eScience Applications on the
SURFnet R&E Network

Cees de Laat

EU

SURFnet

NWO

University of Amsterdam
Internet developments

... more data!

... more realtime!

... more users!
... more data!

Internet developments

Speed

Volume

Deterministic

Real-time

Scalable

Secure

... more users!
<table>
<thead>
<tr>
<th>Category</th>
<th>Ijkdijk/Urban Flood</th>
<th>Medical</th>
<th>LifeWatch</th>
<th>CosmoGrid/eVLBI</th>
<th>CineGrid</th>
<th>EU-GN3/NOVI/Geyesers</th>
<th>SURFnet/GE/L/Cloud</th>
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- **Speed**
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ATLAS detector @ CERN Geneve
One Event in Atlas!
LHC Data Grid Hierarchy
CMS as example, Atlas is similar

Online System
~100 MBytes/sec

~10 Pflops/s
100000 flops/byte

Tier 0 +1

Tier 1

Italian Regional Center
German Regional Center
NIKHEF Dutch Regional Center
Fermilab, USA Regional Center

~2.5 Gbits/sec

Tier 2

Tier 2 Center

~0.6-2.5 Gbps

Tier 3

Institute

~0.25 TIPS

Physics data cache

100 - 1000 Mbits/sec

Tier 4

Workstations

CERN/CMS data goes to 6-8 Tier 1 regional centers, and from each of these to 6-10 Tier 2 centers.

Physicists work on analysis "channels" at 135 institutes. Each institute has ~10 physicists working on one or more channels.

2000 physicists in 31 countries are involved in this 20-year experiment in which DOE is a major player.

CMS detector: 15m X 15m X 22m
12,500 tons, $700M.

human=2m
Very Large Base Interferometer
Deadline for submitting observing proposals

Program committee:
* rates proposals
* allocates observing time

VLBI Observing Session

Disks shipped to JIVE

Correlation at JIVE

Data shipped

Data arrives at scientist's desk!
**eEVN: European VLBI Network**

Data processing centre: Dwingeloo
16 Gbps (2005)

- China
- USA
- South Africa
- Russia

1-30 Gbps

Star topology

Slide courtesy of Richard Schilizzi <schilizzi@jive.nl>
eEVN+ European VLBI Network

Deadline for submitting eVLBI observing proposals

Program committee decides if eVLBI science can be justified

eVLBI Observing Run

Correlation at JIVE

Scientist downloads data from www.jive.nl

Slide courtesy of Richard Schilizzi <schilizzi@jive.nl>
The SCARLe project

SCARLe: a research project to create a Software Correlator for e-VLBI.
VLBI Correlation: signal processing technique to get high precision image from spatially distributed radio-telescope.

Figure 2. Grid architecture that includes programmable network services.

Research:

WS-VLAM
Scheduler
Actuator
Profiler

GridBroker
- CPU
- Storage

NetBroker
- Topology
- Bandwidth

16 Gbit/s - 2 Tflop → THIS IS A DATA FLOW PROBLEM !!!

Telescopes

Input nodes

Correlator nodes

Output node

1000 flops/byte

0.1 Pflops/s

Figure 3. Setup of network connectivity
LOFAR as a Sensor Network

- LOFAR is a large distributed research infrastructure:
  - Astronomy:
    - >100 phased array stations
    - Combined in aperture synthesis array
    - 13,000 small “LF” antennas
    - 13,000 small “HF” tiles
  - Geophysics:
    - 18 vibration sensors per station
    - Infrasound detector per station
  - >20 Tbit/s generated digitally
  - >40 Tflop/s supercomputer
  - innovative software systems
    - new calibration approaches
    - full distributed control
    - VO and Grid integration
    - datamining and visualisation
US and International OptIPortal Sites

- NCMIR
- USGS EDC
- NCSA & TRECC
- SARA
- KISTI
- AIST
- RINCON & Nortel
- TAMU
- UCI
- UIC
- CALIT2

Real time, multiple 10 Gb/s
The “Dead Cat” demo

Where when will it happen?
300000 * 60 kb/s * 2 sensors (microphones) to cover all Dutch dikes
Sensor grid: instrument the dikes

First controlled breach occurred on sept 27th ‘08:

Many small flows $\rightarrow$ 36 Gb/s
CosmoGrid

- **Motivation:**
  previous simulations found >100 times more substructure than is observed!

- Simulate large structure formation in the Universe
  - Dark Energy (cosmological constant)
  - Dark Matter (particles)

- **Method:** Cosmological *N*-body code

- **Computation:** Intercontinental SuperComputer Grid
The hardware setup

- 2 supercomputers:
  - 1 in Amsterdam (60Tflops Power6 @ SARA)
  - 1 in Tokyo (30Tflops Cray XD0-4 @ CFCA)

- Both computers are connected via an intercontinental optical 10 Gbit/s network

270 ms RTT
Why is more resolution better?
1. More Resolution Allows Closer Viewing of Larger Image
2. Closer Viewing of Larger Image Increases Viewing Angle
3. Increased Viewing Angle Produces Stronger Emotional Response
Red End
Robin Noorda & Bethany de Forest
Hey at still.

We're almost done. Sshh...
A. Lightweight users, browsing, mailing, home use  
Need full Internet routing, one to all

B. Business/grid applications, multicast, streaming, VO’s, mostly LAN  
Need VPN services and full Internet routing, several to several + uplink to all

C. E-Science applications, distributed data processing, all sorts of grids  
Need very fat pipes, limited multiple Virtual Organizations, P2P, few to few

For the Netherlands 2011
ΣA = ΣB = ΣC ≈ 1 Tb/s

However:
• A -> all connects  
• B -> on several  
• C -> just a few (SP, LHC, LOFAR)

Ref: Cees de Laat, Erik Radius, Steven Wallace, "The Rationale of the Current Optical Networking Initiatives"  
A. Lightweight users, browsing, mailing, home use
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For the Netherlands 2011
\[ \Sigma A = \Sigma B = \Sigma C \approx 1 \text{Tb/s} \]

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Ref: Cees de Laat, Erik Radius, Steven Wallace, "The Rationale of the Current Optical Networking Initiatives"
Big and small flows don’t go well together on the same wire!
Towards Hybrid Networking!

• Costs of photonic equipment 10% of switching 10% of full routing
  – for same throughput!
  – Photonic vs Optical (optical used for SONET, etc, 10-50 k$/port)
  – DWDM lasers for long reach expensive, 10-50 k$

• Bottom line: look for a hybrid architecture which serves all classes in a cost effective way
  – map A -> L3, B -> L2, C -> L1 and L2

• Give each packet in the network the service it needs, but no more!

L1 ≈ 2-3 k$/port  
L2 ≈ 5-8 k$/port  
L3 ≈ 75+ k$/port
How low can you go?

Application Endpoint A

Local Ethernet

MEMS

Regional dark fiber

15454
6500
HDXc

Trans-Oceanic

Application Endpoint B

Router

Ethernet

SONET

DWDM

Fiber

POS

CERN

StarLight

NetherLight

GLIF
# Hybrid computing

<table>
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<tr>
<th>Routers</th>
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<th>Supercomputers</th>
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<tr>
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<td>↔</td>
<td>Grid  &amp; Cloud</td>
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<tr>
<td>Photonic transport</td>
<td>↔</td>
<td>GPU’s</td>
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</tbody>
</table>

**What matters:**

- Energy consumption/multiplication
- Energy consumption/bit transported
GLIF 2008

Visualization courtesy of Bob Patterson, NCSA
Data collection by Maxine Brown.
In The Netherlands SURFnet connects between 180:
- universities;
- academic hospitals;
- most polytechnics;
- research centers.
with an indirect ~750K user base

~ 8860 km scale comparable to railway system
Common Photonic Layer (CPL) in SURFnet6 supports up to 72 Lambda’s of 10 / 40 / 100 G
Alien light
From idea to
realisation!

40Gb/s alien wavelength transmission via a multi-vendor 10Gb/s DWDM infrastructure

Alien wavelength advantages
- Direct connection of customer equipment\(^1\) → cost savings
- Avoid OEO regeneration → power savings
- Faster time to service\(^2\) → time savings
- Support of different modulation formats\(^3\) → extend network lifetime

Alien wavelength challenges
- Complex end-to-end optical path engineering in terms of linear (i.e. OSNR, dispersion) and non-linear (FWM, SPM, XPM, Raman) transmission effects for different modulation formats.
- Complex interoperability testing.
- End-to-end monitoring, fault isolation and resolution.
- End-to-end service activation.

In this demonstration we will investigate the performance of a 40Gb/s PM-QPSK alien wavelength installed on a 10Gb/s DWDM infrastructure.

New method to present fiber link quality, FoM (Figure of Merit)
In order to quantify optical link grade, we propose a new method of representing system quality: the FOM (Figure of Merit) for concatenated fiber spans.

\[
FOM = \sum \left| \frac{L_i}{N} \right|
\]

\(L_i\): span losses in dB
\(N\): number of spans

Test results
Error-free transmission for 23 hours, 17 minutes → BER < 3.0 \times 10^{-14}

Conclusions
- We have investigated experimentally the all-optical transmission of a 40Gb/s PM-QPSK alien wavelength via a concatenated native and third party DWDM system that both were carrying live 10Gb/s wavelengths.
- The end-to-end transmission system consisted of 1056 km of TWRS (TrueWave Reduced Slope) transmission fiber.
- We demonstrated error-free transmission (i.e. BER below 10-15) during a 23 hour period.
- More detailed system performance analysis will be presented in an upcoming paper.

References
\[1\] "PERFORMANCE EVALUATION OF A 40 Gb/s DDA PM-QPSK ALIEN WAVELENGTH TRANSMISSION SYSTEM", D. BRIGEL, et al., ECOC'2009
\[2\] "A NEW OPTICAL TRANSMISSION NETWORK: MONOCASE OPTICAL SYSTEM", A. SANJAY, et al., ECOC'2009
\[3\] "TRANSMISSION OF ALIEN WAVELENGTHS", J. GERARD, et al., ECOC'2009

Acknowledgements
We are grateful to Nordius for providing us with bandwidth on their fibre link for this experiment, and also for their support and assistance during the experiments. We also acknowledge Telecom Italia and Nortel for their involvement and simulation support.
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Transmission system setup
JOIN SURFnet-NORDUnet 40Gb/s PM-QPSK alien wavelength DEMONSTRATION.

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\[
FOM = \sum_{i=1}^{N} L_i
\]

where:
- \( L_i \) = span losses in dB
- \( N \) = number of spans

Easy-to-use formulas that accurately quantify transmission system performance

References
[2] "40 Tbps TRANSPORT NETWORKS: OPTIMIZABLE OPTICAL NETWORKS"
[4] "HUMAN INTEGRATION TOOL FOR NETWORK MODERNIZATION"

Acknowledgements

We are grateful to NORDUnet for providing us with bandwidth and equipment for this experiment and also for their support and assistance during the experiments. We also acknowledge Telephone and Nortel for their integration work and simulation support.
Setup

UvA
- iPerf
- 2 quad core
- Mellanox
- 40G
- Extreme

CIENA OME6500

CERN
- iPerf
- 2 quad core
- CV
- Mellanox
- Extreme

DIViNe
- 48 core
- DELL

170 ms RTT

Amsterdam – Geneva (CERN) – 1650KM (~1000Miles)
Demo setup codename: FlightCees

- Ciena ActiveFlex(OME) 6500
- Broadcom 40GE 18 port L2 Ethernet Switch
- Supermicro Intel Server
- Dell R815 Server
Live stats - Supercomputing 2010

Total Throughput 74.87 Gbps

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<tr>
<th>Institution</th>
<th>Throughput</th>
</tr>
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<tbody>
<tr>
<td>ciena</td>
<td>50 Gbps</td>
</tr>
<tr>
<td>SURFNET</td>
<td>24.87 Gbps</td>
</tr>
<tr>
<td>Mellanox</td>
<td>19.91 Gbps</td>
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</tbody>
</table>

Incoming Band: Research Booth 34.50 Gbps
Incoming Data Booth 17.91 Gbps
Results (rtt = 17 ms)

- Single flow iPerf 1 core -> 21 Gbps
- Single flow iPerf 1 core <> -> 15+15 Gbps
- Multi flow iPerf 2 cores -> 25 Gbps
- Multi flow iPerf 2 cores <> -> 23+23 Gbps
- DiViNe <> -> 11 Gbps
- Multi flow iPerf + DiVine -> 35 Gbps
- Multi flow iPerf + DiVine <> -> 35 + 35 Gbps
Performance Explained

- Mellanox 40GE card is PCI-E 2.0 8x (5GT/s)
- 40Gbit/s raw throughput but ....
- PCI-E is a network-like protocol
  - 8/10 bit encoding -> 25% overhead -> 32Gbit/s maximum data throughput
  - Routing information
- Extra overhead from IP/Ethernet framing
- Server architecture matters!
  - 4P system performed worse in multithreaded iperf
Server Architecture

DELL R815
4 x AMD Opteron 6100

Supermicro X8DTT-HIBQF
2 x Intel Xeon
CPU Topology benchmark

We used numactl to bind iperf to cores
We zoeken: 🚫 voor complexe netwerken!
Network Description Language

- From semantic Web / Resource Description Framework.
- The RDF uses XML as an interchange syntax.
- Data is described by triplets:
<?xml version="1.0" encoding="UTF-8"?>
<rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:ndl="http://www.science.uva.nl/research/air/ndl#">
    <!-- Description of Netherlight -->
    <ndl:Location rdf:about="#Netherlight"/>
    <ndl:name>Netherlight Optical Exchange</ndl:name>
</ndl:Location>
<!-- TDM3.amsterdam1.netherlight.net -->
<ndl:Device rdf:about="#tdm3.amsterdam1.netherlight.net"/>
<ndl:name>tdm3.amsterdam1.netherlight.net</ndl:name>
<ndl:locatedAt rdf:resource="#amsterdam1.netherlight.net"/>
<ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:501/1"/>
<ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:501/3"/>
<ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:501/4"/>
<ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:503/1"/>
<ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:503/2"/>
<ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:503/3"/>
<ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:503/4"/>
<!-- all the interfaces of TDM3.amsterdam1.netherlight.net -->
<ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:501/1">
    <ndl:name>tdm3.amsterdam1.netherlight.net:POS501/1</ndl:name>
    <ndl:connectedTo rdf:resource="#tdm4.amsterdam1.netherlight.net:5/1"/>
</ndl:Interface>
<ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:501/2">
    <ndl:name>tdm3.amsterdam1.netherlight.net:POS501/2</ndl:name>
    <ndl:connectedTo rdf:resource="#tdm1.amsterdam1.netherlight.net:12/1"/>
</ndl:Interface>
Topology Aggregation

Consecutive Path Requests (Normalized)

Inter-Domain Resource Usage

- Full
- Full Mesh
- Star
- Single Node
- Mixed

Graph with x-axis representing Consecutive Path Requests (Normalized) and y-axis representing Inter-Domain Resource Usage.
Multi-layer descriptions in NDL

- IP layer
- Ethernet layer
- STS layer
- OC-192 layer
- SONET switch with Ethernet intf.
- End host

Université du Quebec
CA Net Canada
StarLight Chicago
MAN LAN New York
NetherLight Amsterdam
Universiteit van Amsterdam
A weird example

Université du Quebec

StarLight Chicago

can adapt GE in STS-24c or STS-3c-7v

Gigabit Ethernet

CA★Net Canada

can adapt GE in STS-24c

OC-192 (22 free)

2x OC-192 (87 free)

MAN LAN

New York

can adapt GE in STS-24c or STS-3c-7v

OC-192 (38 free)

2x OC-192 (63 free)

Universiteit van Amsterdam

can adapt GE in STS-3c-7v

Thanks to Freek Dijkstra & team
A weird example

Université du Québec

CA★Net
Canada

Gigabit Ethernet

Man LAN
New York

2x OC-192 (87 free)

2x OC-192 (63 free)

2x OC-192 (22 free)

OC-192 (38 free)

StarLight
Chicago

can adapt GE in STS-24c or STS-3c-7v

can adapt GE
in STS-24c

can adapt GE
in STS-3c-7v

Universiteit van Amsterdam

NetherLight
Amsterdam

Thanks to Freek Dijkstra & team
The Problem

I want HC and AB
Success depends on the order
Wouldn’t it be nice if I could request [HC, AB, ...]
Another one 😊

I want AB and CD
Success does not even depend on the order!!!
NDL + PROLOG

Research Questions:
• order of requests
• complex requests
• usable leftovers

• Reason about graphs
• Find sub-graphs that comply with rules
Multi-domain 2-layer networks

How do multi-domain 2-layer networks look like?

Guess: Projection algorithm (2-layer: Ethernet /WDM)

Steps:
1. Generate a multi-domain graph by BA-algorithm
2. Generate a graph for each domain by BA-algorithm
3. For each domain graph project random nodes onto WDM layer
4. Connect the domains at each layer according to the multi-domain graph
5. Assign random wavelengths to the adaptation links

Advantage:
- Number of adaptations determined by the degree of the projected nodes
- Multi-domain Ethernet-layer as well as the multi-domain WDM-layer graph are not necessarily connected.

Input parameters:
- Number domains, number of nodes(devices) per domain
- Ratio of Ethernet-devices over WDM-devices per domain
- Distribution of wavelength
Multi-domain 2-layer networks

Projection algorithm

BA-algorithm to generate a graph for each domain
Project random nodes onto WDM layer
Prolog rule:

\texttt{linkedto}(\texttt{Intf1}, \texttt{Intf2}, \texttt{CurrWav})\,:-

\begin{align*}
& \texttt{rdf\_db:rdf}(\texttt{Intf1}, \texttt{ndl:'layer'}, \texttt{Layer}), \\
& \texttt{Layer} == \texttt{'}wdm\#LambdaNetworkElement\texttt{'} , \\
& \texttt{rdf\_db:rdf}(\texttt{Intf1}, \texttt{ndl:'linkedTo'}, \texttt{Intf2}) , \\
& \texttt{compatible\_wavelengths}(\texttt{CurrWav}, \texttt{W2}) .
\end{align*}

\hfill %-- is there a link between Intf1 and Intf2 for wavelength CurrWav ?
\hfill %-- get layer of interface Intf1 \rightarrow Layer
\hfill %-- are we at the WDM-layer ?
\hfill %-- is Intf1 linked to Intf2 in the RDF file?
\hfill %-- get wavelength of Intf2 \rightarrow W2
\hfill %-- is CurrWav compatible with W2 ?

\texttt{linkedto}(\texttt{B4}, \texttt{D4}, \texttt{CurrWav}) \texttt{is} \texttt{true} \texttt{for} \texttt{any} \texttt{value} \texttt{of} \texttt{CurrWav}

\texttt{linkedto}(\texttt{D2}, \texttt{C3}, \texttt{CurrWav}) \texttt{is} \texttt{true} \texttt{if} \texttt{CurrWav} \texttt{==} \texttt{1310}
Path between interfaces A1 and E1:
A1-A2-B1-B4-D4-D2-C3-C4-C1-C2-B2-B3-D3-D1-E2-E1

Scaling: Combinatorial problem
Standardization

- OGF-NML is slowly progressing
  - Schema Document
- OGF-NSI is working frantically
  - Terminology Glossary
  - Architecture Document
  - NSI Protocol Document
RDF describing Infrastructure

Application: find video containing x, then trans-code to it view on Tiled Display
CineGrid Workflow Planner
EU-NOVI

Monitoring Architectures
Semantic Resource Description
Virtual Resource Brokering
Federated Virtualization Technologies

NOVI Innovation Cloud

Security Aware Access

OneLab
FEDERICA
Other Fi Platforms

Future Internet Federation
CookReport
feb 2009 and feb-mar 2010

november ’08
interview with
Kees Neggers (SURFnet),
Cees de Laat (UvA)

and furthermore
on november ’09

Wim Liebrandt (SURF),
Bob Hertzberger (UvA) and
Hans Dijkman (UvA)

BSIK projects
GigaPort &
VL-e / e-Science

Questions ?

ext.delaat.net