

# Tutorial at Hainan University ( 海南大学 )

NorNet at Hainan University in 2021:  
Getting Started with NorNet Core

A Remote Tutorial

Thomas Dreibholz ( 托马斯博士 )

Simula Research Laboratory

15 January 2021



# Contents

- Preparations
- Getting an Overview of the Testbed
- Using a Slice
- A Practical Example
- Conclusion
- Literature

# Overview: Preparations

- Preparations
- Getting an Overview of the Testbed
- Using a Slice
- A Practical Example
- Conclusion
- Literature

# Tutorial Accounts

- You should have received an account
  - Username
  - Password
- Valid for:
  - SSH login server
  - PLC server

**Do you have an account? If not, ask!**

# Initial Tasks

- **Account for our SSH login server** gatekeeper.nntb.no:
  - Server is gateway into NorNet Core network
  - `ssh <username>@gatekeeper.nntb.no`
  - Use port forwarding to access PLC and Monitor servers:
    - `ssh <username>@gatekeeper.nntb.no \`  
    `-L 2000:plc.simula.nornet:443 \`  
    `-L 2001:monitor.simula.nornet:80`
    - Forwards TCP port 2000 to PLC server's HTTPS port
    - Forwards TCP port 2001 to Monitor server's HTTP port
- **Account for the PLC server** plc.simula.nornet (inside NorNet Core only):
  - Login: *<your e-mail address>*
- **VPN into NorNet Core may be possible in the future**

**Try to directly connect to your NorNet Core switch**

# Access to PLC and Monitor

- Via port forwarding:
  - Monitor: <http://localhost:2001/>
  - PLC: <https://localhost:2000/>
- Inside NorNet Core network:
  - Monitor: <http://monitor.simula.nor-net>
  - PLC: <https://plc.simula.nor-net>

**Is everybody able to log in?**

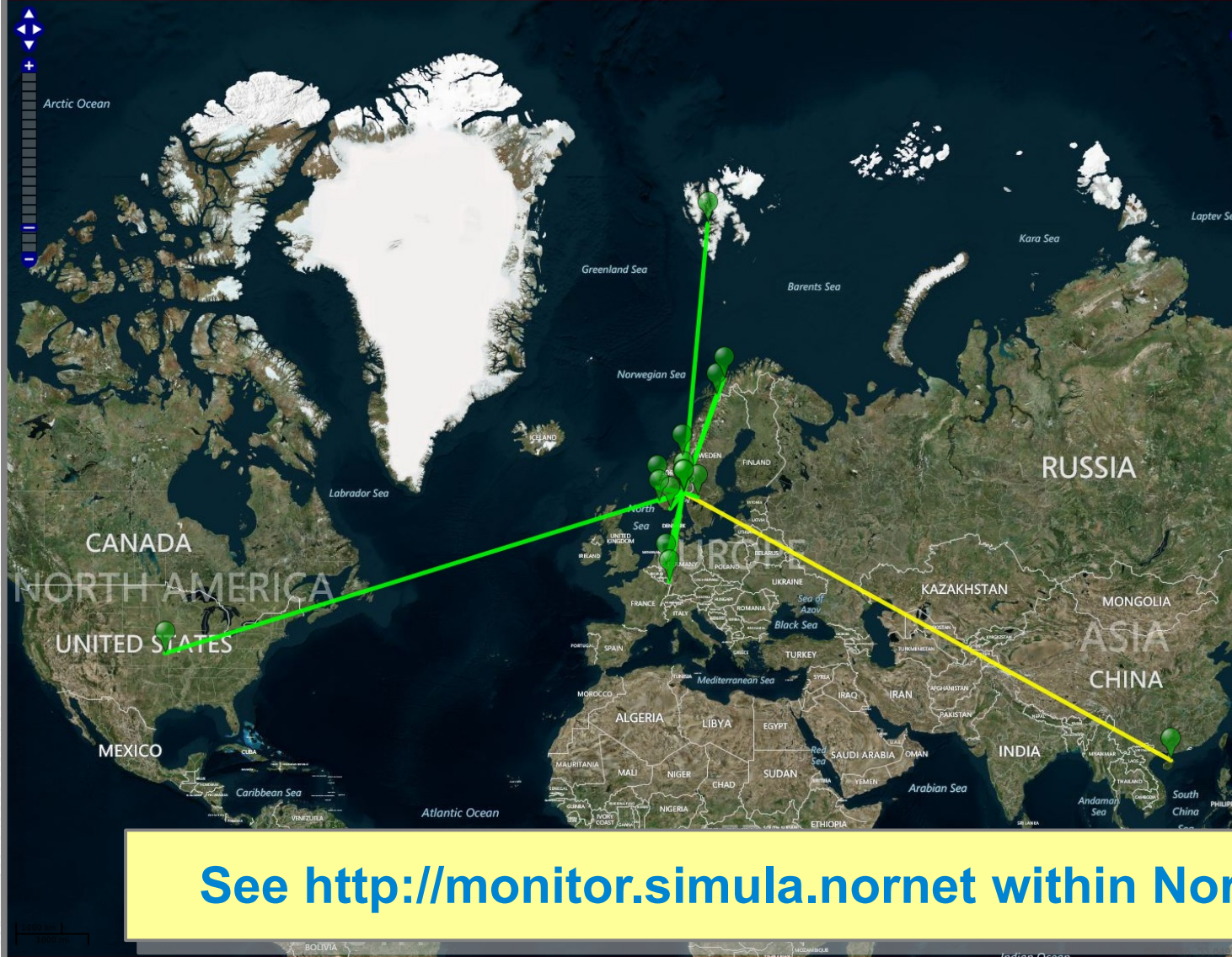
# Overview:

## Getting an Overview of the Testbed

- Preparations
- Getting an Overview of the Testbed
- Using a Slice
- A Practical Example
- Conclusion
- Literature

# “Kontrollsenteret”

Velkommen til NorNet-Kontrollsenter på Simula Research Laboratory, Fornebu



15:10:22

Mandag, 28. juli 2014

Lofasjon

Problemer:

😊 Ingen problem! 😊

J orden:

- @Hainan University
- @Høgskolen i Gjøvik
- @Høgskolen i Narvik
- @Høgskolen i Oslo og Akershus
- @Karlstads Universitet
- @Simula Research Laboratory
- @Universitetet i Agder
- @Universitetet i Bergen
- @Universitetet i Oslo
- @Universitetet i Stavanger
- @Universitetet i Tromsø
- @Universitetet i Trondheim

See <http://monitor.simula.nor-net> within NorNet Core!

For mer informasjon om NorNet-prosjektet, se <https://www.nnfd.no>!

# PLC User Interface: Sites View

Sites - all peers | NorNet Testbed - Mozilla Firefox

https://plc.simula.norhet/db/sites/index.php

**NorNet Testbed** edit primary links

thomas.dreibholz@googlemail.co... Home

Sites - all peers

All sites Local sites My site Joining Sites

Search [ ] and [ ]

|    | PEER   | FULL NAME                   | LOGIN | ABBREV.        | N  | U  | S | ?                     |
|----|--------|-----------------------------|-------|----------------|----|----|---|-----------------------|
| 71 | NorNet | Hoegskolen i Gjoevik        | hig   | HiG            | 6  | 2  | 0 |                       |
| 78 | NorNet | Hoegskolen i Narvik         | hin   | HiN            | 6  | 2  | 0 |                       |
| 1  | NorNet | NorNet Testbed Central      | nn    | NorNet Testbed | 0  | 3  | 5 | No node<br>Not public |
| 77 | NorNet | Universitetet i Trondheim   | ntnu  | NTNU           | 6  | 2  | 1 |                       |
| 69 | NorNet | Simula Research Laboratory  | srl   | SRL            | 12 | 52 | 3 |                       |
| 79 | NorNet | Universitaet Duisburg-Essen | ude   | UDE            | 4  | 2  | 1 |                       |
| 75 | NorNet | Universitetet i Agder       | uia   | UIA            | 6  | 2  | 0 |                       |
| 74 | NorNet | Universitetet i Bergen      | uib   | UIB            | 6  | 2  | 0 |                       |
| 70 | NorNet | Universitetet i Oslo        | uio   | UIO            | 6  | 2  | 0 |                       |
| 73 | NorNet | Universitetet i Stavanger   | uis   | UIS            | 6  | 2  | 0 |                       |
| 72 | NorNet | Universitetet i Tromsøe     | uit   | UIT            | 6  | 2  | 0 |                       |
| 76 | NorNet | Universitetet paa Svalbard  | unis  | UNIS           | 6  | 2  | 0 |                       |

**Notes**  
N = number of nodes  
U = number of users  
S = number of slices  
? = status  
Hold down the shift key to select multiple columns to sort  
Enter & or | in the search area to switch between AND and OR search modes

See <https://plc.simula.norhet> within NorNet Core!

# PLC User Interface: Nodes View

Nodes - all peers | NorNet Testbed - Mozilla Firefox

Nodes - all peers | NorNet Testbed

https://plc.simula.nor-net/db/nodes/index.php

**NorNet Testbed** edit primary links

thomas.dreibholz@googlemail.co...

- Logout of NorNet Testbed
- My Account
  - My Site Accounts
  - Local Accounts (slow)
  - All Accounts (slow)
- Sites
  - My Site
  - Pending Requests
- Nodes
  - My Site Nodes
  - Register Node
- Slices
  - My Site Slices
  - Create Slice
  - Sirius
- Admin search
  - Add Node
  - Tags
  - Node groups
  - Peers
  - Events
- About MyPLC
  - PLCAPI doc
  - NMAPI doc

**drupal**

- create content
- my account
- administer
- log out

**Home**

**Nodes - all peers**

All nodes My site nodes Local nodes

Node table layout ?  
can't open file

Add/remove columns Column description and configuration

| A  | Architecture name    |                                     |
|----|----------------------|-------------------------------------|
| DA | Date added           |                                     |
| DL | Deployment           |                                     |
| DN | Toplevel domain name |                                     |
| IP | IP address           | <input checked="" type="checkbox"/> |
| OS | Operating system     |                                     |
| SN | Site name            | <input checked="" type="checkbox"/> |

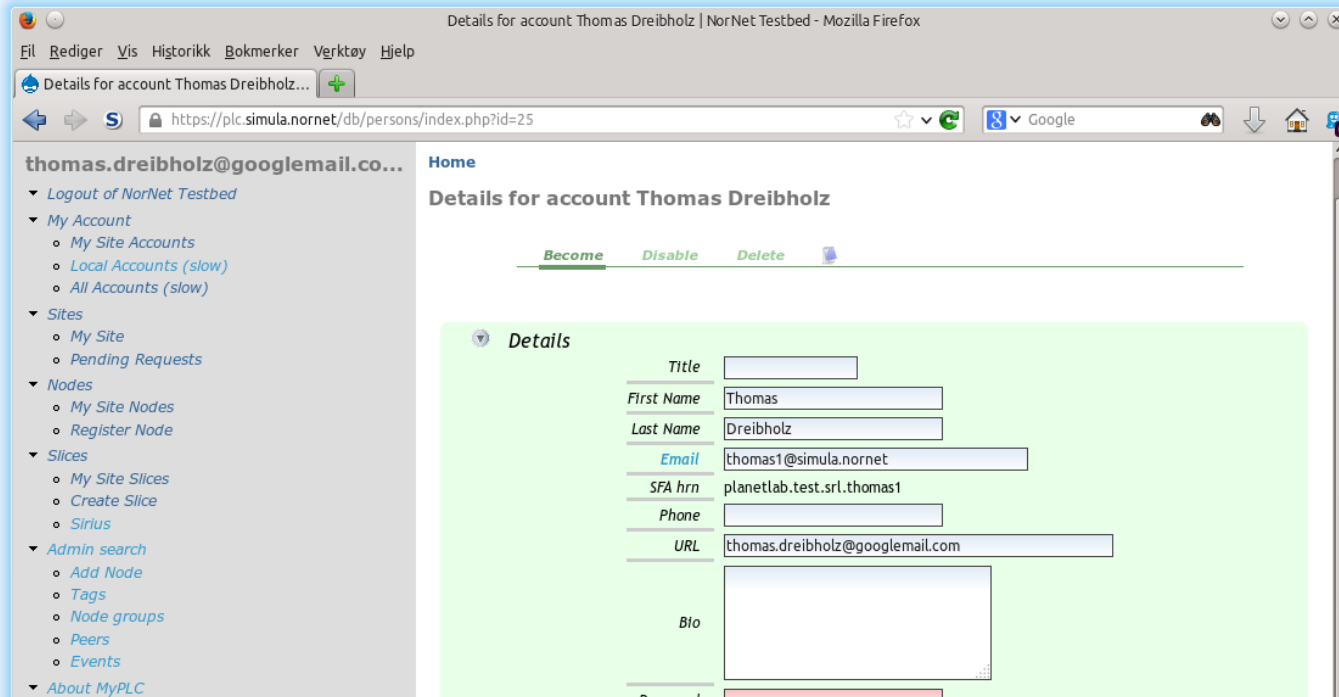
**Authority**

Node state: should be "boot"

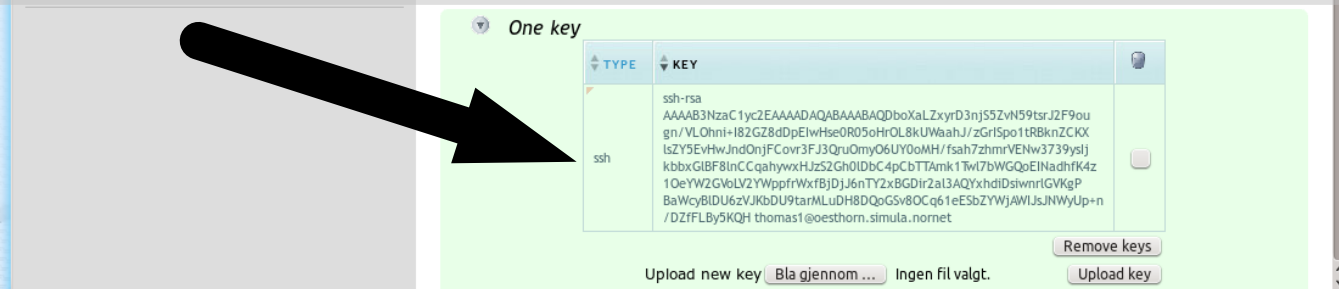
Search

| ID  | HOSTNAME                   | AU     | ST   | RES | IP           | SN   | ? |
|-----|----------------------------|--------|------|-----|--------------|------|---|
| 456 | adventfjorden.unis.nor-net | NorNet | boot |     | 10.30.42.104 | unis |   |
| 404 | akerbrygge.simula.nor-net  | NorNet | boot |     | 10.1.1.100   | srl  |   |
| 414 | akerselva.simula.nor-net   | NorNet | boot |     | 10.1.1.110   | srl  |   |
| 470 | altenessen.ude.nor-net     | NorNet | boot |     | 10.30.42.100 | ude  |   |
| 428 | amundsen.uit.nor-net       | NorNet | boot |     | 10.1.4.100   | uit  |   |
| 432 | arctandria.uit.nor-net     | NorNet | boot |     | 10.1.4.104   | uit  |   |
| 436 | askje.uis.nor-net          | NorNet | boot |     | 10.1.5.102   | uis  |   |
| 430 | aunegaarden.uit.nor-net    | NorNet | boot |     | 10.1.4.102   | uit  |   |
| 459 | bakklandet.ntnu.nor-net    | NorNet | boot |     | 10.1.9.101   | ntnu |   |
| 471 | baldeneysee.ude.nor-net    | NorNet | boot |     | 10.30.42.101 | ude  |   |

# PLC User Interface: Account View



- Upload your SSH public key here!
- Public keys get distributed to all nodes (may take up to 1 hour!)



# Overview: Using a Slice

- Preparations
- Getting an Overview of the Testbed
- Using a Slice
- A Practical Example
- Conclusion
- Literature

# The Test Slice *srl\_test*

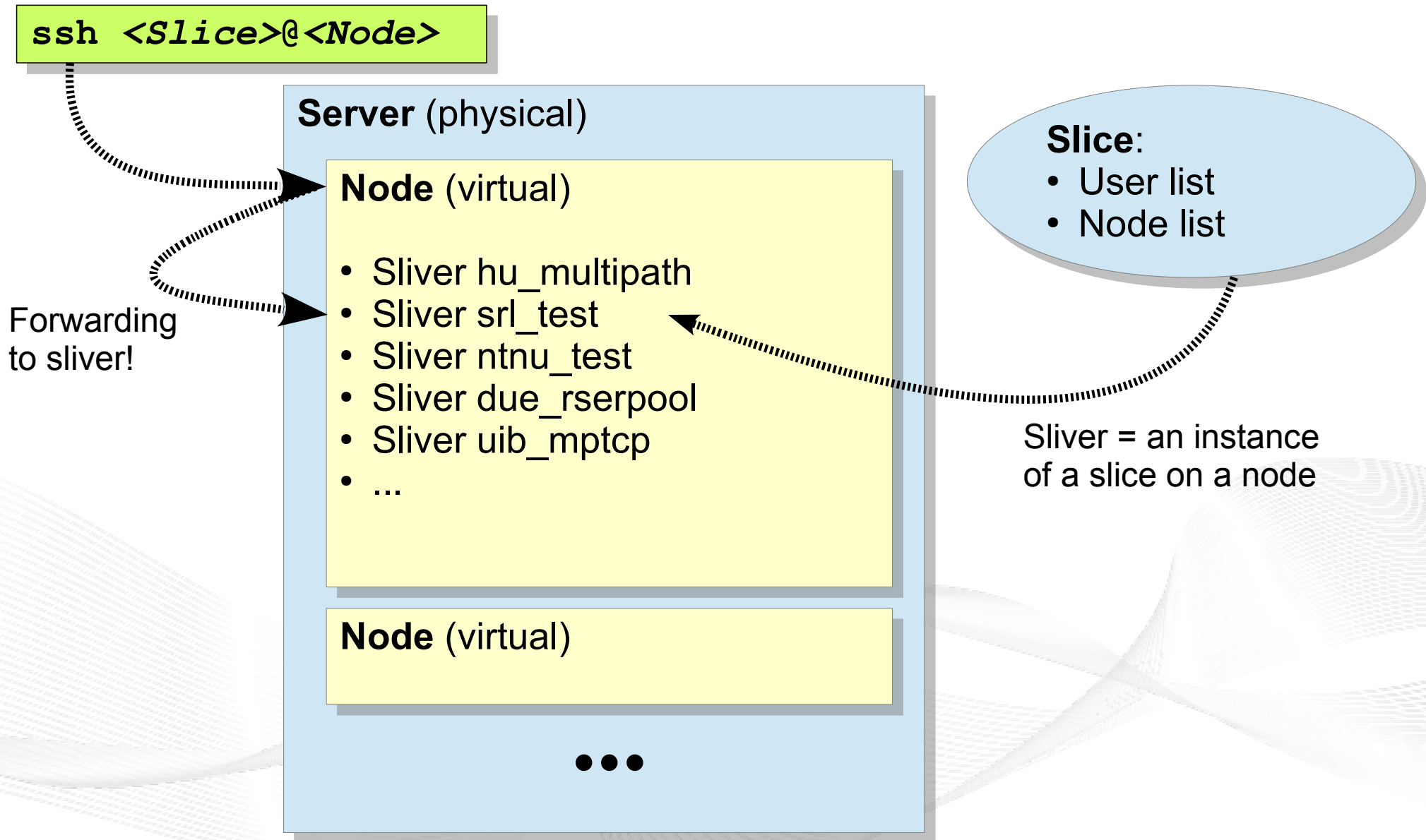
- A test slice has already been created:
  - Name: *srl\_test*
  - Special NorNet Core properties:
    - Own IP addresses on each node
    - IPv4 and IPv6
    - Multiple ISPs (at sites with several ISPs)
- The slice is instantiated on all nodes by a sliver (LXC container)
- Your account is mapped as user to *srl\_test*

# Logging In

- From the login server:
  - `ssh -i <your private key> <slice name>@<node name>`
- Examples (private key is in `~/.ssh/id_rsa`, slice is `srl_test`):
  - `ssh -i ~/.ssh/id_rsa srl_test@boao.hu.nornet`
  - `ssh -i ~/.ssh/id_rsa srl_test@altenessen.ude.nornet`
  - `ssh -i ~/.ssh/id_rsa srl_test@nordlys.unis.nornet`
  - `ssh -i ~/.ssh/id_rsa srl_test@julenisse.uia.nornet`
  - `ssh -i ~/.ssh/id_rsa srl_test@vaenern.kau.nornet`
  - `ssh -i ~/.ssh/id_rsa srl_test@vaekeroe.simula.nornet`
- Note: login is via node's SSH server to sliver on the node!

**Use PLC to find other nodes. There are more than 100 nodes!**

# Note the Different Entities: Server, Node, Sliver



# Inside a Sliver

- Each sliver contains a Fedora Core 25 environment
- **Obtain root access:**
  - `su`
  - `sudo bash`
- **Install custom software:**
  - `dnf install <package> ...`
  - Example: `dnf install netperfmeter`
- **Show IP addresses and routes:**
  - `ip -4 addr show ; ip -4 route show`
  - `ip -6 addr show ; ip -6 route show`

**Remember: slivers have their own addresses!**

# Nodes, Slivers and Addresses

- Node:
  - The node itself, e.g. amundsen.uit.nor-net
  - Used for SSH login
- How to find sliver addresses of a node?
  - Look inside the sliver itself (login to sliver → ip addr show)
  - Ask the DNS server:
    - Use “dig” (part of bind-utils package for Fedora Core)
    - `dig <slice name>.<node name>.<site name>.nor-net`
    - But replace “\_” by “-” in slice name!
  - Examples for srl\_test slice:
    - `dig srl-test.boao.hu.nor-net any`  
to obtain primary provider (it is in the CNAME, here: “cernet”)
    - `dig srl-test.boao.all.hu.nor-net any`  
to obtain all providers' addresses
    - `dig srl-test.solvang.all.simula.nor-net`  
without “any” → gets only A RRs (i.e. IPv4 addresses)

# A dig Example

```
ola1@nordberg:~$ dig srl-test.solvang.all.simula.nor-net any
; <<>> DiG 9.9.2-P1 <<>> srl-test.solvang.all.simula.nor-net any
...
;; ANSWER SECTION:
srl-test.solvang.all.simula.nor-net. 86400 IN A 10.2.1.130
srl-test.solvang.all.simula.nor-net. 86400 IN A 10.1.1.130
srl-test.solvang.all.simula.nor-net. 86400 IN AAAA 2001:700:4100:101::82:69
srl-test.solvang.all.simula.nor-net. 86400 IN AAAA 2001:700:4100:201::82:69
srl-test.solvang.all.simula.nor-net. 86400 IN HINFO "Amiga 5000" "Slice srl_test"
srl-test.solvang.all.simula.nor-net. 86400 IN LOC 59 53 45.240 N 10 37 39.360 E 15.00m
;; AUTHORITY SECTION:
simula.nor-net. 86400 IN NS ns.ntnu.nor-net.
...
```

**IPv4**

**IPv6**

**Geographic location**

**Software**

# Overview: A Practical Example

- Preparations
- Getting an Overview of the Testbed
- Using a Slice
- A Practical Example
- Conclusion
- Literature

# A Multi-Path Routing Test

- Select two nodes at different sites
  - List: <https://www.nntb.no/pub/nor-net-configuration/NorNetCore-Sites.html>
  - Login to *srl\_test* sliver: `ssh srl_test@<node name>`
  - Check IP addresses: `ip -4 addr show dev eth0`
  - Example:
    - `srl-test.kettwig.ude.nor-net:` 10.30.42.122 10.31.42.122
      - ISPs: 30=DFN, 31=Versatel (an ADSL connection)
    - `srl-test.frogner.simula.nor-net:` 10.1.1.131 10.2.1.131 10.4.1.131 10.9.1.131
      - ISPs: 1=UNINETT, 2=Kvantel, 4=Telenor, 9=PowerTech
- Try ping/traceroute:
  - `ping [-f] [-s <size>] [-c <count>] <dest IP> -I <src IP>`
  - `traceroute <dest IP> -s <src IP>`
  - Look at the second and third hop (and their reverse DNS lookups)!
  - What do you see?

# Some Flood Ping Results

```
srl_test@kettwig.ude.nornet # ping -c 1000 -s 1400 -f 10.1.1.129 -I 10.30.42.122
PING 10.1.1.129 (10.1.1.129) from 10.30.42.122 : 1400(1428) bytes of data.
1000 packets transmitted, 1000 received, 0% packet loss, time 14591ms
rtt min/avg/max/mdev = 70.115/108.064/177.958/26.870 ms
```

DFN → UNINETT

```
srl_test@kettwig.ude.nornet # ping -c 1000 -s 1400 -f 10.2.1.129 -I 10.30.42.122
PING 10.2.1.129 (10.2.1.129) from 10.30.42.122 : 1400(1428) bytes of data.
1000 packets transmitted, 1000 received, 0% packet loss, time 14783ms
rtt min/avg/max/mdev = 31.009/76.446/136.024/27.666 ms
```

DFN → Kvantel

```
srl_test@kettwig.ude.nornet # ping -c 1000 -s 1400 -f 10.1.1.129 -I 10.31.42.122
PING 10.1.1.129 (10.1.1.129) from 10.31.42.122 : 1400(1428) bytes of data.
1000 packets transmitted, 999 received, 0% packet loss, time 14412ms
rtt min/avg/max/mdev = 121.153/175.432/252.685/28.585 ms
```

Versatel → UNINETT

```
srl_test@kettwig.ude.nornet # ping -c 1000 -s 1400 -f 10.2.1.129 -I 10.31.42.122
PING 10.2.1.129 (10.2.1.129) from 10.31.42.122 : 1400(1428) bytes of data.
1000 packets transmitted, 999 received, 0% packet loss, time 14182ms
rtt min/avg/max/mdev = 78.643/124.496/207.773/26.729 ms
```

Versatel → Kvantel

RTT differences among provider combinations; higher ADSL delay (Versatel)

# Some Traceroute Results

```
srl_test@kettwig.ude.nor-net # traceroute 10.1.1.129 -s 10.30.42.122
```

```
traceroute to 10.1.1.129 (10.1.1.129), 30 hops max, 60 byte packets
```

- 1 essen.dfn.ude.nor-net (10.30.42.1) 2.104 ms 2.849 ms 2.831 ms
- 2 dfn.ude.uninett.simula.nor-net (192.168.178.10) 95.059 ms 95.024 ms 94.961 ms
- 3 srl-test.frogner.uninett.simula.nor-net (10.1.1.129) 105.432 ms 105.281 ms 105.220 ms

DFN → UNINETT

```
srl_test@kettwig.ude.nor-net # traceroute 10.2.1.129 -s 10.30.42.122
```

```
traceroute to 10.2.1.129 (10.2.1.129), 30 hops max, 60 byte packets
```

- 1 essen.dfn.ude.nor-net (10.30.42.1) 1.190 ms 1.739 ms 1.031 ms
- 2 dfn.ude.uninett.simula.nor-net (192.168.178.10) 56.972 ms 56.722 ms 56.853 ms
- 3 srl-test.frogner.kvantel.simula.nor-net (10.2.1.129) 100.773 ms 99.513 ms 99.337 ms

DFN → Kvantel

```
srl_test@kettwig.ude.nor-net # traceroute 10.1.1.129 -s 10.31.42.122
```

```
traceroute to 10.1.1.129 (10.1.1.129), 30 hops max, 60 byte packets
```

- 1 essen.versatel.ude.nor-net (10.31.42.1) 1.830 ms 2.633 ms 2.609 ms
- 2 versatel.ude.uninett.simula.nor-net (192.168.133.222) 127.768 ms 127.954 ms 127.507 ms
- 3 srl-test.frogner.uninett.simula.nor-net (10.1.1.129) 182.544 ms 182.564 ms 182.269 ms

Versatel → UNINETT

```
srl_test@kettwig.ude.nor-net # traceroute 10.2.1.129 -s 10.31.42.122
```

```
traceroute to 10.2.1.129 (10.2.1.129), 30 hops max, 60 byte packets
```

- 1 essen.versatel.ude.nor-net (10.31.42.1) 1.178 ms 1.805 ms 1.769 ms
- 2 versatel.ude.uninett.simula.nor-net (192.168.133.222) 88.834 ms 91.932 ms 96.620 ms
- 3 srl-test.frogner.kvantel.simula.nor-net (10.2.1.129) 79.603 ms 75.599 ms 69.910 ms

Versatel → Kvantel

**Hop 2: Router's ICMP TTL Exceeded is sent back via Simula's primary ISP!**

# What else to do?

- Try the same with IPv6!
  - `ping6 [-f] [-s <size>] [-c <count>] <dest IP> -I <src IP>`
  - `traceroute6 <dest IP> -s <src IP>`
- Try NetPerfMeter!
  - Supports TCP including **MPTCP**, SCTP, UDP, DCCP
  - Server side: `netperfmeter <port>`
  - Client side: `netperfmeter <server>:<port> <flow details> ...`  
(see manpage for details!)
- Install custom software
  - But note: do not assume the slivers to be permanent storages
  - Write scripts to automatise installation
  - In case of problems, nodes may just be wiped and reinstalled

**And, of course, try your own experiments in NorNet!**

# Overview: Conclusion

- Preparations
- Getting an Overview of the Testbed
- Using a Slice
- A Practical Example
- Conclusion
- Literature

# Conclusion and Future Work

- **NorNet Core is ready for your ideas!**
  - Think about your experiments
  - Let them run in NorNet Core
- How to get permanent access?
  - **Talk to us!**
  - Provide some information on your project  
Let us **discuss the details** about running your experiment in NorNet Core!

**In case of questions, ask us!**

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

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

# Overview: Literature

- Preparations
- Getting an Overview of the Testbed
- Using a Slice
- A Practical Example
- Conclusion
- Literature

# Literature

- Dreibholz, T.; Ferlin, S.; Alay, Ö.; Elmokashfi, A. M.; Livadariu, I. A.; Zhou, X.: “[MPTCP Experiences in the NorNet Testbed](#)” (TXT, 26 KiB), IETF, Individual Submission, Internet Draft draft-dreibholz-mptcp-nornet-experience-05, December 3, 2019.
- Luo, Y.; Zhou, X.; Dreibholz, T.; Kuang, H.: “[A Real-Time Video Streaming System over IPv6+MPTCP Technology](#)” (PDF, 212 KiB), Proceedings of the 1st International Workshop on Recent Advances for Multi-Clouds and Mobile Edge Computing (M2EC) in conjunction with the 33rd International Conference on Advanced Information Networking and Applications (AINA), pp. 1007–1019, DOI [10.1007/978-3-030-15035-8\\_99](#), ISBN 978-3-030-15034-1, Matsue, Shimane/Japan, March 27, 2019.
- Hong, J.; Dreibholz, T.; Schenkel, J. A.; Hu, J. A.: “[An Overview of Multi-Cloud Computing](#)” (PDF, 109 KiB), Proceedings of the 1st International Workshop on Recent Advances for Multi-Clouds and Mobile Edge Computing (M2EC) in conjunction with the 33rd International Conference on Advanced Information Networking and Applications (AINA), pp. 1055–1068, DOI [10.1007/978-3-030-15035-8\\_103](#), ISBN 978-3-030-15034-1, Matsue, Shimane/Japan, March 27, 2019.
- Dreibholz, T.; Mazumdar, S.; Zahid, F.; Taherkordi, A.; Gran, E. G.: “[Mobile Edge as Part of the Multi-Cloud Ecosystem: A Performance Study](#)” (PDF, 9966 KiB), Proceedings of the 27th Euromicro International Conference on Parallel, Distributed and Network-Based Processing (PDP), pp. 59–66, DOI [10.1109/EMPDP.2019.8671599](#), ISBN 978-1-7281-1644-0, Pavia, Lombardia/Italy, February 13, 2019.
- Tan, Q.; Yang, X.; Zhao, L.; Zhou, X.; Dreibholz, T.: “[A Statistic Procedure to Find Formulae for Buffer Size in MPTCP](#)” (PDF, 1747 KiB), Proceedings of the 3rd IEEE Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), pp. 900–907, DOI [10.1109/IAEAC.2018.8577570](#), ISBN 978-1-5386-4509-3, Chongqing/People's Republic of China, October 13, 2018.
- Wang, K.; Dreibholz, T.; Zhou, X.; Fu, F.; Tan, Y.; Cheng, X.; Tan, Q.: “[On the Path Management of Multi-Path TCP in Internet Scenarios based on the NorNet Testbed](#)” (PDF, 379 KiB), Proceedings of the IEEE International Conference on Advanced Information Networking and Applications (AINA), pp. 1–8, DOI [10.1109/AINA.2017.29](#), ISBN 978-1-5090-6028-3, Taipei, Taiwan/People's Republic of China, March 27, 2017.
- Zhou, F.; Dreibholz, T.; Zhou, X.; Fu, F.; Tan, Y.; Gan, Q.: “[The Performance Impact of Buffer Sizes for Multi-Path TCP in Internet Setups](#)” (PDF, 1006 KiB), Proceedings of the IEEE International Conference on Advanced Information Networking and Applications (AINA), pp. 9–16, DOI [10.1109/AINA.2017.26](#), ISBN 978-1-5090-6028-3, Taipei, Taiwan/People's Republic of China, March 27, 2017.
- Dreibholz, T.: “[NorNet – Building an Inter-Continental Internet Testbed based on Open Source Software](#)” (PDF, 9587 KiB), Proceedings of the LinuxCon Europe, Berlin/Germany, October 5, 2016.
- Dreibholz, T.: “[NorNet – The Internet Testbed for Multi-Homed Systems](#)” (PDF, 11198 KiB), Proceedings of the Multi-Service Networks Conference (MSN, Coseners), Abingdon, Oxfordshire/United Kingdom, July 8, 2016.
- Fu, F.; Zhou, X.; Dreibholz, T.; Wang, K.; Zhou, F.; Gan, Q.: “[Performance Comparison of Congestion Control Strategies for Multi-Path TCP in the NorNet Testbed](#)” (PDF, 172 KiB), Proceedings of the 4th IEEE/CIC International Conference on Communications in China (ICCC), pp. 607–612, DOI [10.1109/ICCCChina.2015.7448667](#), ISBN 978-1-5090-0243-6, Shenzhen, Guangdong/People's Republic of China, November 3, 2015.
- Dreibholz, T.; Zhou, X.; Fu, F.: “[Multi-Path TCP in Real-World Setups – An Evaluation in the NorNet Core Testbed](#)” (PDF, 211 KiB), 5th International Workshop on Protocols and Applications with Multi-Homing Support (PAMS), pp. 617–622, DOI [10.1109/WAINA.2015.74](#), ISBN 978-1-4799-1775-4, Gwangju/South Korea, March 25, 2015.
- Gran, E. G.; Dreibholz, T.; Kvalbein, A.: “[NorNet Core – A Multi-Homed Research Testbed](#)” (PDF, 1458 KiB), Computer Networks, Special Issue on Future Internet Testbeds, vol. 61, pp. 75–87, DOI [10.1016/j.bjp.2013.12.035](#), ISSN 1389-1286, March 14, 2014.
- Dreibholz, T.; Gran, E. G.: “[Design and Implementation of the NorNet Core Research Testbed for Multi-Homed Systems](#)” (PDF, 20082 KiB), Proceedings of the 3rd International Workshop on Protocols and Applications with Multi-Homing Support (PAMS), pp. 1094–1100, DOI [10.1109/WAINA.2013.71](#), ISBN 978-0-7695-4952-1, Barcelona, Catalonia/Spain, March 27, 2013.

Any Questions?



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