

Invited Talk at Hainan University ( 海南大学 )

## NorNet at Hainan University

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### An Introduction to the NorNet Testbed

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# 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
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# Where is Norway?



Oslo 奥斯陆

ca. 8,700 km



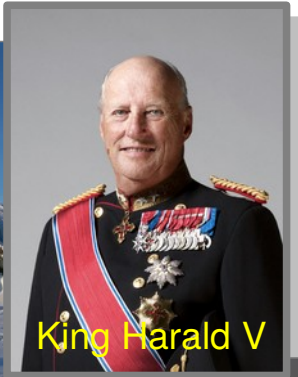
Haikou 海口

**Facts about Norway**

Capital:	Oslo
Size:	ca. 385,000 km <sup>2</sup>
Population:	ca. 5,165,800
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
  - **Resilient Networks and Applications**
- Norway's leading place for computer science research

[ **simula** . research laboratory ]



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

# Overview: Motivation

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# Motivation: Robust Networks

- More and more applications rely on ubiquitous Internet access!
- However, our current networks are not as robust as they should be ...



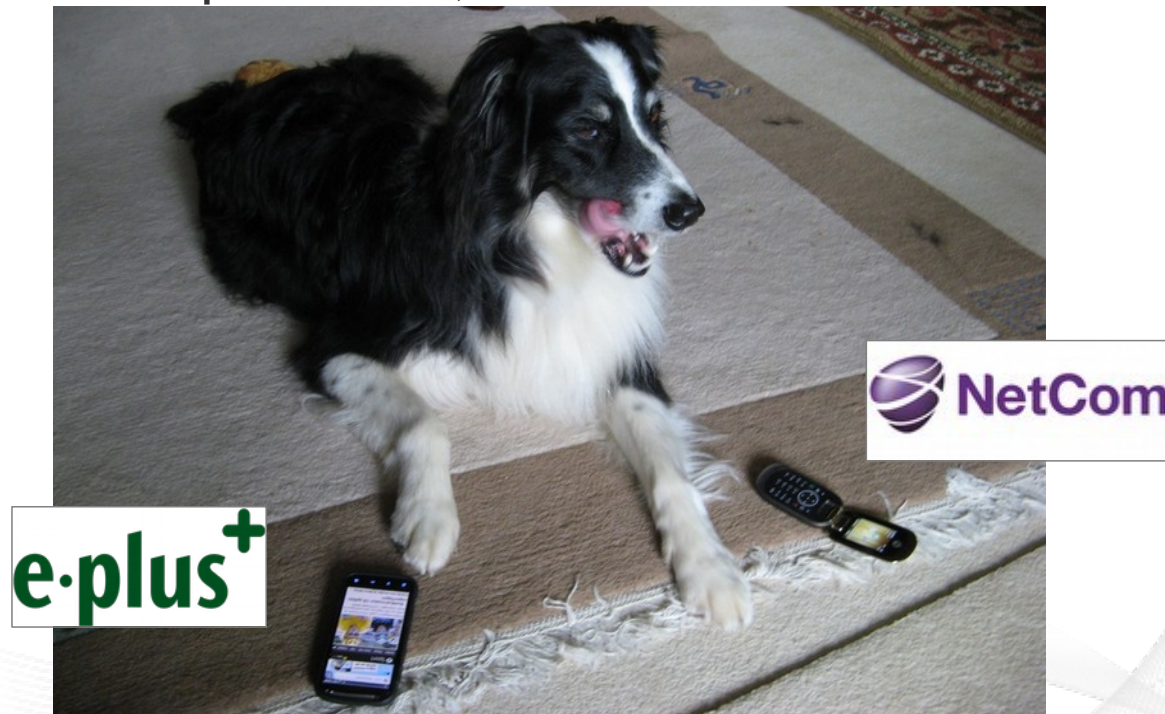
**How to make networks more robust?**



# 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
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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 + CN, DE (4x), SE, US, KR, AU
  - Edge: hundreds of nodes in Norway



# Overview: NorNet Core

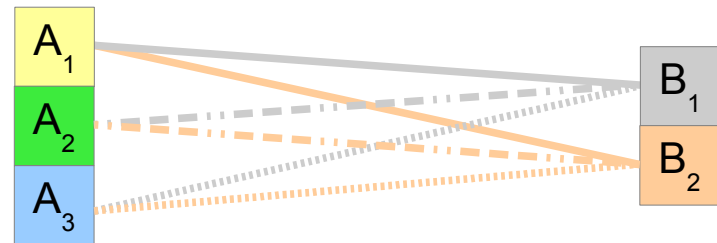
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# Idea for NorNet Core: Tunnelling

- 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:

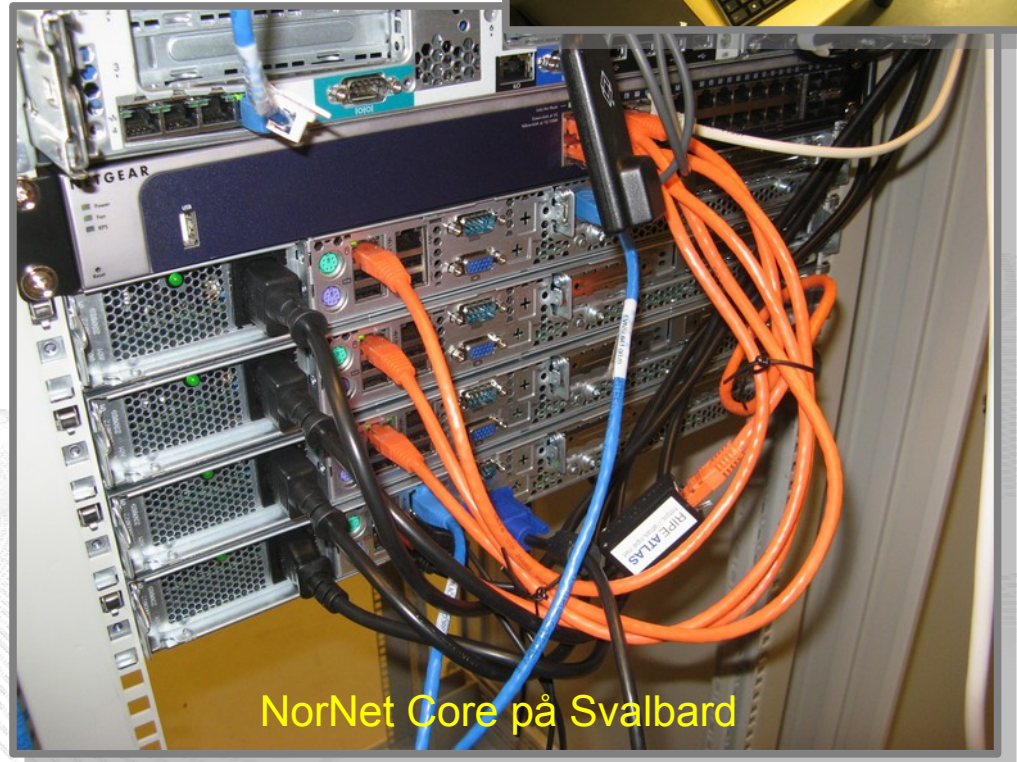
- 1x switch
- 4x server
  - 1x tunnelbox
  - 3x research systems
- At least two ISP connections
  - Research network provider
  - Other providers
- IPv4 and IPv6 (if available)

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 (May 2016)

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	HAW Hamburg	DFN			
20	Technische Universität Darmstadt	DFN			

 IPv4 and IPv6

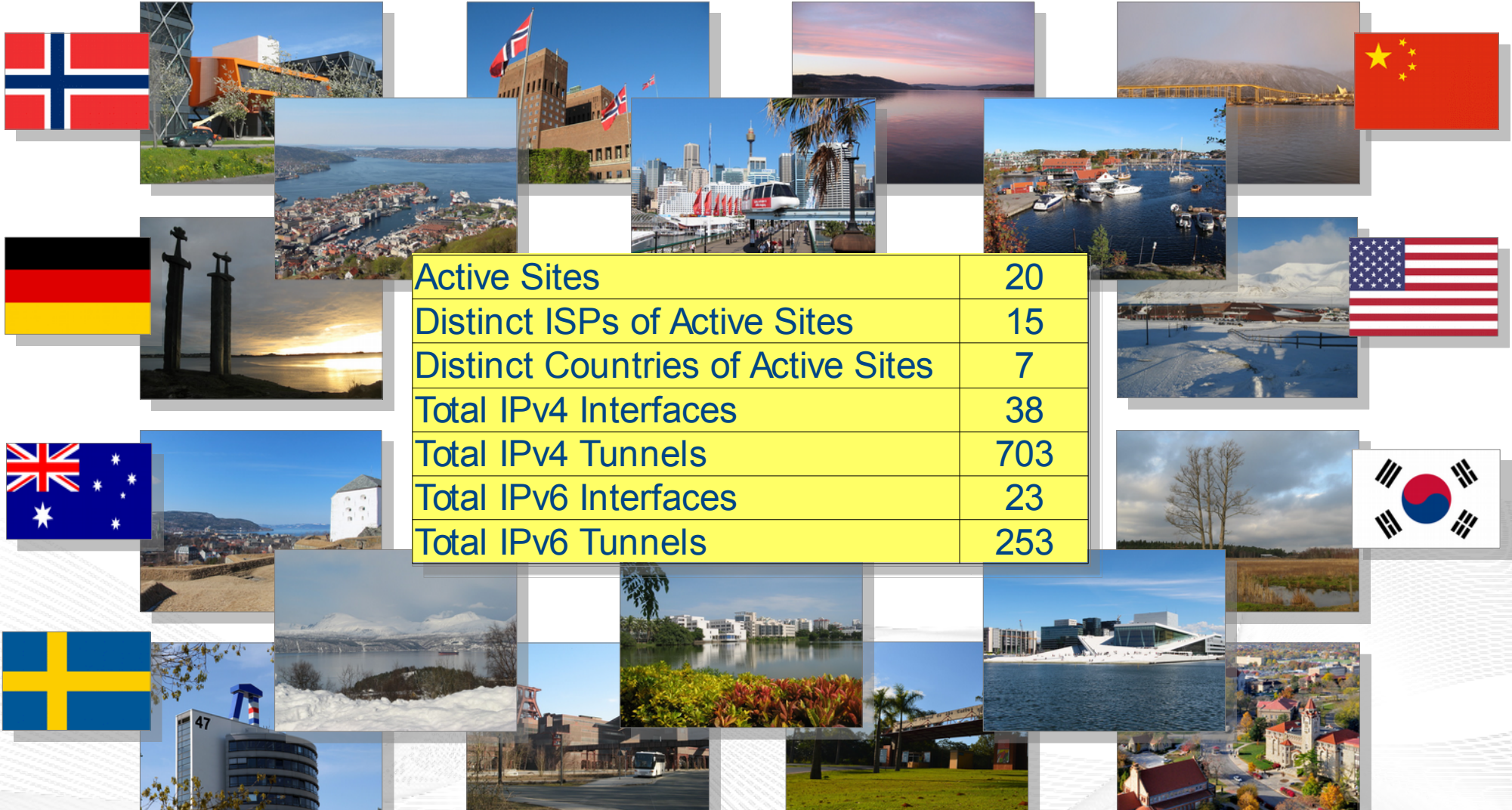
 ISP negotiation in progress

 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 (May 2016)



Active Sites	20
Distinct ISPs of Active Sites	15
Distinct Countries of Active Sites	7
Total IPv4 Interfaces	38
Total IPv4 Tunnels	703
Total IPv6 Interfaces	23
Total IPv6 Tunnels	253

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

# Remote Systems

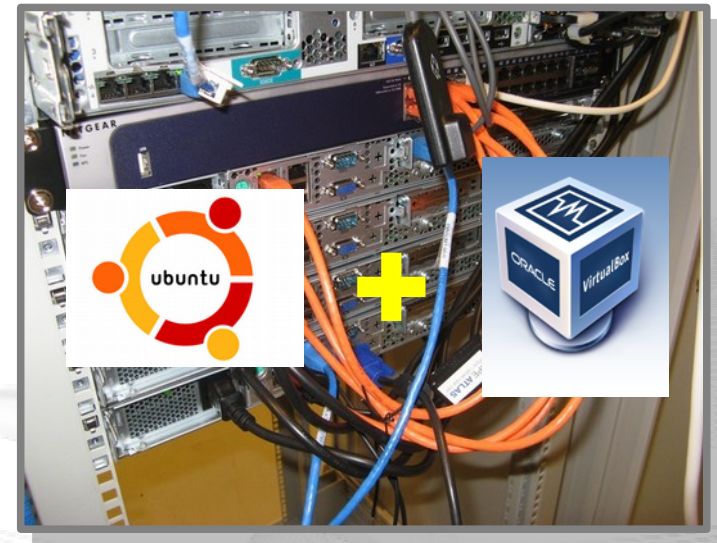
Our servers may be really remote!

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 14.04 LTS
  - KVM
  - 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



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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”)





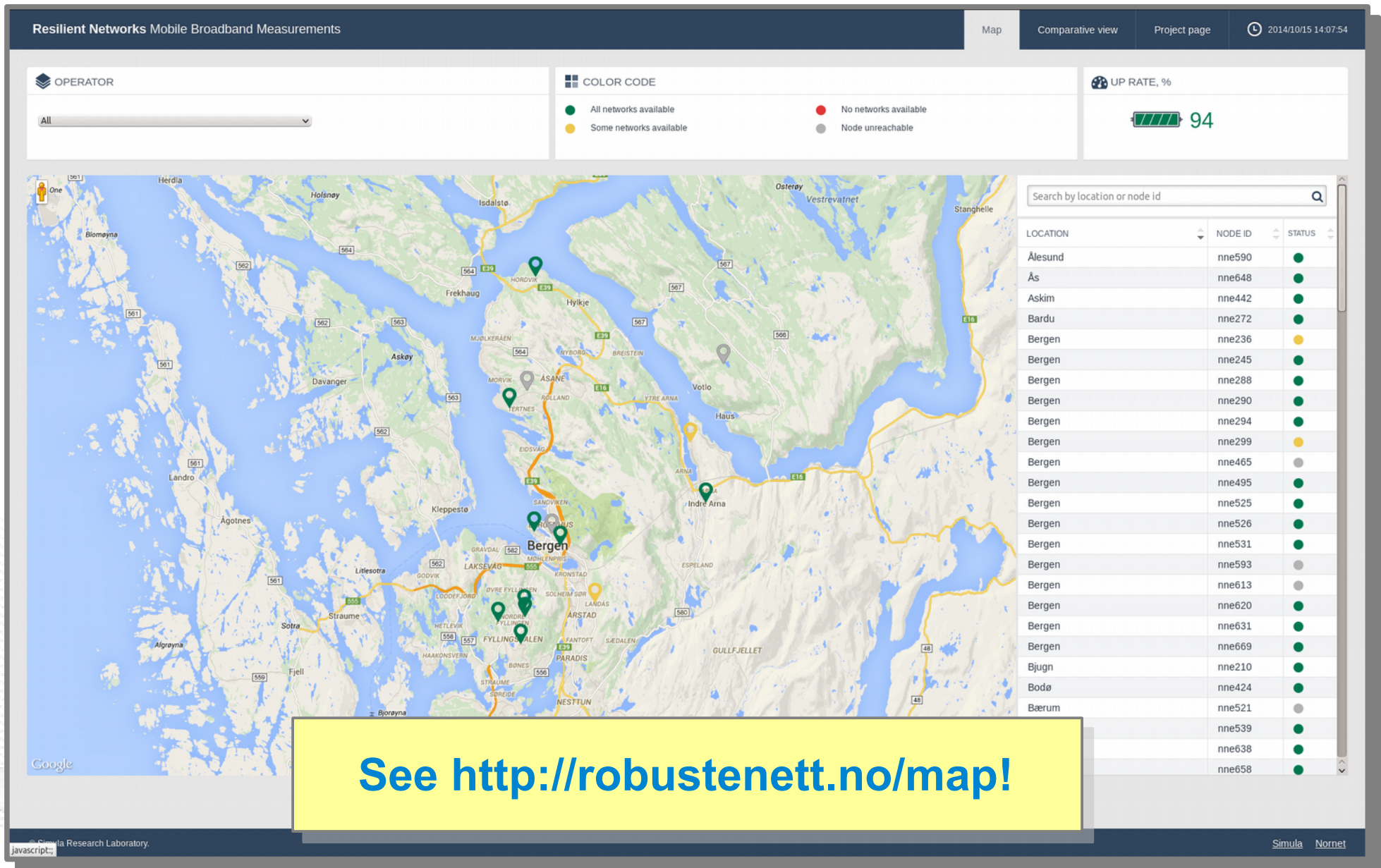
# The NorNet Edge Box: Ready for Deployment

## Box contents:

- Ufoboard
- Up to 4x USB UMTS or LTE:
  - Telenor, Telia,
  - Network Norway, Tele2
- 1x ICE CDMA mobile broadband
- 1x Ethernet
- 1x WLAN (optional)
- Power supplies
- Handbook



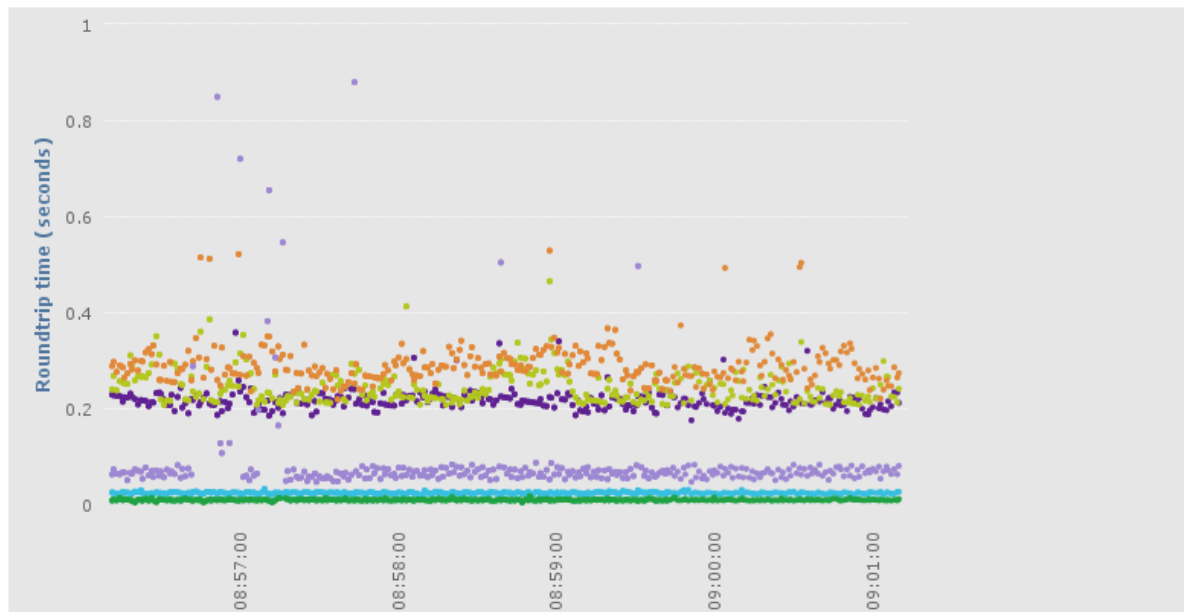
# Live Visualisation of NorNet Edge (1)



# 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.

<http://robustennet.no/map/>

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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!**

**You** may use NorNet Core, too!

**Join the tutorial session!  
Here at Hainan University today!**

- Contents:
  - Get access to NorNet Core
  - User and slice management
  - Access to slices
  - Using and configuring slivers with own software
  - How to make use of multi-homing?

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# 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!**