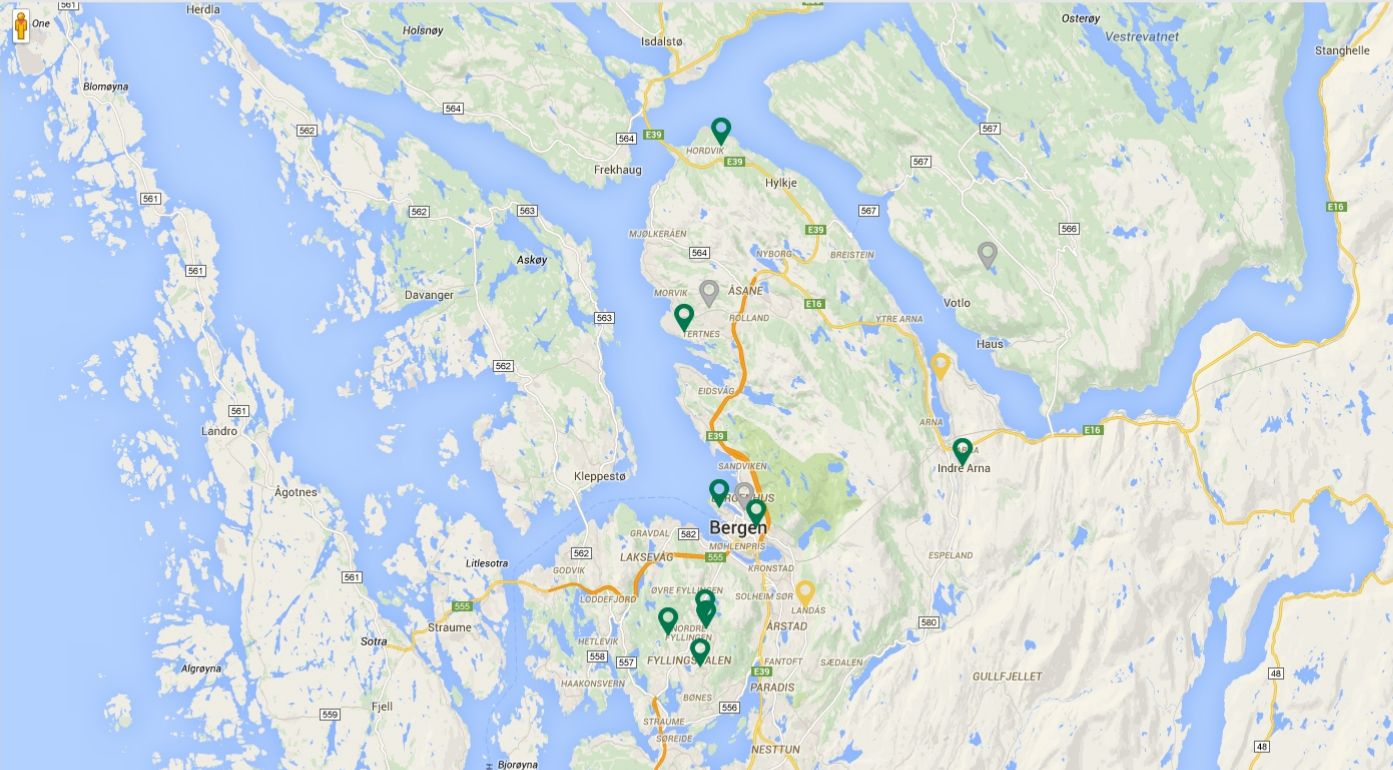
Map Comparative view Project page 2014/10/15 14:07:54

OPERATOR: All

COLOR CODE

- All networks available
- Some networks available
- No networks available
- Node unreachable

UP RATE, %: 94



Search by location or node id

LOCATION	NODE ID	STATUS
Ålesund	nne590	●
Ås	nne648	●
Askim	nne442	●
Bardu	nne272	●
Bergen	nne236	●
Bergen	nne245	●
Bergen	nne288	●
Bergen	nne290	●
Bergen	nne294	●
Bergen	nne299	●
Bergen	nne465	●
Bergen	nne495	●
Bergen	nne525	●
Bergen	nne526	●
Bergen	nne531	●
Bergen	nne593	●
Bergen	nne613	●
Bergen	nne620	●
Bergen	nne631	●
Bergen	nne669	●
Bjugn	nne210	●
Bodø	nne424	●
Bærum	nne521	●
	nne539	●
	nne638	●
	nne658	●

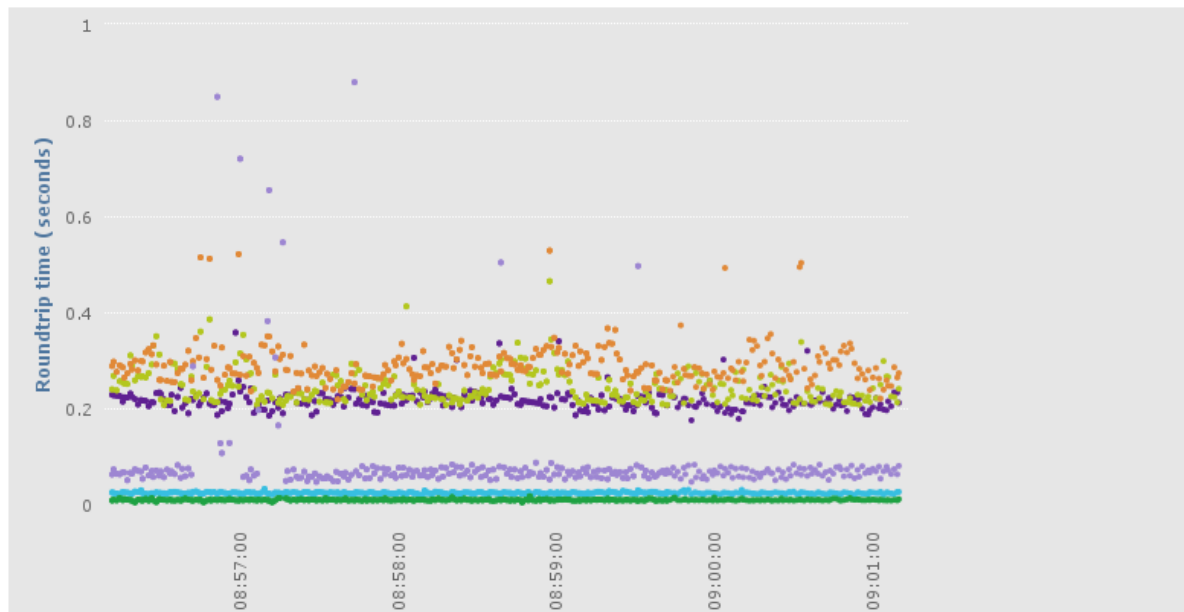
See <http://robustenett.no/map!>

© Simula Research Laboratory. javascript; Simula Nornet

# 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://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

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# Users and Research

***“The road to hell is paved with unused testbeds.”***

**[James P. G. Sterbenz]**

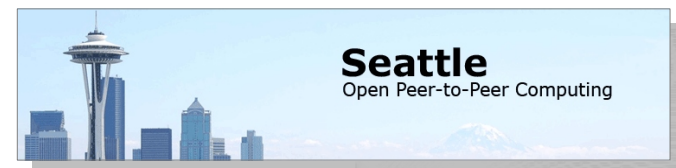
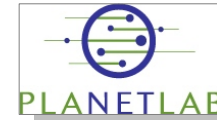
- We already got some users!
- Examples:
  - Multi-Path Transport (Simula, UDE, UiO, HU, etc.)
  - VoIP Misuse Detection (UDE)
  - Application Server Availability (NTNU)
  - Balia Congestion Control (Bell Labs in South Korea)
  - IPv4/IPv6 Performance Comparison (Simula)
  - ...

**List to be extended!**

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

# 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

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# Conclusion and Future Work

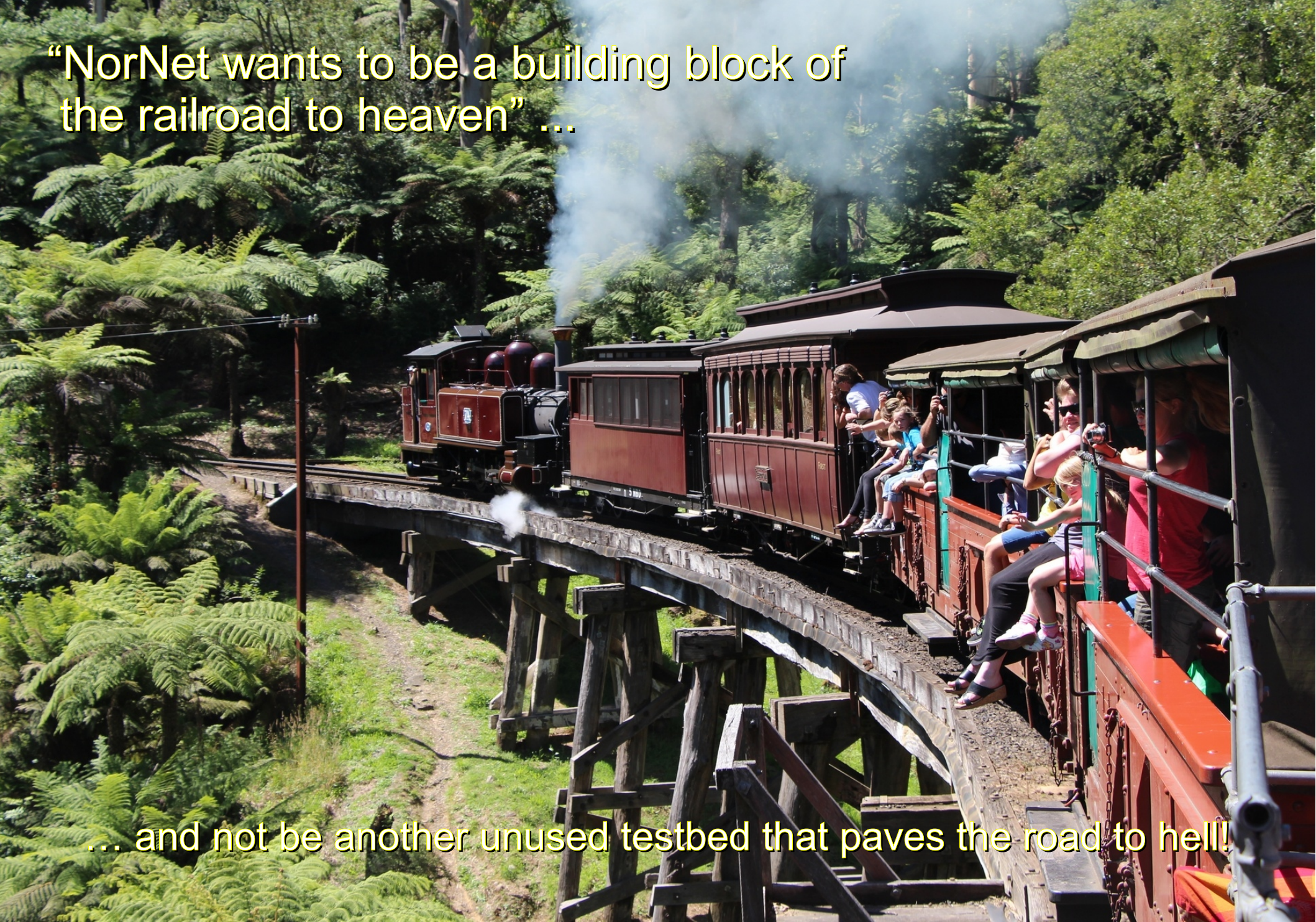
- NorNet is working
  - Nice testbed size (19+ sites for Core, hundreds for Edge)
  - We have a slowly growing number of users and sites
  - International visibility



- Future work:
  - **To further extend NorNet's scope *beyond* multi-path transport topic**
  - Software-Defined Networking (SDN)?
  - Network Function Virtualisation (NFV)?
  - Cloud Computing and applications?

**To be discussed!**

“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!**