Informatics Institute

- CSA: Computer Systems Architecture (dr. A.D. Pimentel)
- FCN: Federated Collaborative Networks (Prof. dr. H. Afsarmanesh)
- IAS: Intelligent Autonomous Systems (Prof. dr. ir. F.C.A. Groen)
- ILPS: Information and Language Processing Systems (Prof. dr. M. de Rijke)
- ISIS: Intelligent Sensory Information Systems (Prof. dr. ir. A.W.M. Smeulders)
- SCS: Section Computational Science (Prof. dr. P.M.A. Sloot)
- SNE: System and Network Engineering (Prof. dr. ir. C.T.A.M. de Laat)
- TCS: Theory of Computer Science (Prof. dr. J.A. Bergstra)
… more users!

… more data!

… more realtime!

Internet developments
... more users!

Internet developments

... more data!

Speed
Volume

Deterministic
Real-time

Scalable
Secure
GPU cards are disruptive!

20,000,000$

7 year

500$

Top 500

#1

#500

fastest supercomputer in the world
nr. 500 supercomputer in the world
1 single Graphics Processing Unit
Data storage: doubling every 1.5 year!
Multiple colors / Fiber

Per fiber: ~ 80-100 colors * 50 GHz
Per color: 10 – 40 – 100 Gbit/s
BW * Distance ~ 2*10^{17} bm/s

New: Hollow Fiber!
⇒ less RTT!
Optical transmission

Virtualization

... more possibilities
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
\[ \Sigma A = \Sigma B = \Sigma C \approx 1 \text{ Tb/s} \]

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"
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
<table>
<thead>
<tr>
<th>Category</th>
<th>Jifdik/Urban Flood</th>
<th>LifeWatch/ENVR</th>
<th>CosmoGrid/eVLBI</th>
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<th>SURFnet/GLIF/Cloud</th>
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**Attributes:**
- Speed
- Volume
- Deterministic
- Real-time
- Scalable
- Secure
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Where will it happen?
IJKDIJK
Sensors: 15000km* 800 bps/m ->12 Gbit/s to cover all Dutch dikes
Sensor grid: instrument the dikes

First controlled breach occurred on sept 27th ‘08:

Many small flows -> 12 Gb/s
The network is virtualized as a collection of resources

UPVNs enable network resources to be programmed as part of the application

Mathematica interacts with virtualized networks using UPVNs and optimize network + computation

ref: Robert J. Meijer, Rudolf J. Strijkers, Leon Gommans, Cees de Laat, User Programmable Virtualized Networks, accepted for publication to the IEEE e-Science 2006 conference Amsterdam.
In the Intercloud virtual servers and networks become software

- Virtual Internets adapt to the environment, grow to demand, iterate to specific designs
- Network support for application specific interconnections are merely optimizations: Openflow, active networks, cisco distributed switch
- But how to control the control loop?
Interactive Networks

- SuperComputing 2008
- SuperComputing 2009 (in programmable Grid networks demo)
- SuperComputing 2011
- Next Generation Telecom networks workshop 2011
- LHCONE architecture workshop 2011
Interactive Networks

Rudolf Strijkers 1,2
Marc X. Makkes 1,2
Mihai Christea 1
Laurence Muller 1
Robert Belleman 1
Cees de Laat 1
Robert Meijs 1,2

1 University of Amsterdam, Amsterdam The Netherlands
2 TNO Information and Communication Technology, Groningen, The Netherlands
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ATLAS detector @ CERN Geneve
ATLAS detector @ CERN Geneve
100,000 flops/byte

10 Pflops/s

Status 2002!
Diagram for SAGE video streaming to ATS

Lab 10, Nortel

SAGE Display
SAGE Servers
MERS

1 Gbps

Netherlight Canarie

Internet

Content Choice

User
Regular Browser

UvA, Amsterdam

comp clusters

Traffic Generators

MERS
MERS
MERS

Content Portal
Streaming Server
100 TB Storage

Content Request

Nortel CIENA Confidential
Experimental Data

- **Sage without background traffic**
- **Sage with background traffic**

10 Second Traffic bursts with No PBT

10 Second Traffic bursts with PBT

PBT is **SIMPLE** and **EFFECTIVE** technology to build a shared Media-Ready Network.
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.

\[ \text{FOM} = \sum_{i=1}^{N} \left( \frac{L_i}{10} \right) \]

A \( \rightarrow \) \text{FOM 5004}
B \( \rightarrow \) \text{FOM 5005}
C \( \rightarrow \) \text{FOM 5007}

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

Transmission system setup
JOINT SURFnet/NORDUnet 40Gb/s PM-QPSK alien wavelength DEMONSTRATION.

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.

Test results
Error-free transmission for 23 hours, 17 minutes → BER \(< 3.9 \times 10^{-15}\)

References
[2] "Reusing optical network infrastructure", O. Gerstel et al., 2009
[5] "Nortel/Northnet functional communication"

Acknowledgements
We would like to thank Nortel and Nortel for providing us with access to their DWDM equipment for this demonstration. We would also like to thank Northnet for their support during the experiments. We also acknowledge the support of all our colleagues for their contributions to the project.
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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.

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

Where:
- \(FOM\) is the Figure of Merit
- \(L_i\) is the span loss in dB
- \(N\) is the number of spans

Test results
Error-free transmission for 23 hours, 17 minutes → BER < \(3 \times 10^{-14}\)

Conclusions
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References
\[1\] "OPEX SAVINGS OF ALL-OPTICAL CORE NETWORKS", ANTHONY LOE, ORG. ENGINEER, BELLLABS
\[2\] "WE ARE INFORMATION FOR PROVIDING US WITH BACKGROUND ON THIS EXPERIMENT AND ALSO FOR THEIR SUPPORT AND ASSISTANCE DURING THE EXPERIMENTS. WE ALSO ACKNOWLEDGE TELUS AND NORTEL FOR THEIR INTEGRATION WORK AND SIMULATION SUPPORT"

Acknowledgements
Setup codename: FlightCees

UvA
- iPerf
- Intel Core i7 3.2 GHz Q-core
- Mellanox 40G E

CIENA
- OME 6500

Hamburg
- iPerf
- AMD Phenom II X6 3.6 GHz HexCore

Copenhagen
- iPerf
- 2x dual 2.8 GHz Q-core
- Mellanox

CERN
- CIENA DWDM

Amsterdam – Geneva (CERN) – Copenhagen – 4400 km (2700 km alien light)
Visit CIENA Booth
surf to http://tnc11.delaat.net

ClearStream
End-to-End Ultra Fast Transmission Over a Wide Area 40 Gbit/s Lambda

Amsterdam (UvA) Live RX Traffic

Copenhagen POP RX Traffic

Incoming Amsterdam 25.5 Gbps
Incoming Copenhagen 20.97 Gbps
Total Throughput 46.47 Gbps RTT 44.032 ms
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
We used `numactl` to bind `iperf` to cores
GLIF 2011 Visualization courtesy of Bob Patterson, NCSA
Data collection by Maxine Brown.
We investigate: for complex networks!
The GLIF – lightpaths around the world
LinkedIN for Infrastructure

- From semantic Web / Resource Description Framework.
- The RDF uses XML as an interchange syntax.
- Data is described by triplets (Friend of a Friend):

```
Subject → Predicate → Object
```

Examples:
- **Location**
  - name
  - connectedTo
- **Device**
  - description
  - capacity
- **Interface**
  - locatedAt
  - encodingType
- **Link**
  - hasInterface
  - encodingLabel
<?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:504/1"/>
         <ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:504/2"/>
         <ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:504/3"/>
     </ndl:Device>
     <!-- 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>
</rdf:RDF>
Multi-layer descriptions in NDL
Path between interfaces A1 and E1:
A1-A2-B1-B4-D4-D2-C3-C1-C2-B2-B3-D3-D1-E2-E1

Scaling: Combinatorial problem
Virtualisatie van infrastructuur & QoS
Information Modeling

Define a common information model for **infrastructures** and **services**. Base it on Semantic Web.

---

J. van der Ham, F. Dijkstra, P. Grosso, R. van der Pol, A. Toonk, C. de Laat
*A distributed topology information system for optical networks based on the semantic web*,  
In: Elsevier Journal on Optical Switching and Networking, Volume 5, Issues 2-3, June 2008, Pages 85-93

R.Koning, P.Grosso and C.de Laat
*Using ontologies for resource description in the CineGrid Exchange*  
SNE @ UvA

- Privacy/Trust
- Authorization/policy
- Programmable networks
- 40-100Gig/TCP/WF/QoS
- Topology/Architecture
- Optical Photonic

Legend:
- Green-IT
- Jokdijk/Urban Flood
- LifeWatch/ENVRI
- CosmoGrid/eVLBI
- EU-GN3/NOVI/Geyser
- SURFnet/GLIF/Cloud

X indicates presence.

Legend:
- X indicates presence.

Legend:
- X indicates presence.
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
RDF describing Infrastructure

Application: find video containing x, then trans-code to it view on Tiled Display

PG&CdL
Why?

I want to:

“Show Big Bug Bunny in 4K on my Tiled Display using green Infrastructure”

- Big Bugs Bunny can be on multiple servers on the Internet.
- Movie may need processing / recoding to get to 4K for Tiled Display.
- Needs deterministic Green infrastructure for Quality of Experience.
- Consumer / Scientist does not want to know the underlying details.
  ➔ His refrigerator also just works.
Applications and Networks become aware of each other!
The Ten Problems with the Internet

1. Energy Efficient Communication
2. Separation of Identity and Address
3. Location Awareness
4. Explicit Support for Client-Server Traffic and Distributed Services
5. Person-to-Person Communication
6. Security
7. Control, Management, and Data Plane separation
8. Isolation
9. Symmetric/Asymmetric Protocols
10. Quality of Service

Nice to have:
• Global Routing with Local Control of Naming and Addressing
• Real Time Services
• Cross-Layer Communication
• Manycast
• Receiver Control
• Support for Data Aggregation and Transformation
• Support for Streaming Data
• Virtualization

TimeLine

Sustainable Internet

Cognitive Nets and clouds

Virtualized Internet

Machine Learning + “I Want” Internet 3.0

Good Old Trucking

TCP

RDUDP, SCTCP, ...

ATM

(G)MPLS

PBT/PLSB

OpenFlow

NDL #SF for complex nets

CineGrid #SF for CineGrid

Programmable Networks #NetApp’s

GreenIT&Nets

2000

2005

2011

2020
TimeLine

- Sustainable Internet
- Cognitive Nets and clouds
- Virtualized Internet
- Good Old Trucking

“I Want” Internet 3.0

I retire

2020

2040
Complex e-Infrastructure!
Complex e-Infrastructure!
Cloud Computing

Domain Apps

... ...

Domain Apps

eScience Middleware

+ ML + reasoning (ProLog?) + Scheduling + ...

Service Plane

SAGE
CGLX
Cromium

SAGE
OCCI
JSDL
SAGA

GIR
UR

NSI
NetConf
SNMP
OpenFlow

PerfSonar

DIAS
ByteIO
iRODs

DIAS
ByteIO
OGSA
WebServ

Domain Apps

Apps
ECO-Scheduling
Hybrid Networking <-> Computing

Routers ↔ Supercomputers

Ethernet switches ↔ Grid & Cloud

Photonic transport ↔ GPU’s

What matters:
- Energy consumption/multiplication
- Energy consumption/bit transported
Challenges

• **Data – Data – Data**
  – Archiving, publication, searchable, transport, self-describing, DB innovations needed, multi disciplinary use

• **Virtualisation**
  – Another layer of indeterminism

• **Greening the Infrastructure**
  – e.g. Department Of Less Energy: [http://www.ecrinitiative.org/pdfs/ECR_3_0_1.pdf](http://www.ecrinitiative.org/pdfs/ECR_3_0_1.pdf)

• **Disruptive developments**
  – BufferBloath, Revisiting TCP, influence of SSD’s & GPU’s
  – Multi layer Glif Open Exchange model
  – Invariants in LightPaths (been there done that 😊)
    • X25, ATM, SONET/SDH, Lambda’s, MPLS-TE, VLAN’s, PBT, OpenFlow, ….
  – Authorization & Trust & Security and Privacy
The Way Forward!

- Nowadays scientific computing and data is dwarfed by commercial & cloud, there is also no scientific water, scientific power.
  - Understand how to work with elastic clouds
  - Trust & Policy & Firewalling on VM/Cloud level
- Technology cycles are 3 – 5 year
  - Do not try to unify but prepare for diversity
  - Hybrid computing & networking
  - Compete on implementation & agree on interfaces and protocols
- Limitation on natural resources and disruptive events
  - Energy becomes big issue
  - Follow the sun
  - Avoid single points of failure (aka Amazon, Blackberry, …)
  - Better very loosely coupled than totally unified integrated…
Q & A

Slides thanks to:

• Paola Grosso
• Sponsors see slide 1. 😊
• SNE Team & friends, see below

http://ext.delaat.net/