Mastering Complex Cyber Infrastructure
Cees de Laat

EU
COMMIT
UvA
NWO
PID/EFRO
SURFnet
TNO
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!

Internet developments

... more realtime!
Internet developments

... more data!

Google

Speed

Volume

Deterministic

Real-time

Scalable

Secure

... more users!
GPU cards are disruptive!

Top 500 #1 #500

20,000,000 $ 7 year

500 $
Data storage: doubling every 1.5 year!
Multiple colors / Fiber

Per fiber: \(~ 80-100 \text{ colors} \times 50 \text{ GHz}\)
Per color: \(10 – 40 – 100 \text{ Gbit/s}\)

\(\text{BW} \times \text{Distance} \approx 2 \times 10^{17} \text{ b/s}\)

New: Hollow Fiber!
⇒ less RTT!
Optical transmission

... more possibilities

Virtualization
Next Generation Wireless LAN Technology
802.11ac 1 Gbps throughput with WiFi

WiFi is one of the most preferred communication protocols for LAN due to the easy comparison and convenience in the digital home. While consumer PC products have just started to migrate to much higher bandwidths of 802.11n wireless LAN now working on next-generation standard definition is already in progress.
Wireless Networks

It is a bit freaky with this wireless technology.

protocol LAN due to the easy comparison and convenience in the digital home. While consumer PC products has just started to migrate to a much higher bandwidth of 802.11n wireless LAN now working on next-generation standard definition is already in progress.
<table>
<thead>
<tr>
<th>Feature</th>
<th>Green-IT</th>
<th>Privacy/Trust</th>
<th>Authorization/policy</th>
<th>Programmable networks</th>
<th>40-100Gig/TCP/WF/QoS</th>
<th>Topology/Architecture</th>
<th>Optical Photonic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Volume</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Deterministic</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real-time</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scalable</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secure</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Diagram notes:
- SNE @ UvA
- Green-IT
- Privacy/Trust
- Authorization/policy
- Programmable networks
- 40-100Gig/TCP/WF/QoS
- Topology/Architecture
- Optical Photonic
- IJddijk/Urban Flood
- LifeWatch/ENVR
- CosmoGrid/eVLBI
- CineGrid
- EU-GN3/NOVI/Geyser
- SURFnet/GLIF/Cloud
<table>
<thead>
<tr>
<th>Category</th>
<th>IJkdijk/Urban Flood</th>
<th>LifeWatch/ENVR</th>
<th>CosmoGrid/eVLBI</th>
<th>EU-GN3/NOVI/Geyser</th>
<th>SURFnet/GLIF/Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green-IT</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Privacy/Trust</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authorization/policy</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programmable networks</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-100Gig/TCP/WF/QoS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Topology/Architecture</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Optical Photonic</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

**Speed**
- Volume

**Deterministic**
- Real-time

**Scalable**
- Secure
<table>
<thead>
<tr>
<th>Topic</th>
<th>Jijdijk/Urban Flood</th>
<th>LifeWatch/ENVRI</th>
<th>CosmoGrid/eVLBI</th>
<th>EU-GN3/NOVI/Geyser</th>
<th>SURFnet/GLIF/Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green-IT</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Privacy/Trust</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authorization/policy</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Programmable networks</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-100Gig/TCP/WF/QoS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Topology/Architecture</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Optical Photonic</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Despite the weather now, reminder: 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 $\rightarrow$ 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.

User Programmable Virtualized Networks.

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

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

1 University of Amsterdam, Amsterdam The Netherlands
2 TNO Information and Communication Technology, Groningen, The Netherlands
<table>
<thead>
<tr>
<th></th>
<th>IJkdijk/Urban Flood</th>
<th>LifeWatch/ENVR1</th>
<th>CosmoGrid/eVLBI</th>
<th>EU-GN3/NOVI/Geyser</th>
<th>SURFnet/GLIF/Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green-IT</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Privacy/Trust</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authorization/policy</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Programmable networks</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-100Gig/TCP/WF/QoS</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Topology/Architecture</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Optical Photonic</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
ATLAS detector @ CERN Geneve
ATLAS detector @ CERN Geneve
LHC Data Grid Hierarchy

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

Tier 1
- Italian Regional Center
- German Regional Center
- NIKHEF Dutch Regional Center
- Fermilab, USA Regional Center

Tier 2
- Tier2 Center
- Tier2 Center
- Tier2 Center
- Tier2 Center

Tier 3
- Institute
- Institute
- Institute

Tier 4
- Physics data cache
- 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.
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!

$L_1 \approx 2-3$ k$/port$

$L_2 \approx 5-8$ k$/port$

$L_3 \approx 75+$ k$/port$
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.

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

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

Easy-to-use formula 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 \(< 3.0 \times 10^{-15}\)

References

\[1\] "OPERATIONAL SOLUTIONS FOR AN END-END ALIEN PLANET", O. GERSTE et al, GTCC'09
\[2\] "THE OPTICAL TRANSPORT NETWORKS" MARK EIS, CARR, JOHN, ET AL
\[3\] "FAS WAVE OF ALL-OPTICAL CORE NETWORKS", MARK EIS, MATTHEW, ET AL
\[4\] "NORTHELF NETWORK SOLUTIONS" W. MARSHALL, ET AL

Acknowledgements

We are grateful to NORDUnet for providing us with bandwidth on their DWDM link for this experiment and also for their support and assistance during the experiments. We also acknowledge Telius and Nortel for their integration work and simulation support.
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.

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

\(A\) span losses in dB
\(N\) number of spans

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 < 3.0 \times 10^{-15}
Setup codename: FlightCees

**UvA**
- iPerf
- i7 3.2 GHz Q-core
- Amd Ph II 3.6 GHz HexC
- Mellanox
- 40G E

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

**CERN**
- CIENA OME 6500
- CIENA DWDM
- 17 ms RTT

**Hamburg**
- CIENA OME 6500
- Alcatel DWDM
- 27 ms RTT

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

Subject -- Object Subject -- Object Subject

Location: name, connectedTo
Device: description, capacity
Interface: locatedAt, encodingType
Link: hasInterface, encodingLabel
NetherLight in RDF

<?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:501/2"/>
        <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"/>
        <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:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:504/4"/>
    </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>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:501/3">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS501/3</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm1.amsterdam1.netherlight.net:20/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:501/4">
        <ndl:connectedTo rdf:resource="#tdm1.amsterdam1.netherlight.net:11/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:503/1">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS503/1</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm4.amsterdam1.netherlight.net:5/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:503/2">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS503/2</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm2.amsterdam1.netherlight.net:8/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:503/3">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS503/3</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm1.amsterdam1.netherlight.net:12/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:503/4">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS503/4</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm1.amsterdam1.netherlight.net:11/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:504/1">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS504/1</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm4.amsterdam1.netherlight.net:5/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:504/2">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS504/2</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm2.amsterdam1.netherlight.net:8/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:504/3">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS504/3</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm1.amsterdam1.netherlight.net:12/1"/>
    </ndl:Interface>
    <ndl:Interface rdf:about="#tdm3.amsterdam1.netherlight.net:504/4">
        <ndl:name>tdm3.amsterdam1.netherlight.net:POS504/4</ndl:name>
        <ndl:connectedTo rdf:resource="#tdm1.amsterdam1.netherlight.net:11/1"/>
    </ndl:Interface>
</rdf:RDF>
Multi-layer descriptions in NDL

End host

Université du Quebec

CA Net Canada

StarLight Chicago

MAN LAN New York

NetherLight Amsterdam

End host

SONET switch with Ethernet intf.

Ethernet & SONET switch

SONET switch

SONET switch with Ethernet intf.

Universiteit van Amsterdam
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
Complex e-Infrastructure!
Complex e-Infrastructure!
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*
<table>
<thead>
<tr>
<th>Topic</th>
<th>IJKdijk/Urban Flood</th>
<th>LifeWatch/ENVRI</th>
<th>CosmoGrid/eVLBI</th>
<th>EU-GN3/NOVI/Geyser</th>
<th>SURFnet/GLIF/Cloud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green-IT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Privacy/Trust</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authorization/policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programmable networks</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-100Gig/TCP/WF/QoS</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Topology/Architecture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical Photonic</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Why is more resolution is 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

4320

7680

0.75 \times \text{Picture Height}

1.5 \times \text{Picture Height}

2160

3840

3.0 \times \text{Picture Height}

7.6 \text{ Gb/s}

1920

24 \text{ Gb/s}

30°

60°

100°

Yutaka TANAKA
SHARP CORPORATION
Advanced Image Research Laboratories
Hey at still.

We're almost done. Sshh...
Red End
Robin Noorda & Bethany de Forest
The “Dead Cat” demo

SC2004,
Pittsburgh,
Nov. 6 to 12, 2004
iGrid2005,
San Diego,
sept. 2005

Many thanks to:
AMC
SARA
GigaPort
UvA/AIR
Silicon Graphics, Inc.
Zoölogisch Museum

M. Scarpa, R.G. Belleman, P.M.A. Sloot and C.T.A.M. de Laat, "Highly Interactive Distributed Visualization",
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.
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
  - Machine Learning
  - Virtualized Internet
  - Good Old Trucking

- GreenIT&Nets
- SF for Clouds
- NDL SF for complex nets
- Programmable Networks
- NetApp’s
- CineGrid
- SF for CineGrid
- NM
- OCCI
- NSI
- LightPaths
- GLIF
- Hybrid Nets
- Policy
- TBN
- (G)MPLS
- PBT/PLSB
- OpenFlow
- TCP
- ATM
- ATM, GMPLS, SONET/SDH
- TCP, SCTCP, ...
- AAA
- TBN
- Policy
- NM
- OCCI
- NSI

“Internet 3.0”

2005 - 2020
TimeLine

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

“I Want” Internet 3.0

“I retire”

2020 | 2040
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…
ECO-Scheduling
Q & A

Slides thanks to:
- Paola Grosso
- Sponsors see slide 1. 😊
- SNE Team & friends, see below