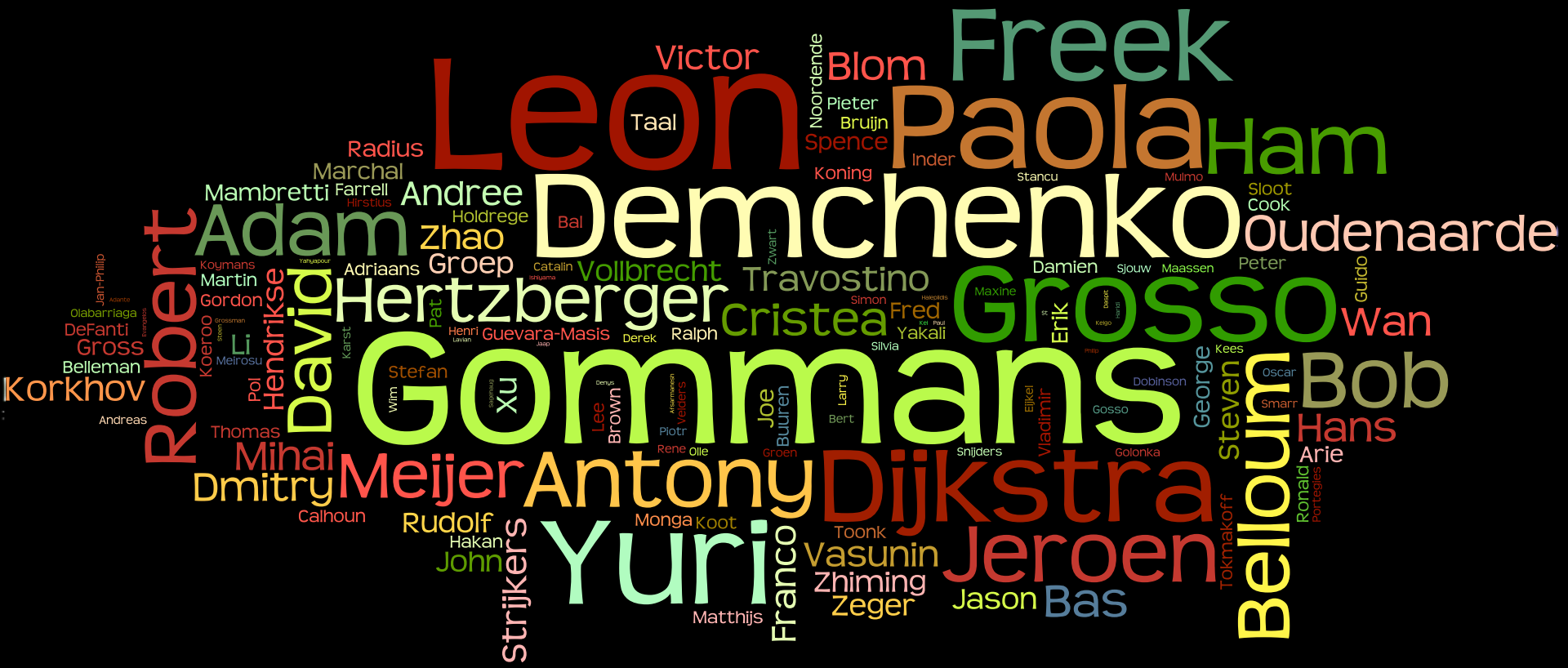
# Smart Cyber Infrastructure for Big Data Processing

## Cees de Laat



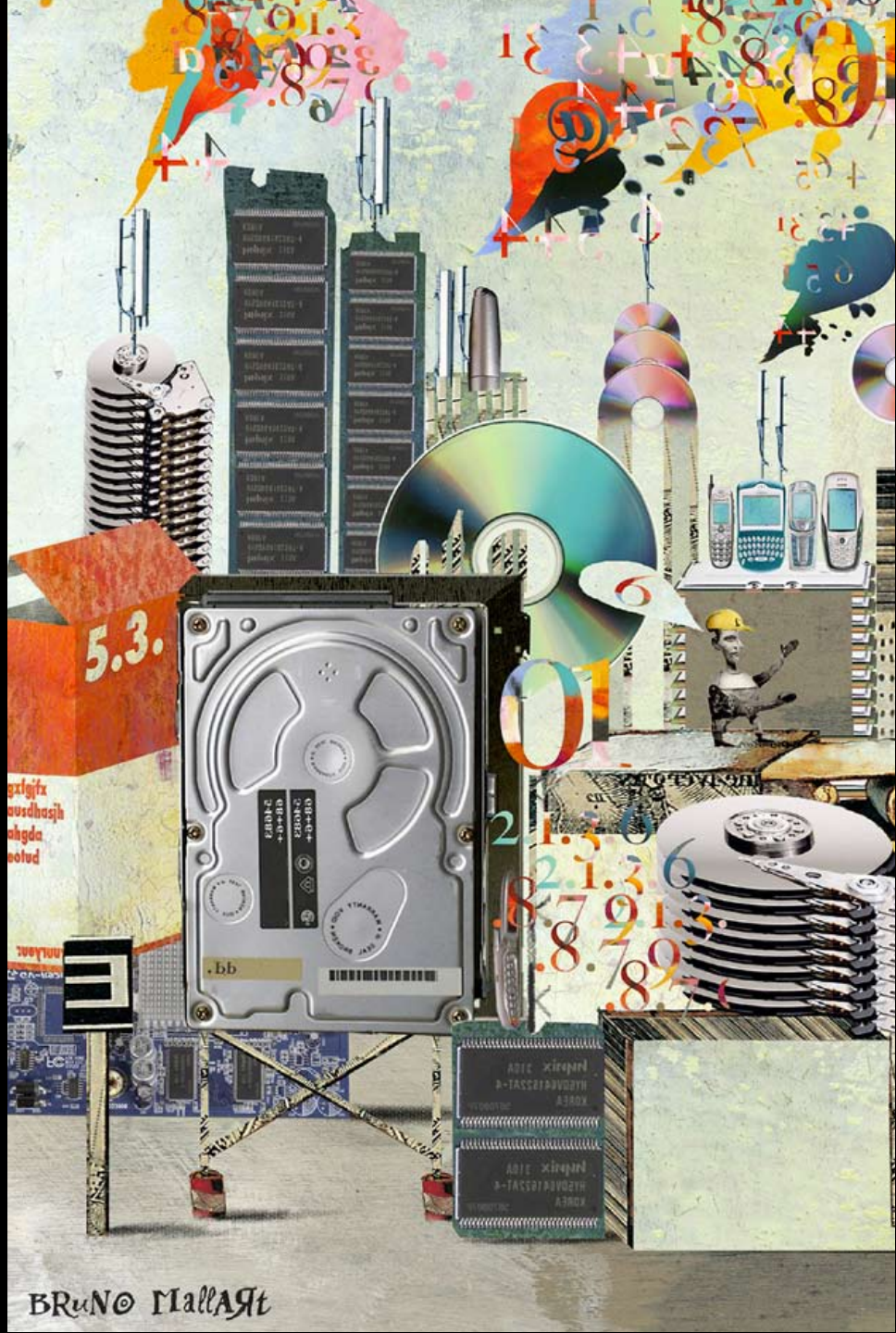
From King's Dutch Academy of Sciences

# The Dutch Research Agenda

"Information technology (IT) now permeates all aspects of public, commercial, social, and personal life. bank cards, satnav, and weather radar... IT has become completely indispensable."

"But to guarantee the reliability and quality of constantly bigger and more complicated IT, we will need to find answers to some fundamental questions!"

https://www.knaw.nl/nl/actueel/publicaties/the-dutch-research-agenda/@@download/pdf_file/20111029.pdf



# Reduction of Complexity by Integration

By combining services such as telephony, television, data, and computing capacity within a single network, we can cut down on complexity, energy consumption and maintenance.

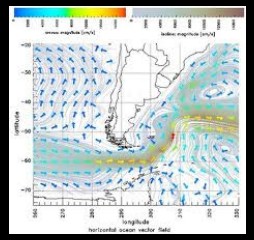
- How can we describe and analyze complex information systems effectively?
- How can we specify and measure the quality and reliability of a system?
- How can we combine various different systems?
- How can we design systems in which separate processors can co-operate efficiently via mutual network connections within a much larger whole?
- Can we design information systems that can diagnose their own malfunctions and perhaps even repair them?
- How can we specify, predict, and measure system performance as effectively as possible?

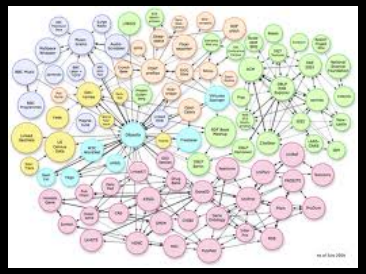
SNE addresses a.o. the **highlighted** questions!

http://www.knaw.nl/Content/Internet_KNAW/publicaties/pdf/20111029.pdf

# Internet developments

... more data!


... more realtime!









... more users!

# Internet developments

... more data!

Speed

Volume

Deterministic

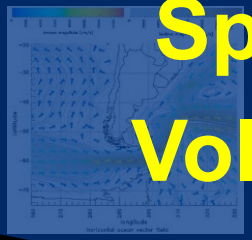
Real-time

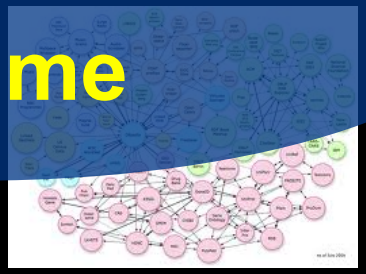
Scalable

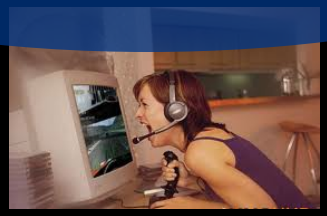
Secure

... more users!











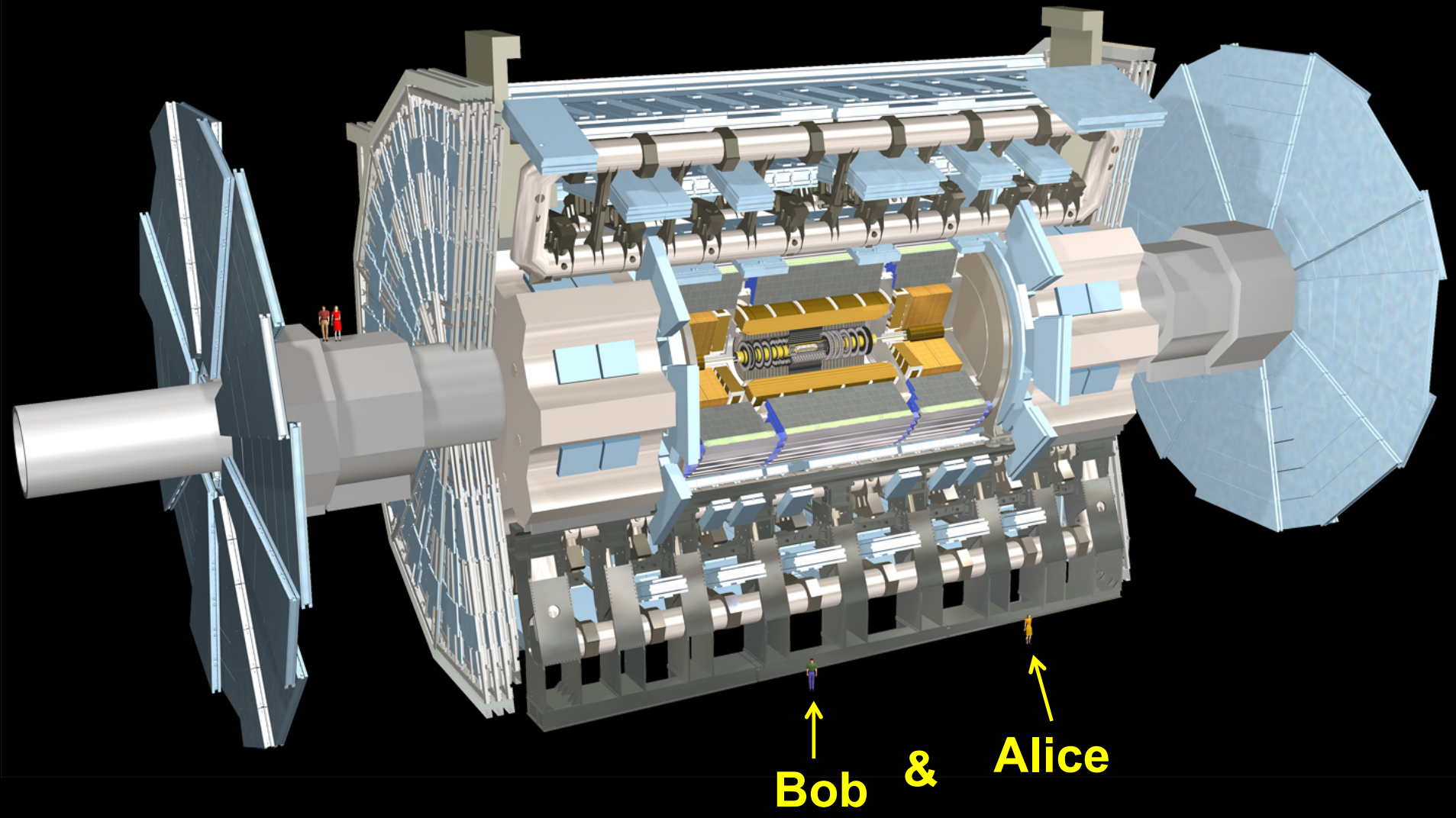



# Mission

*To create smart and safe data processing infrastructures that can be tailored to diverse application needs!*

- ***Capacity***
  - ***Bandwidth on demand, QoS, architectures, photonics, performance***
- *Capability*
  - *Programmability, virtualization, complexity, semantics, workflows*
- *Security*
  - *Anonymity, integrity of data in distributed data processing*
- *Sustainability*
  - *Greening infrastructure, awareness*
- *Resilience*
  - *Systems under attack, failures, disasters*

# ATLAS detector @ CERN Geneve



# What Happens in an **Internet Minute?**


## And **Future Growth** is **Staggering**

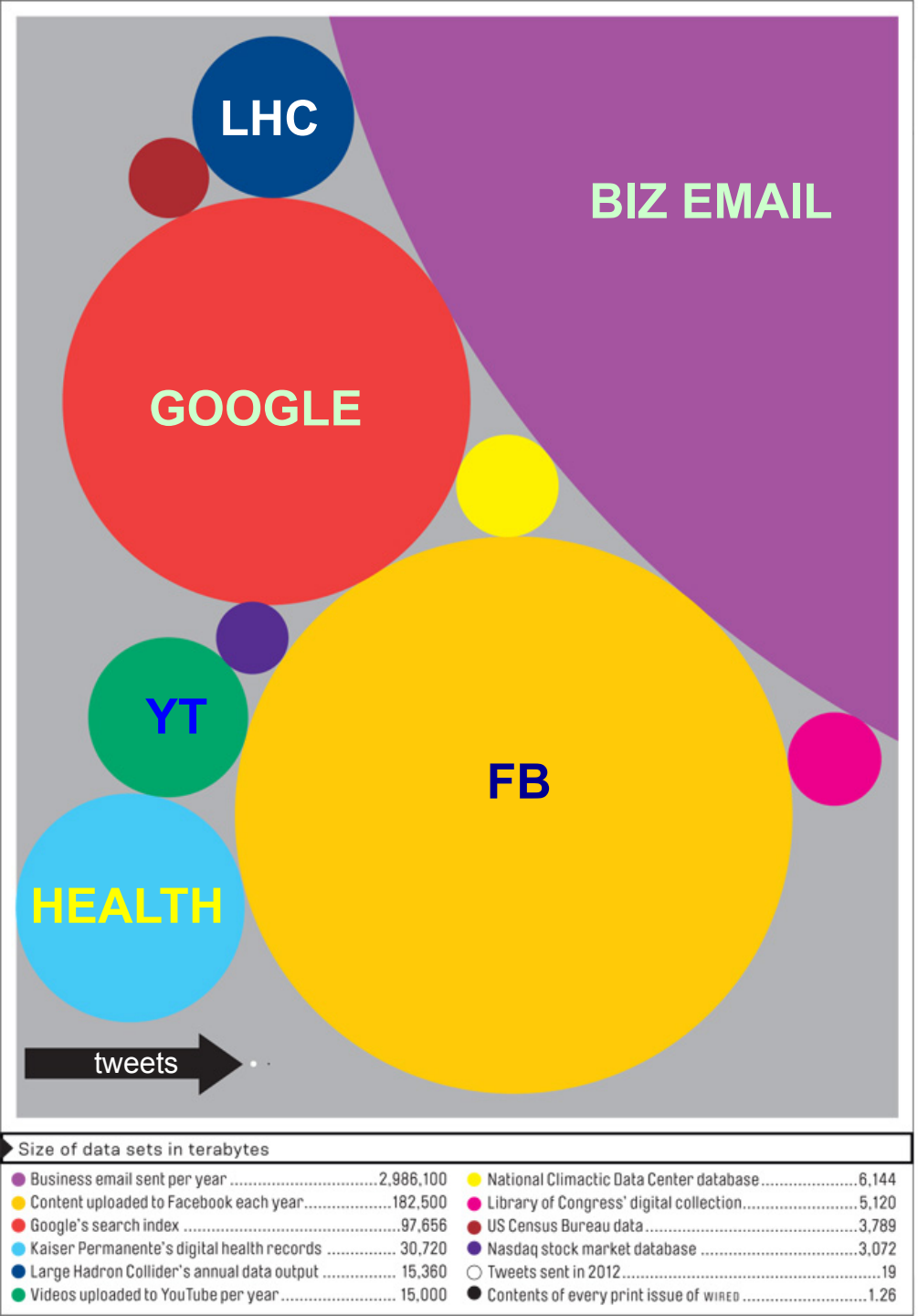
**Today**, the number of networked devices = the global population

By **2015**, the number of networked devices = 2x the global population

In **2015**, it would take you **5 years**


to view all video crossing IP networks each **second**

intel



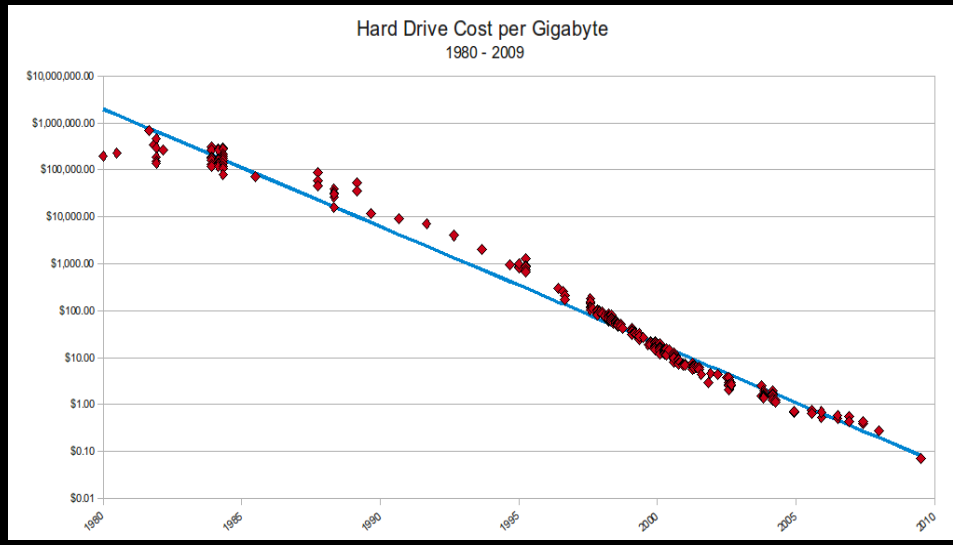

There is always a bigger fish

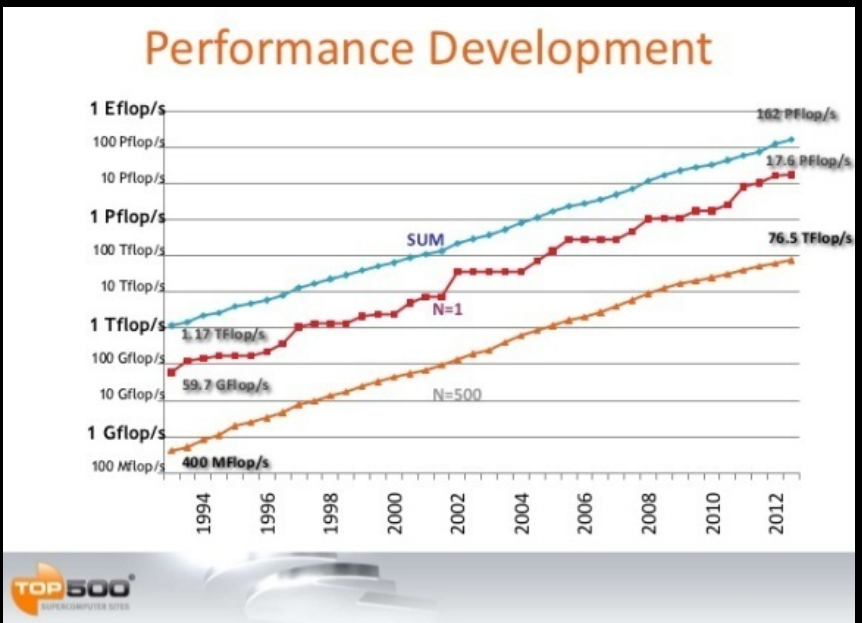
# Reliable and Safe!

This omnipresence of IT makes us not only strong but also vulnerable.

- A virus, a hacker, or a system failure can instantly send digital shockwaves around the world.

The hardware and software that allow all our systems to operate is becoming bigger and more complex all the time, and the capacity of networks and data storage is increasing by leaps and bounds.



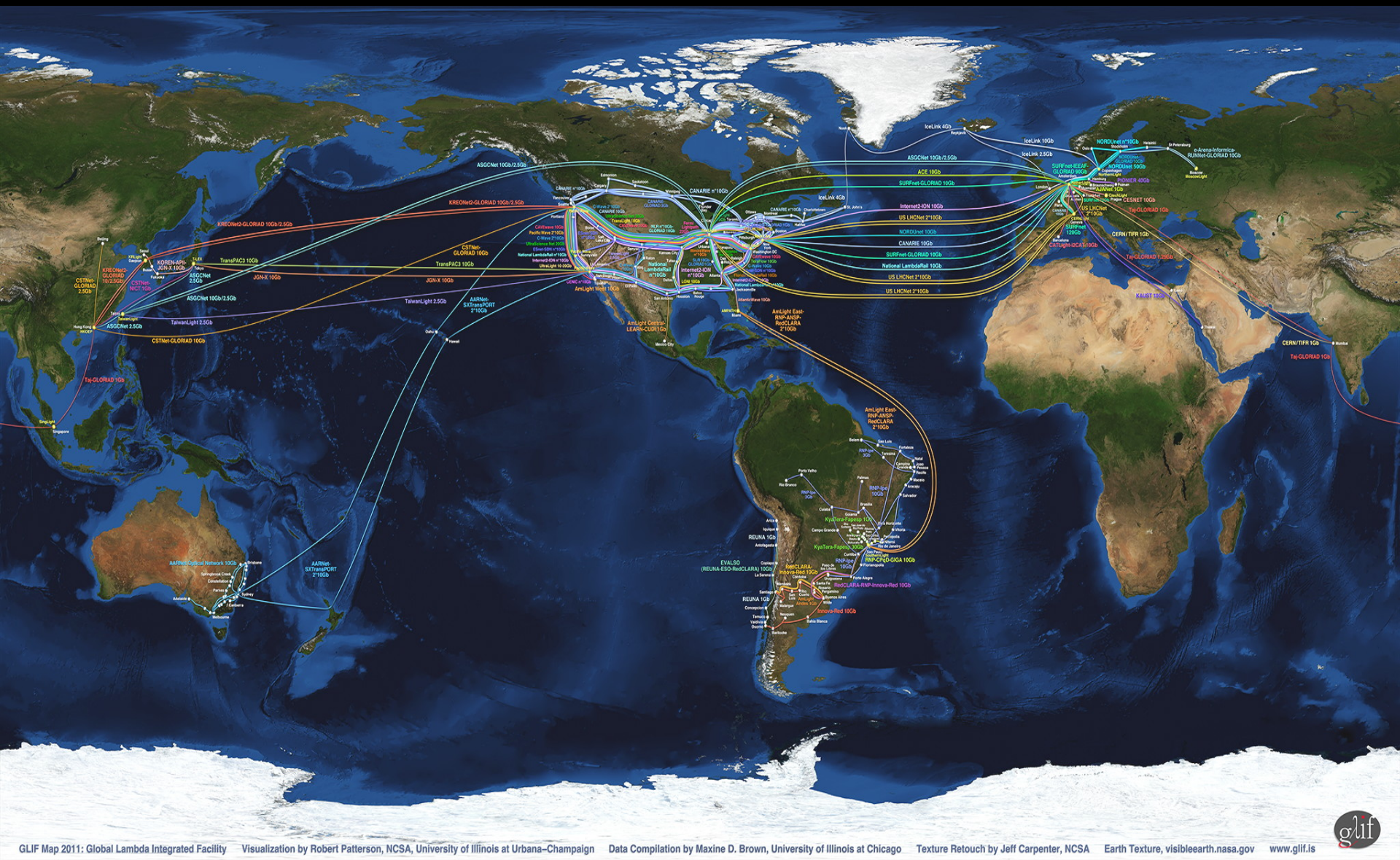




We will soon reach the limits of what is currently feasible and controllable.

https://www.knaw.nl/shared/resources/actueel/publicaties/pdf/20111029.pdf

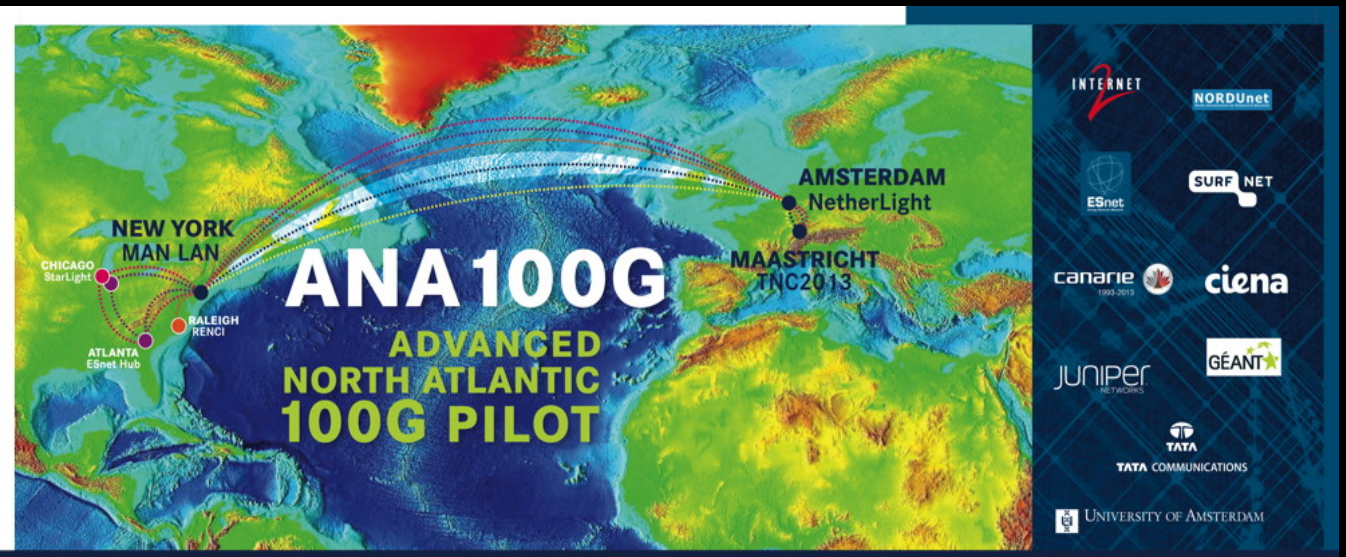
# The GLIF – LightPaths around the World

F Dijkstra, J van der Ham, P Grosso, C de Laat, “A path finding implementation for multi-layer networks”, Future Generation Computer Systems 25 (2), 142-146.



# ExoGeni @ OpenLab - UvA

Installed and up June 3th 2013



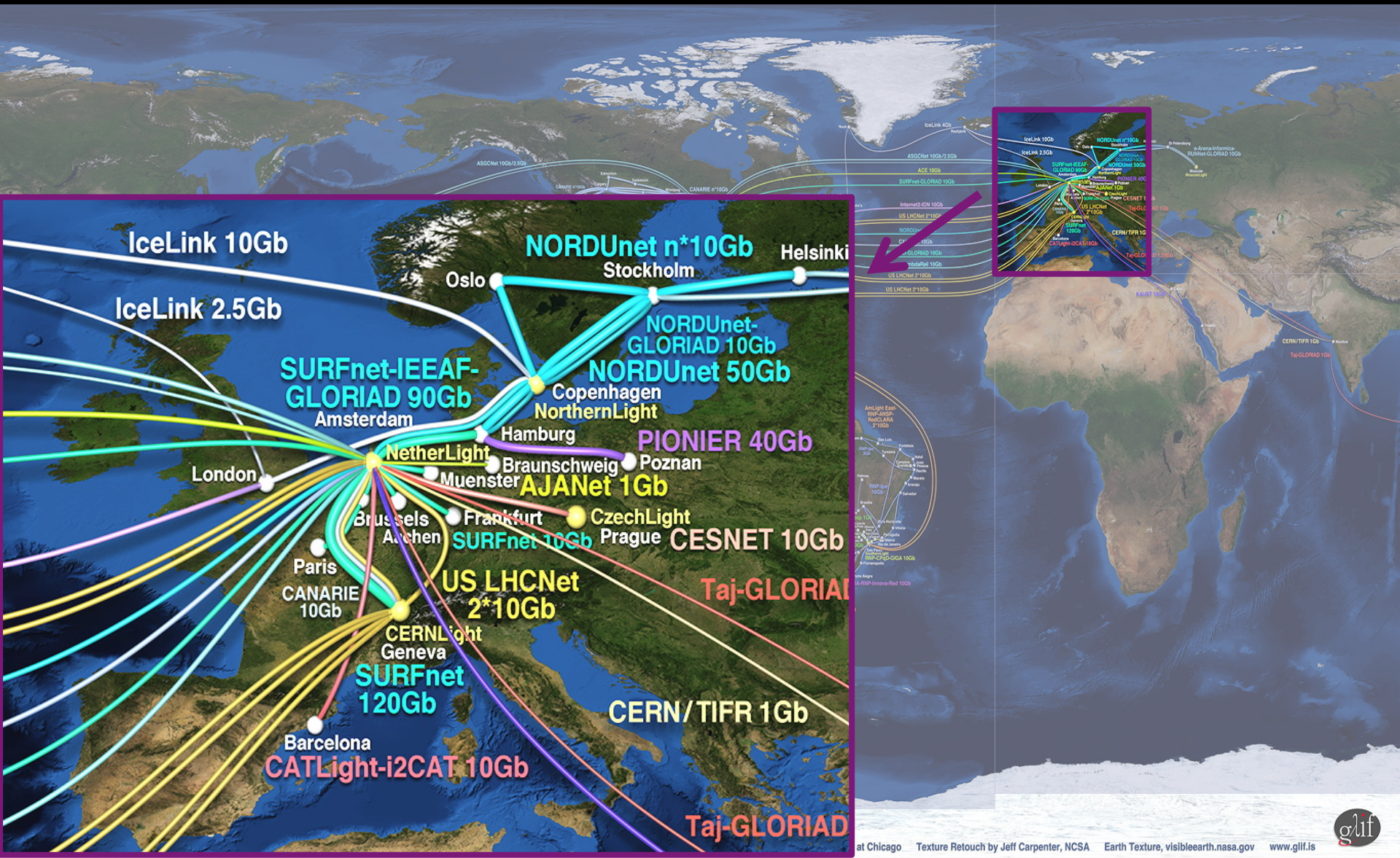

## TNC2013 DEMOS JUNE, 2013

| DEMO | TITLE | OWNER | AFFILIATION | E-MAIL | A-SIDE | Z-SIDE | PORTS(S) MAN LAN | PORTS(S) TNC2013 | DETAILS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Big data transfers with multipathing, OpenFlow and MPTCP | Ronald van der Pol | SURFnet | ronald.vanderpol@surfnet.nl | TNC/MECC, Maastricht NL | Chicago, IL | Existing 100G link between internet2 and ESnet | 2x40GE (Juniper)+ 2x 10GE (OME6500) | In this demonstration we show how multipathing, OpenFlow and Multipath TCP (MPTCP) can help in large file transfers between data centres (Maastricht and Chicago). An OpenFlow application provisions multiple paths between the servers and MPTCP will be used on the servers to simultaneously send traffic across all those paths. This demo uses 2x40G on the transatlantic 100G link. ESnet provides 2x40G between MAN LAN and StarLight, ACE and USLHCnet provide additional 10GEs. |
| 2 | Visualize 100G traffic | Inder Monga | ESnet | imonga@es.net | | | | | Using an SNMP feed from the Juniper switch at TNC2013,and/or Brocade ALZS node in MANLAN, this demo would visualize the total traffic on the link, of all demos aggregated. The network diagram will show the transatlantic topology and some of the demo topologies. |
| 3 | How many modern servers can fill a 100Gbps Transatlantic Circuit? | Inder Monga | ESnet | imonga@es.net | Chicago, Ill | TNC showfloor | 1x 100GE | 8x 10GE | In this demonstration, we show that with the proper tuning and tool, only 2 hosts on each continent can generate almost 80Gbps of traffic. Each server has 4 100 NICS connected to a 40G virtual circuit, and has iperf3 running to generate traffic. ESnet's new "iperf3" throughput measurement tool, still in 'beta', combines the best features from other tools such as iperf, nuttcp, and netperf. See: https://my.es.net/demos/tnc2013/ |
| 4 | First European ExoGENI at Work | Jeroen van der Ham | UvA | vdham@uva.nl | RENCI, NC | UvA, Amsterdam, NL | 1x 10GE | 1x 10GE | The ExoGENI racks at RENCI and UvA will be interconnected over a 10G pipe and be on continuously, showing GENI connectivity between Amsterdam and the rest of the GENI nodes in the USA. |
| 5 | Up and down North Atlantic @ 100G | Michael Enrico | DANTE | michael.enrico@dante.net | TNC showfloor | TNC showfloor | 1x 100GE | 1x 100GE | The DANTE 100GE test set will be placed at the TNC2013 showfloor and connected to the Juniper at 100G. When this demo is running a loop @ MAN LAN's Brocade switch will ensure that the traffic sent to MAN LAN returns to the showfloor. On display is the throughput and RTT (to show the traffic traveled the Atlantic twice) |

Connected via the new 100 Gb/s transatlantic To US-GENI

# Amsterdam is a major hub in The GLIF

F Dijkstra, J van der Ham, P Grosso, C de Laat, “A path finding implementation for multi-layer networks”, Future Generation Computer Systems 25 (2), 142-146.



# Alien light From idea to realisation!

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

NCF

## 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.

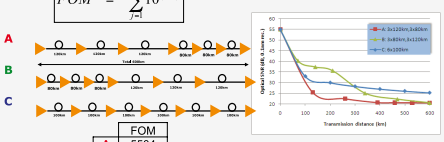
**In this demonstration we will investigate the performance of a 40Gb/s PM-QPSK alien wavelength installed on a 10Gb/s DWDM infrastructure.**

## 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.

$$FOM = \sum_{j=1}^{N} 10^{\left(\frac{L_j}{10}\right)}$$

Lj, span losses in dB
N, number of spans

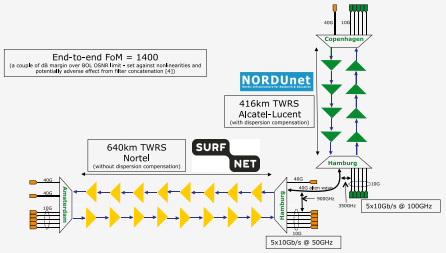



| | FOM |
|---|---|
| A | 5504 |
| B | 5504 |
| C | 1897 |

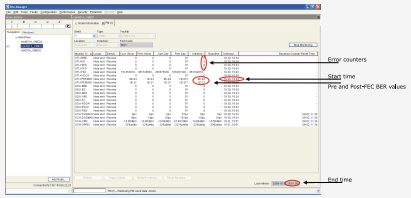
Easy-to-use formula that accurately quantifies transmission system performance

## Transmission system setup

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




## Test results




Error-free transmission for 23 hours, 17 minutes → BER < 3.0 $10^{-16}$

## 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.

NORTEL NORDUnet telindus together with ISTY SURF NET


REFERENCES [1] "OPERATIONAL SOLUTIONS FOR AN OPEN DWDM LAYER", O. GERSTEL ET AL, OFC'2009 | [2] "AT&T OPTICAL TRANSPORT SERVICES", BARBARA E. SMITH, OFC'09
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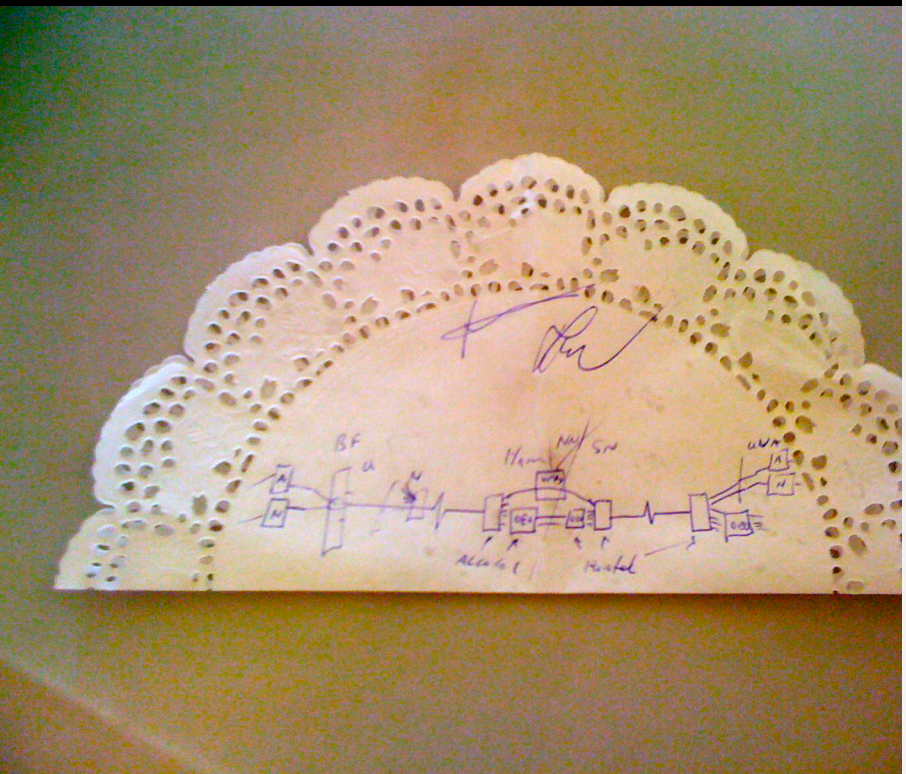

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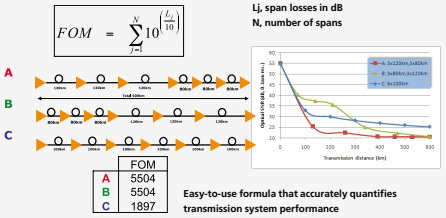


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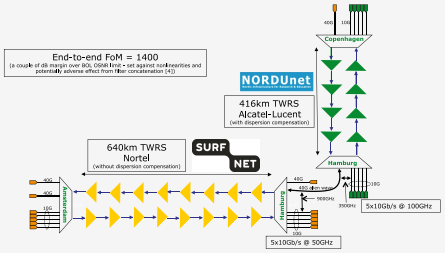


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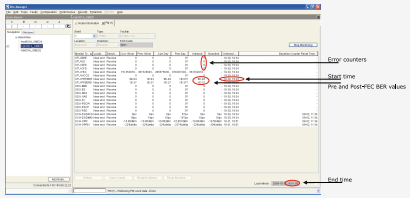


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# ClearStream @ TNC2011

Setup codename: FlightCees

UvA

iPerf
I7 3.2 GHz Q-core

iPerf
Amd Ph II 3.6 GHz HexC

Mellanox

40G E

Copenhagen

iPerf
2* dual 2.8 GHz Q-core

iPerf

Mellanox

CIENA OME 6500

CERN

Hamburg

CIENA DWDM

Alcatel DWDM

CIENA OME 6500

CIENA OME 6500

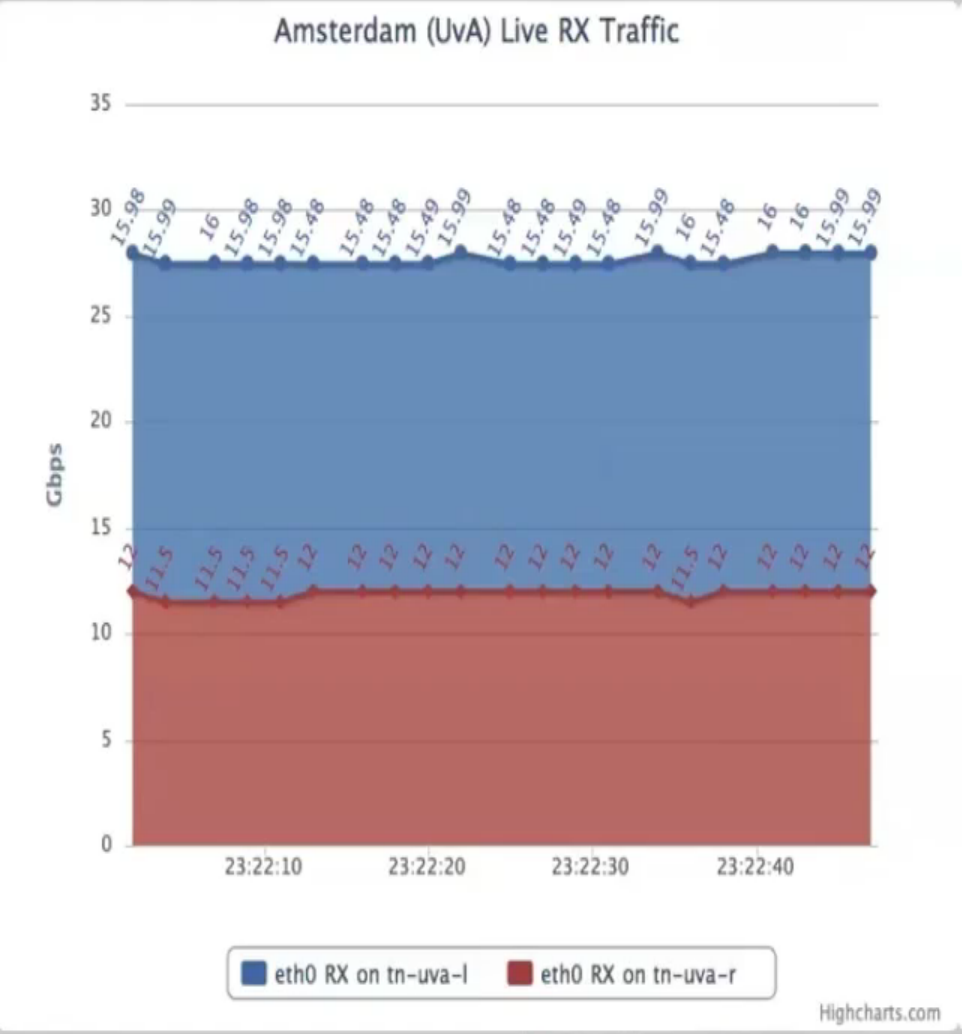
17 ms RTT

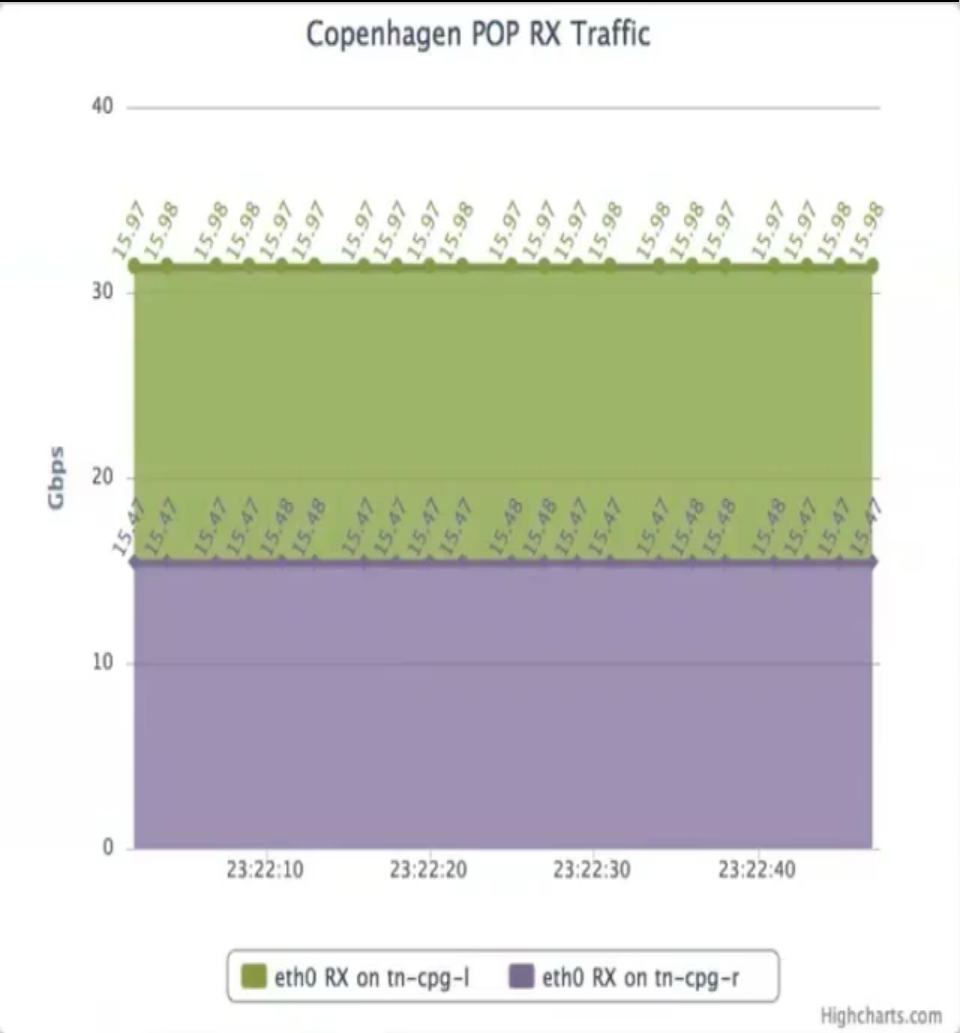
27 ms RTT

Amsterdam – Geneva (CERN) – Copenhagen – 4400 km (2700 km alien light)

# Visit CIENA Booth

## surf to http://tnc.delaat.net/tnc11

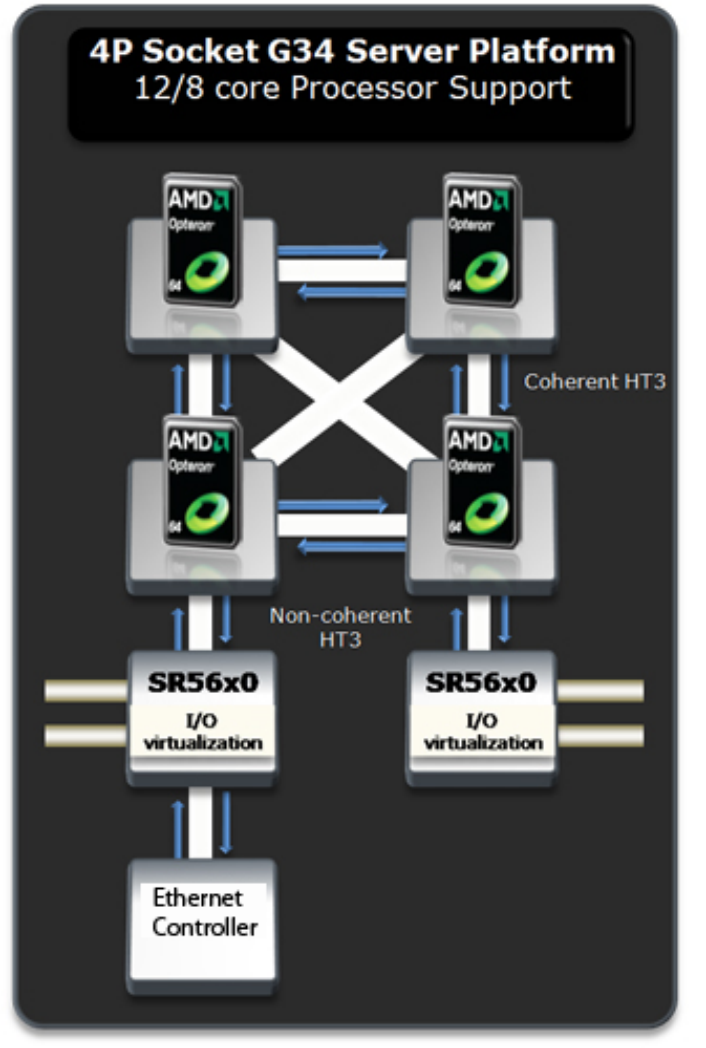



**27.99 Gbps to Amsterdam <-> 31.45 Gbps to Copenhagen**

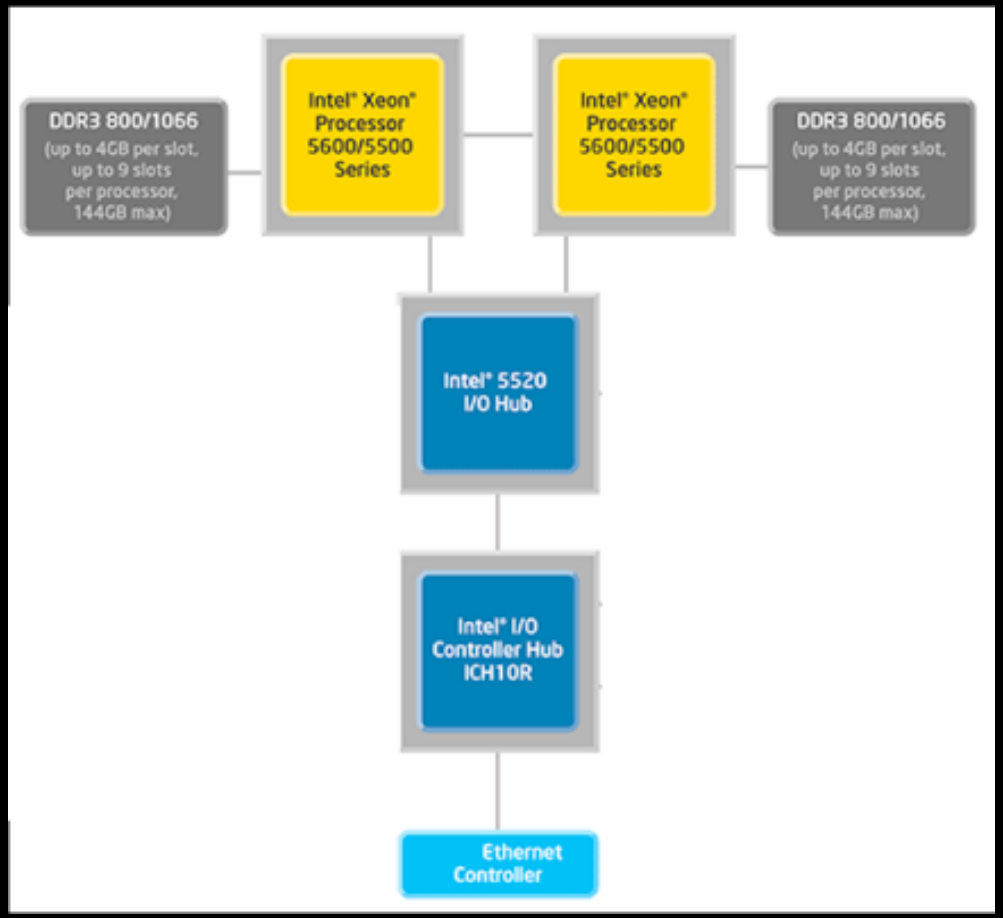
**Total Throughput 59.44 Gbps RTT 44.010 ms**

# Server Architecture




DELL R815

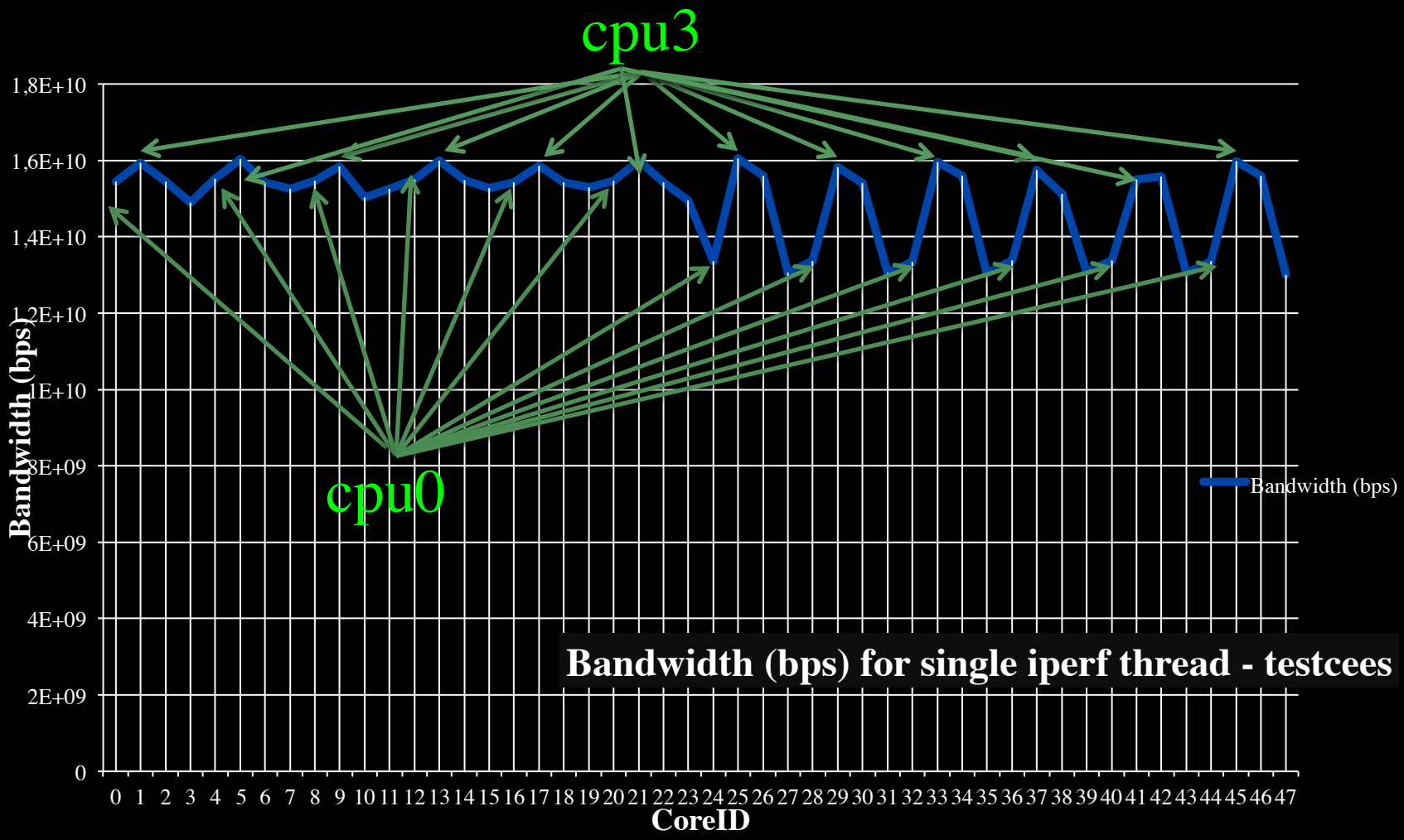
4 x AMD Opteron 6100




Supermicro X8DTT-HIBQF

2 x Intel Xeon

# CPU Topology benchmark




We used numactl to bind iperf to cores

# Mission

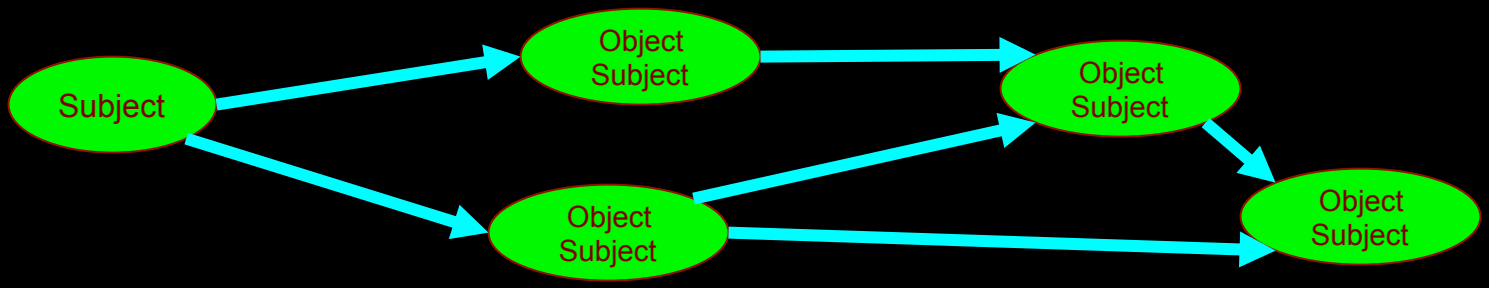
*Can we create smart and safe data processing infrastructures that can be tailored to diverse application needs?*

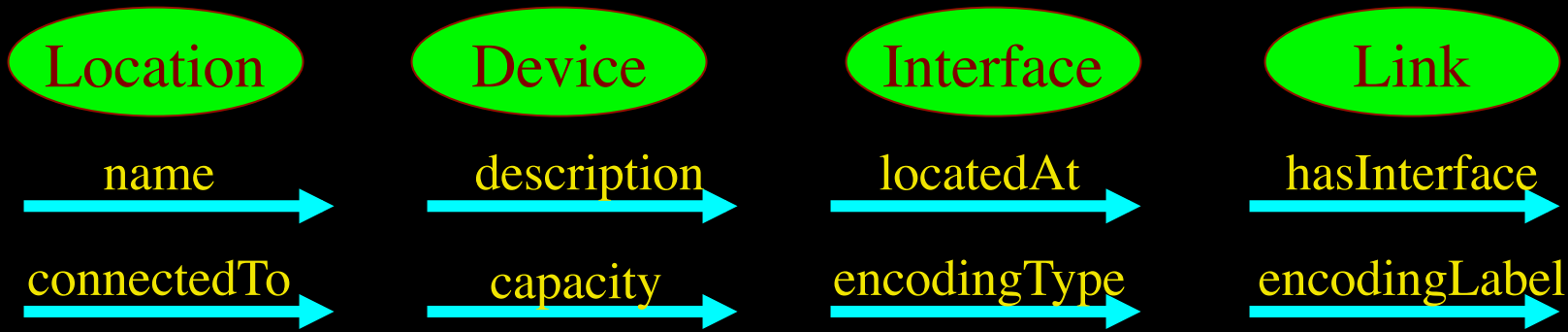
- *Capacity*
  - *Bandwidth on demand, QoS, architectures, photonics, performance*
- ***Capability***
  - ***Programmability, virtualization, complexity, semantics, workflows***
- *Security*
  - *Anonymity, integrity of data in distributed data processing*
- *Sustainability*
  - *Greening infrastructure, awareness*
- *Resilience*
  - *Systems under attack, failures, disasters*

We investigate: for complex networks!

# 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):

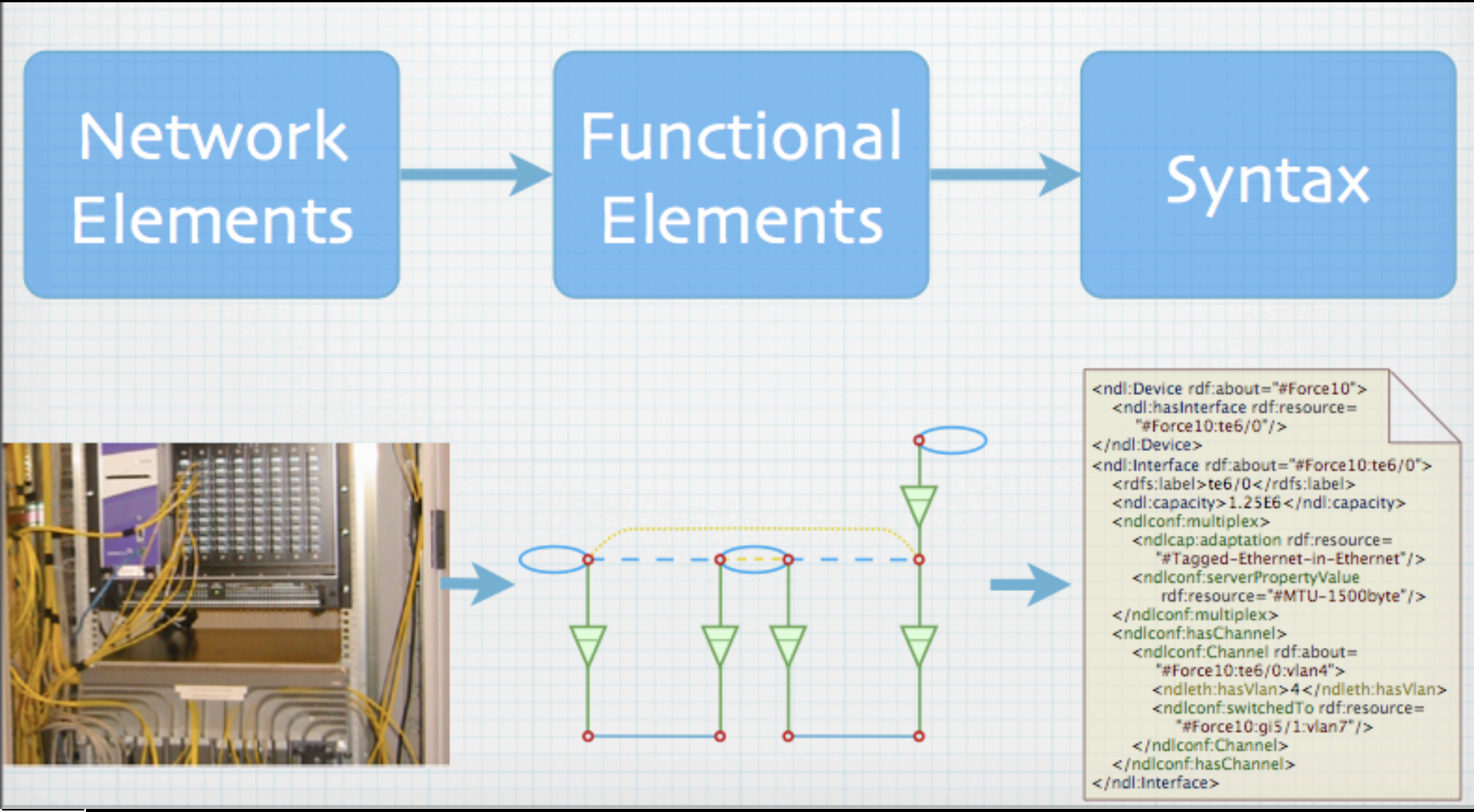



# Network Description Language

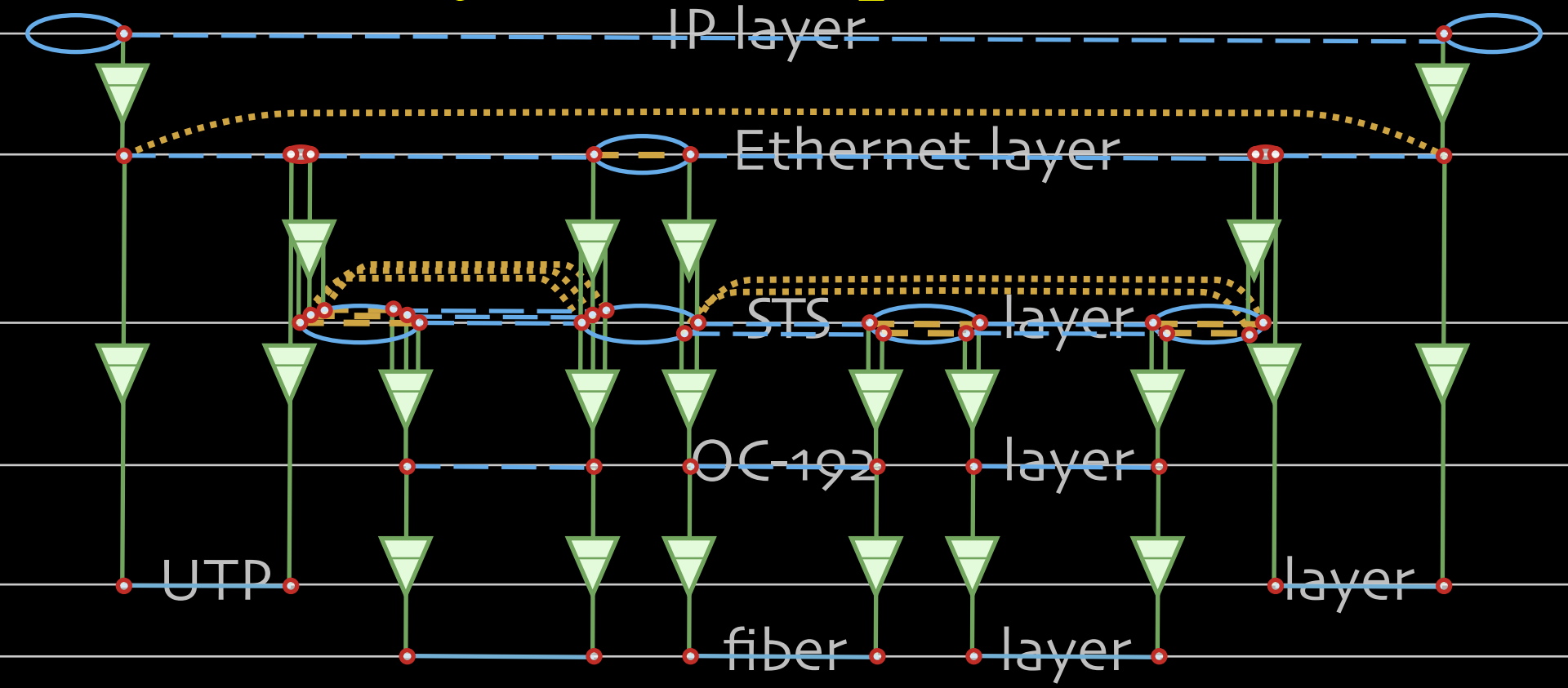
Choice of RDF instead of XML syntax

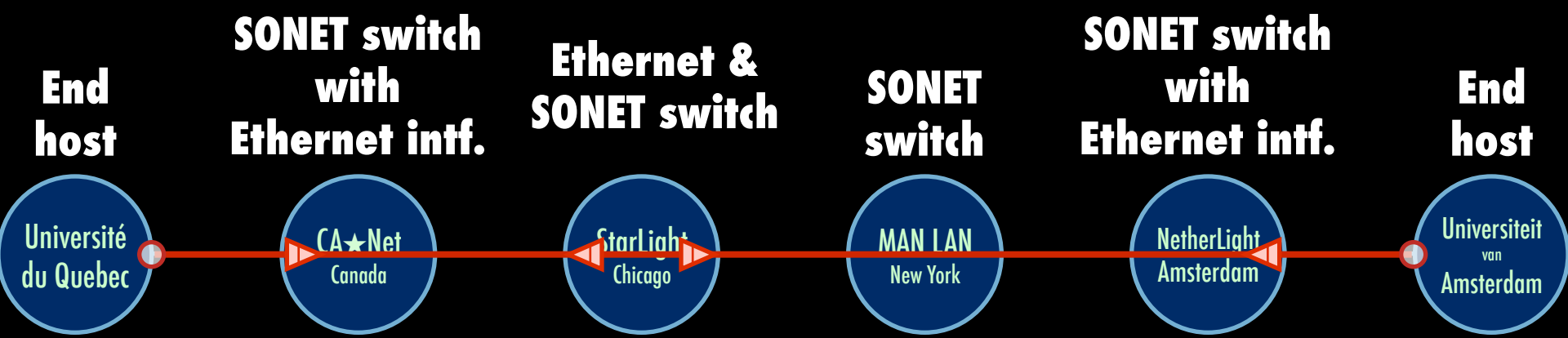
Grounded modeling based on G0805 description:

Article: F. Dijkstra, B. Andree, K. Koymans, J. van der Ham, P. Grosso, C. de Laat, *"A Multi-Layer Network Model Based on ITU-T G.805"*

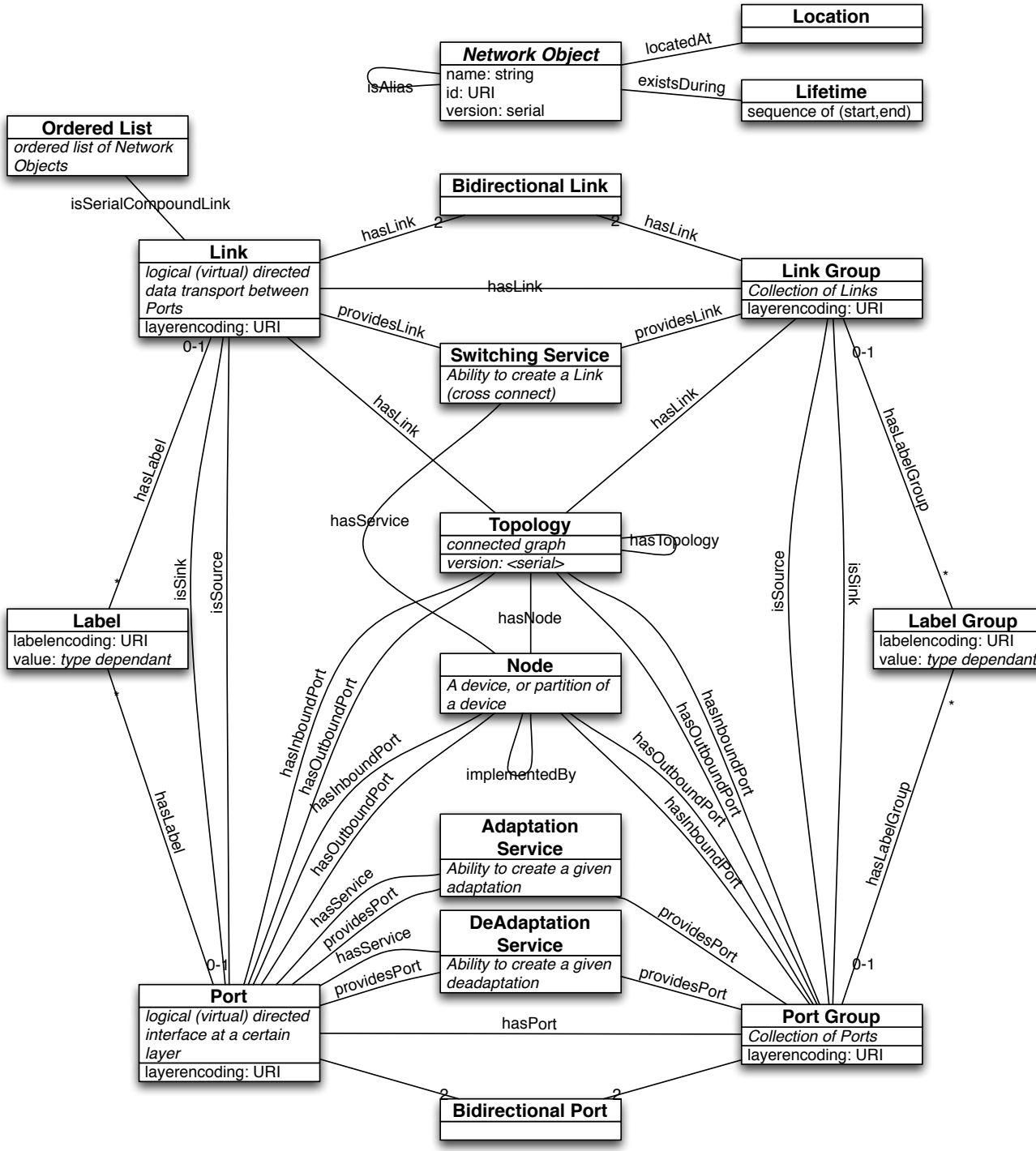


# Multi-layer descriptions in NDL



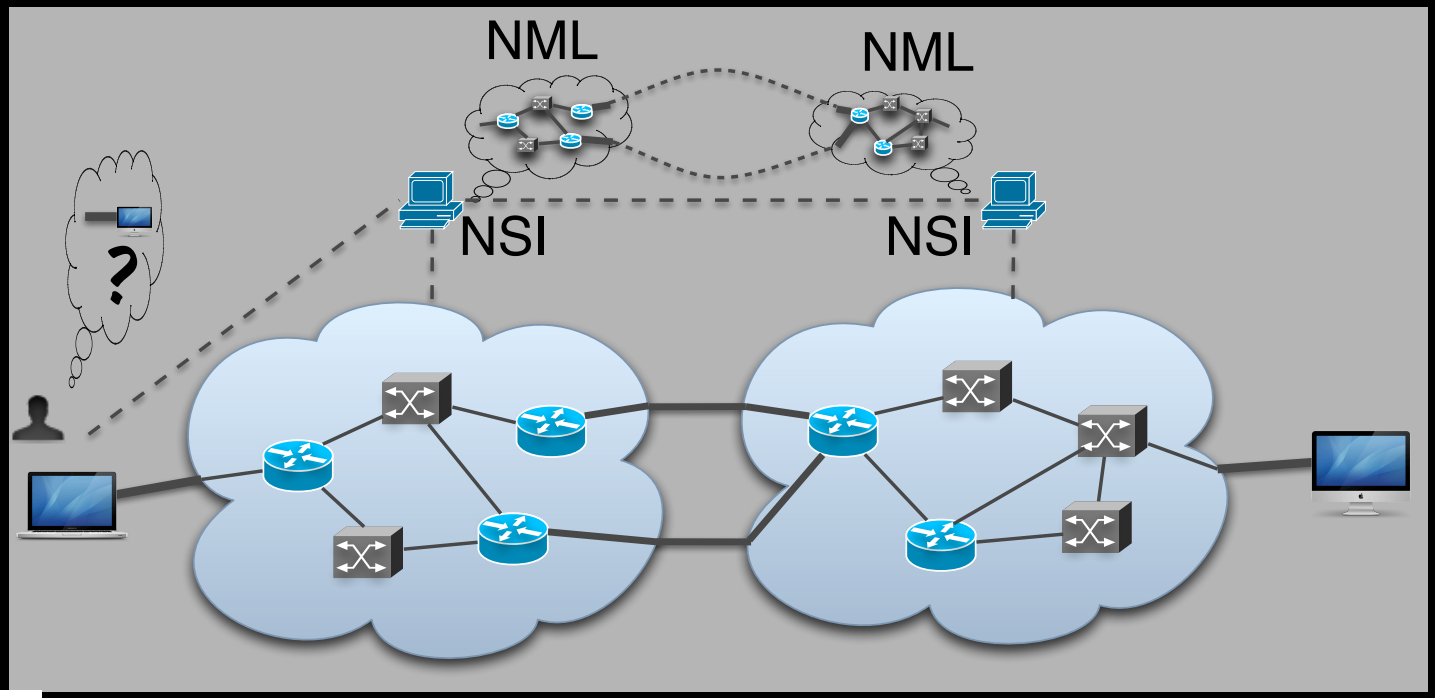
# NML
# OGF spec


Location
Network Object
name: string
id: URI
version: serial
locatedAt
existsDuring
Lifetime
sequence of (start,end)
isAlias
Ordered List
ordered list of Network Objects
isSerialCompoundLink
Bidirectional Link
hasLink
2
2
hasLink
Link
logical (virtual) directed data transport between Ports
layerencoding: URI
hasLink
Link Group
Collection of Links
layerencoding: URI
providesLink
providesLink
0-1
Switching Service
Ability to create a Link (cross connect)
0-1
hasLabel
hasLink
hasLink
hasLabelGroup
hasService
Topology
connected graph
version: <serial>
hasTopology
isSink
isSource
isSource
isSink
Label
labelencoding: URI
value: type dependant
hasNode
Label Group
labelencoding: URI
value: type dependant
Node
A device, or partition of a device
hasInboundPort
hasOutboundPort
hasInboundPort
hasOutboundPort
implementedBy
hasOutboundPort
hasInboundPort
hasOutboundPort
hasInboundPort
hasLabel
hasLabelGroup
Adaptation Service
Ability to create a given adaptation
hasService
providesPort
providesPort
DeAdaptation Service
Ability to create a given deadaptation
hasService
providesPort
providesPort
0-1
0-1
Port
logical (virtual) directed interface at a certain layer
layerencoding: URI
hasPort
Port Group
Collection of Ports
layerencoding: URI
2
2
Bidirectional Port

# Network Topology Description

Network topology research supporting automatic network provisioning

- Inter-domain networks
- Multiple technologies
- Based on incomplete information
- Possibly linked to other resources

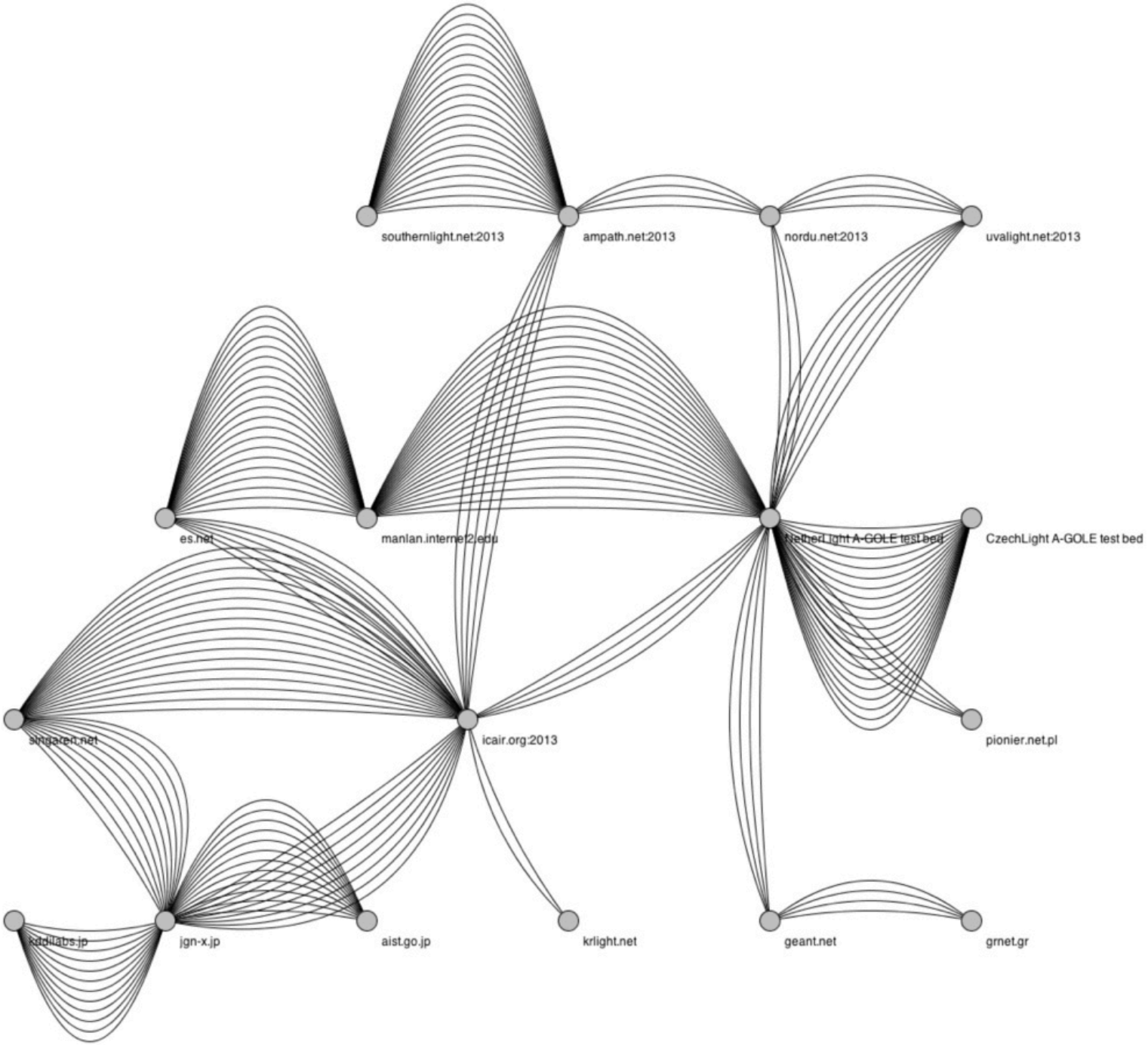



OpenGridForum
OPEN FORUM | OPEN STANDARDS

http://redmine.ogf.org/projects/nml-wg
http://redmine.ogf.org/projects/nsi-wg

http://sne.science.uva.nl/ndl

# GLIF 2013 in NML



# CdL

Applications and Networks become aware of each other!

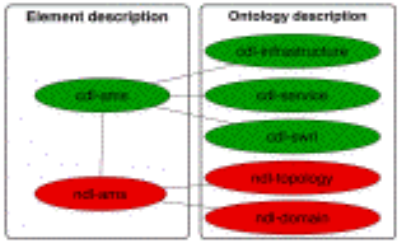
## CineGrid Description Language

CineGrid is an initiative to facilitate the exchange, storage and display of high-quality digital media.

The CineGrid Description Language (CDL) describes CineGrid resources. Streaming, display and storage components are organized in a hierarchical way.

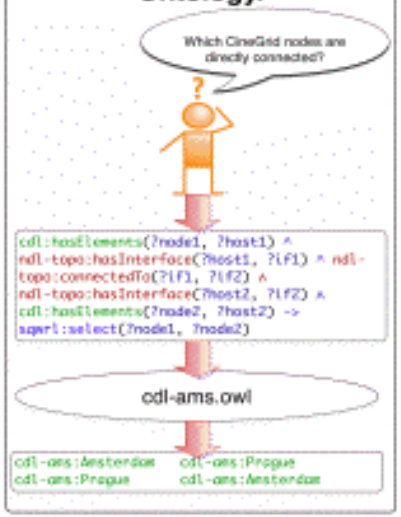
CDL has bindings to the NDL ontology that enables descriptions of network components and their interconnections.

With CDL we can reason on the CineGrid infrastructure and its services.




### UML representation of CDL

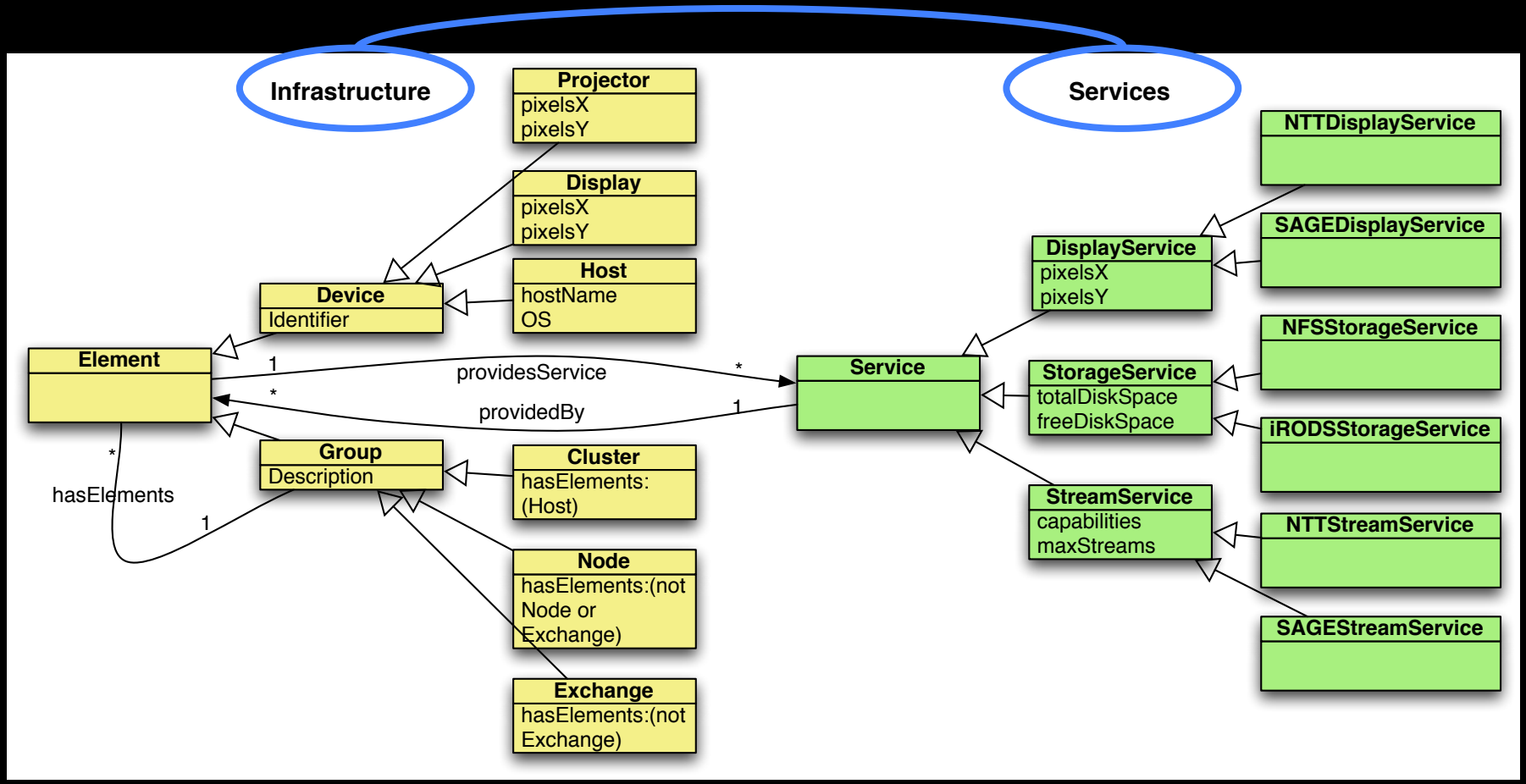
### SQWRL is used to query the Ontology.




***CDL*** links to ***NDL*** using the ***owl:SameAs*** property. ***CDL*** defines the services, ***NDL*** the network interfaces and links. The combination of the two ontologies identifies the host pairs that support matching services via existing network connections.

# Information Modeling

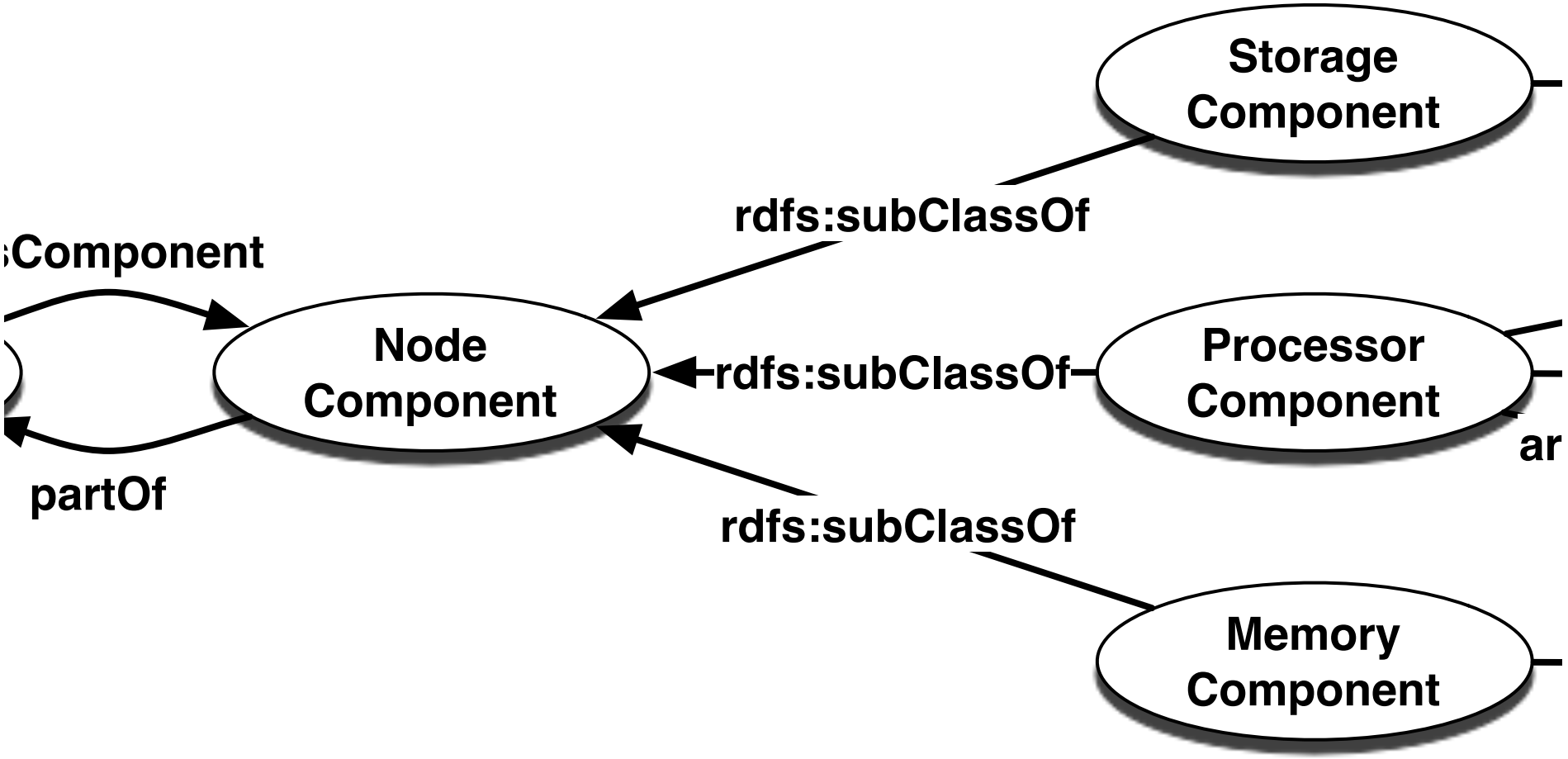
Define a common information model for ***infrastructures*** and ***services***.
Base it on Semantic Web.



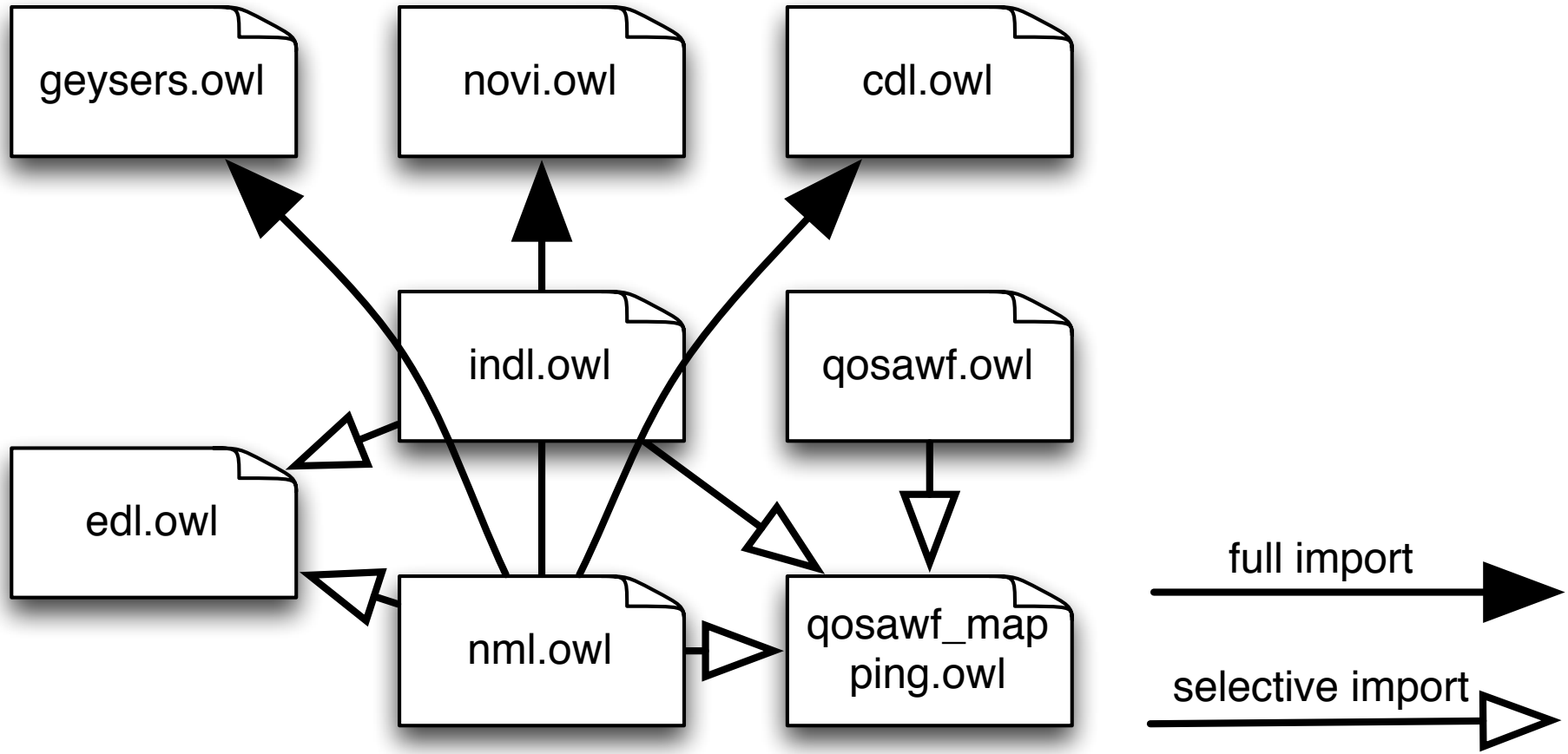

J. van der Ham, F. Dijkstra, P. Grosso, R. van der Pol, A. Toonk, C. de Laat
*A distributed topology information system for optical networks based on the semantic web*, Elsevier Journal on Optical Switching and Networking, Volume 5, Issues 2-3, June 2008, Pages 85-93

R.Koning, P.Grosso and C.de Laat
*Using ontologies for resource description in the CineGrid Exchange*
In: Future Generation Computer Systems (2010)

# Node components

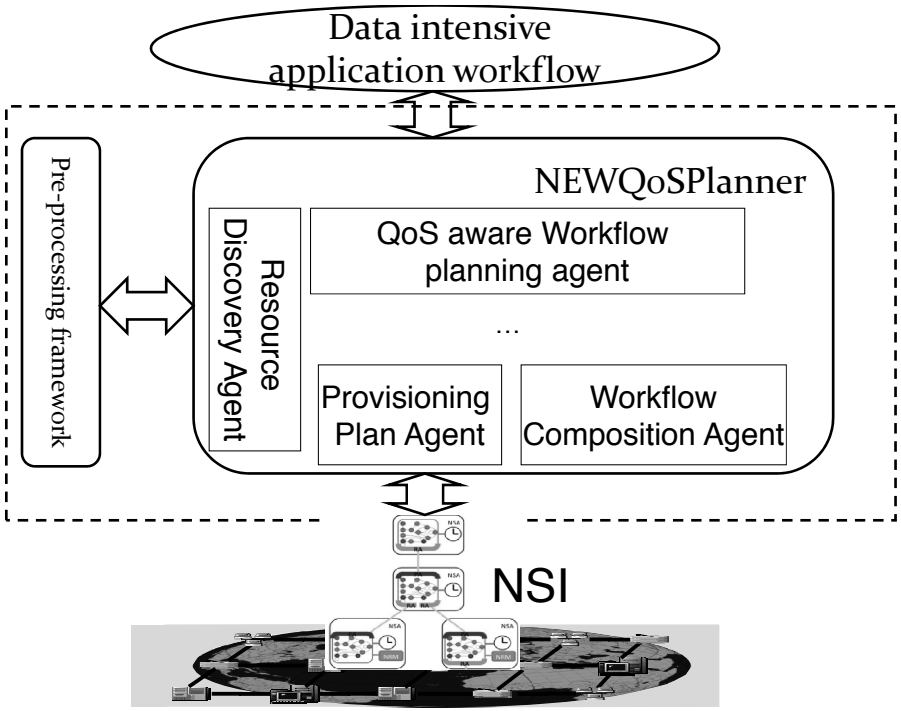


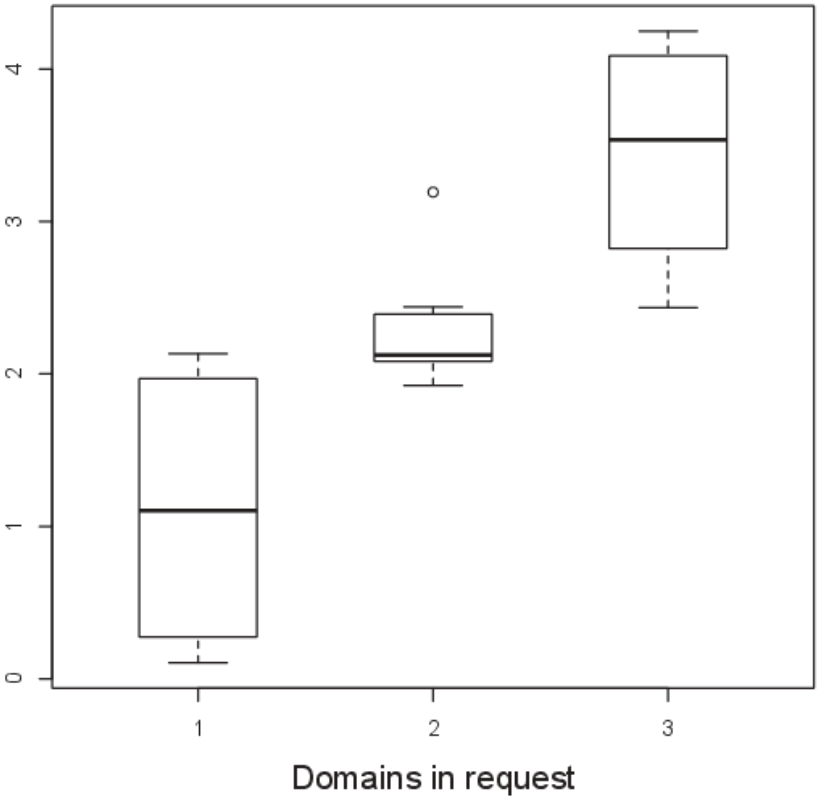
# Our connecting models



# NewQOSPlanner

The NSI – Network Service Interface – creates on the fly connections between domains.

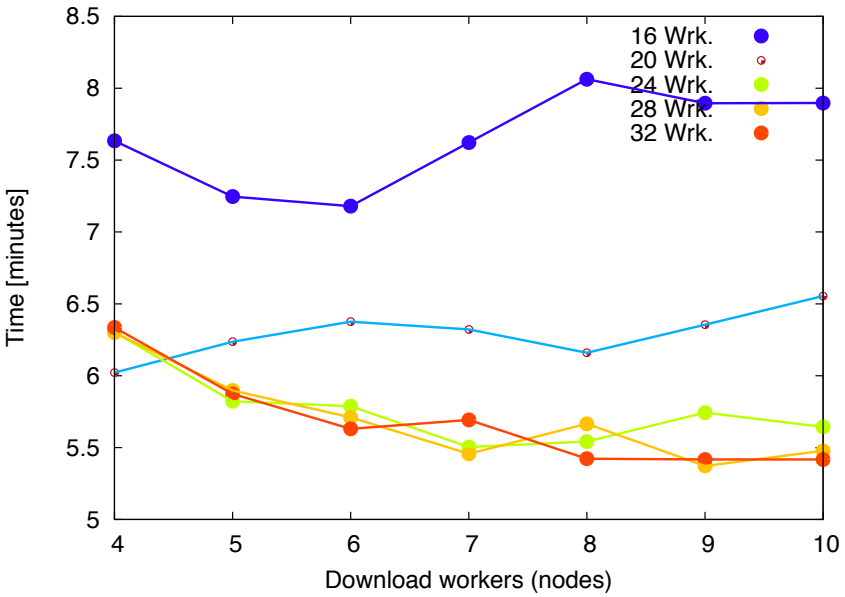


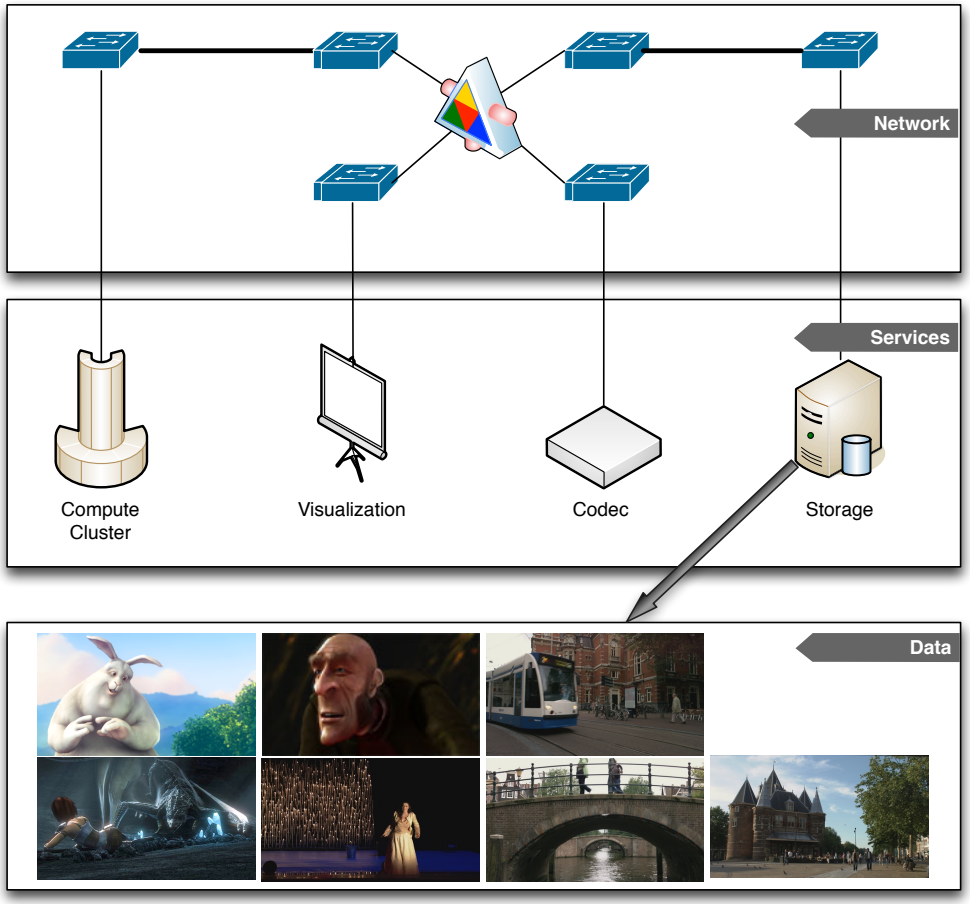




Z. Zhao, J. v/d Ham, A. Taal, R. Koning, P. Grosso and C. de Laat
*Planning data intensive workflows on inter-domain resources using the Network Service Interface (NSI)* In: WORKS 2012

# HyperFlow

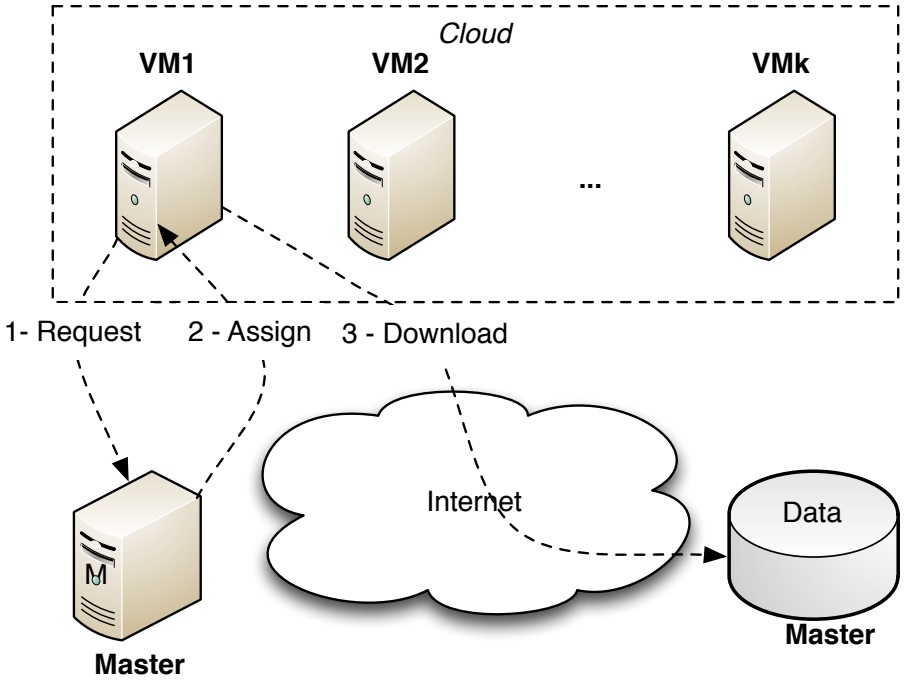
Encoding times improve as the end nodes are connected via dynamic lightpaths

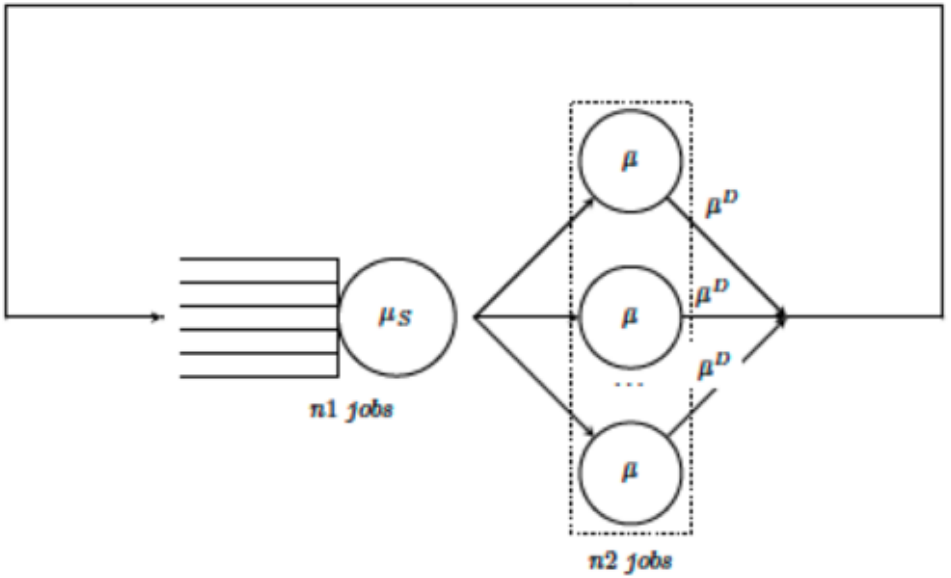


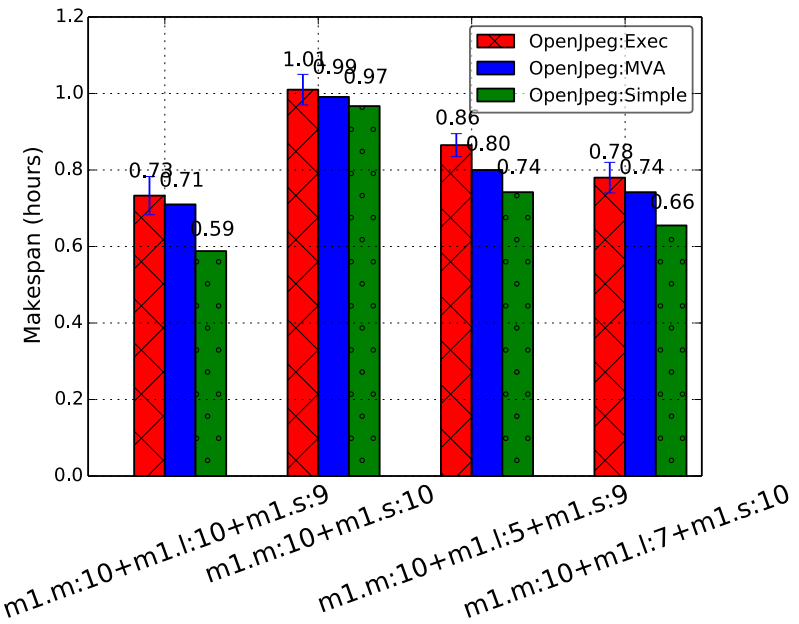

C. Dumitru, Z. Zhao, P. Grosso and C. de Laat
*HybridFlow: Towards Intelligent Video Delivery and Processing Over Hybrid Infrastructures*
(In CTS 2013))

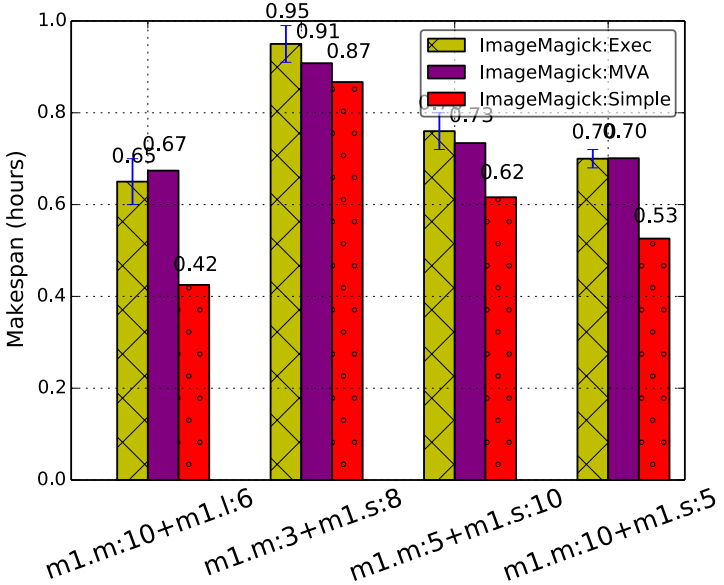
# A queuing model approach

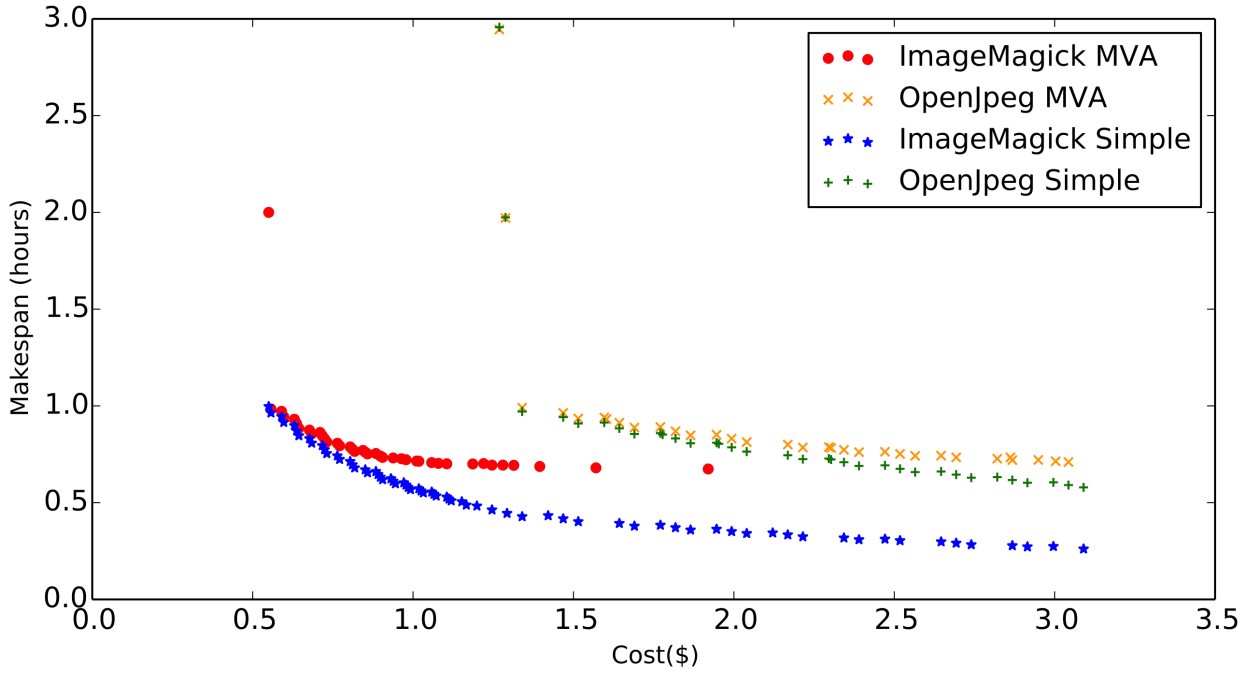


# Pareto fronts




Cosmin Dumitru, Ana-Maria Oprescu, Miroslav Zivkovic, Rob van der Mei, Paola Grosso, Cees de Laat, "A Queueing Theory Approach to Pareto Optimal Bags-of-Tasks Scheduling on Clouds", accepted for Euro-Par 2014

# Mission

*Can we create smart and safe data processing infrastructures that can be tailored to diverse application needs?*

- *Capacity*
  - *Bandwidth on demand, QoS, architectures, photonics, performance*
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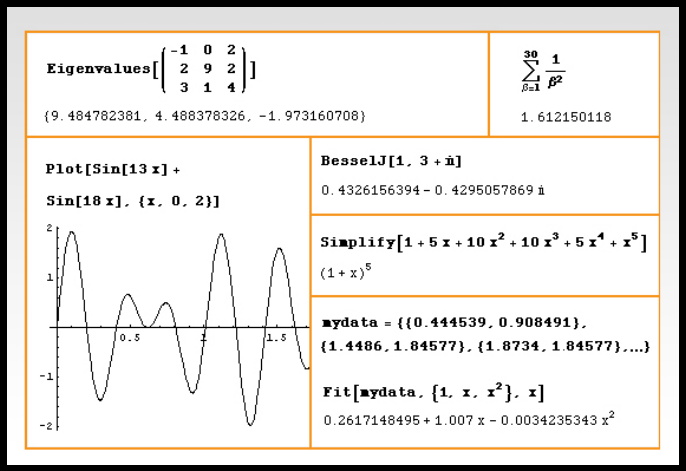
  - ***Programmability, virtualization, complexity, semantics, workflows***
- *Security*
  - *Anonymity, integrity of data in distributed data processing*
- *Sustainability*
  - *Greening infrastructure, awareness*
- ***Resilience***
  - ***Systems under attack, failures, disasters***

# Tera-Thinking

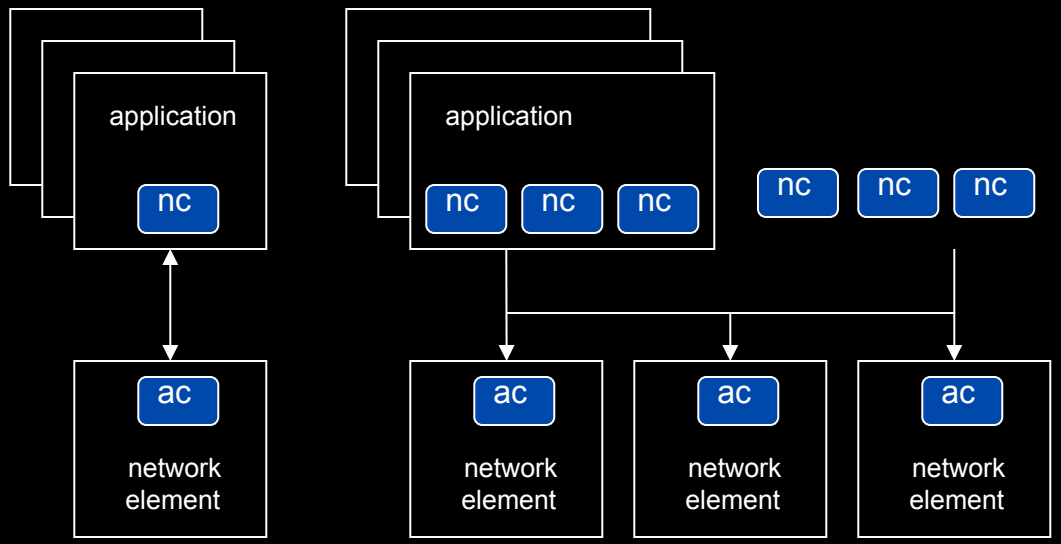
- What constitutes a Tb/s network?
- think back to teraflop computing!
  - MPI turns a room full of pc's in a teraflop machine
- massive parallel channels in hosts, NIC's
- TeraApps programming model supported by
  - TFlops -> MPI / Globus / Cloud
  - TBytes -> DAIS / MONETdb …
  - TPixels -> SAGE
  - TSensors -> LOFAR, LHC, LOOKING, CineGrid, ...
  - Tbit/s -> ?
  - ? -> Programmable Networks

# User Programmable Virtualized Networks allows the results of decades of computer science to handle the complexities of application specific networking.

- The network is virtualized as a collection of resources
- UPVNs enable network resources to be programmed as part of the application
- Mathematica, a powerful mathematical software system, can interact with real networks using UPVNs







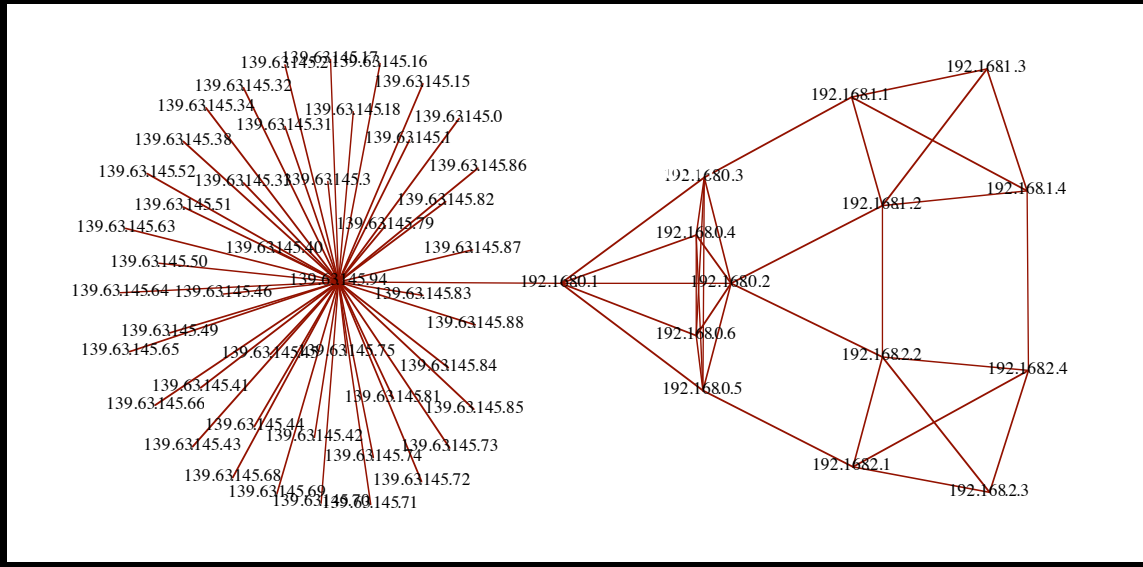

StarPlane

# Mathematica enables advanced graph queries, visualizations and real-time network manipulations on UPVNs

## Topology matters can be dealt with algorithmically
## Results can be persisted using a transaction service built in UPVN

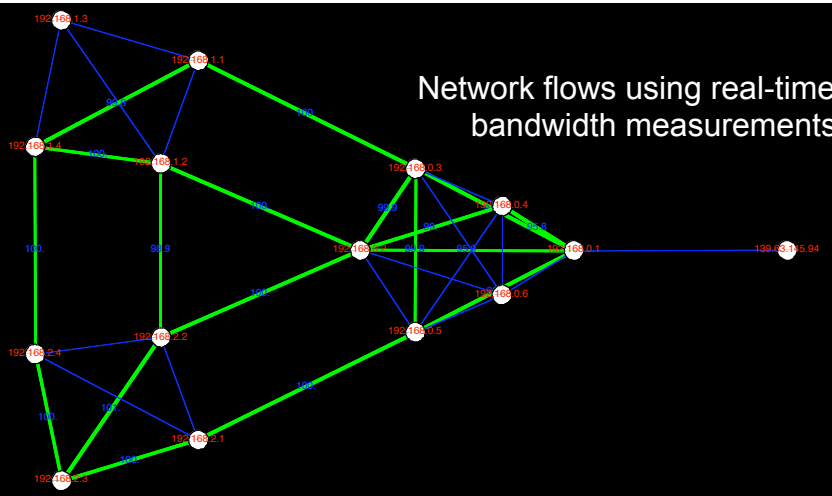
### Initialization and BFS discovery of NEs

```
Needs["WebServices`"]
<<DiscreteMath`Combinatorica`
<<DiscreteMath`GraphPlot`
InitNetworkTopologyService["edge.ict.tno.nl"]

Available methods:

{DiscoverNetworkElements,GetLinkBandwidth,GetAllIpLinks,Remote,
NetworkTokenTransaction}

Global`upvnverbose = True;

AbsoluteTiming[nes = BFSDiscover["139.63.145.94"];][[1]]

AbsoluteTiming[result = BFSDiscoverLinks["139.63.145.94", nes];][[1]]

Getting neigbours of: 139.63.145.94
Internal links: {192.168.0.1, 139.63.145.94}
(...)
Getting neigbours of:192.168.2.3

Internal links: {192.168.2.3}
```




### Transaction on shortest path with tokens

```
nodePath = ConvertIndicesToNodes[
ShortestPath[
g,
Node2Index[nids,"192.168.3.4"],
Node2Index[nids,"139.63.77.49"]],
nids];
Print["Path: ", nodePath];
If[NetworkTokenTransaction[nodePath, "green"]==True,
Print["Committed"], Print["Transaction failed"]];

Path:
{192.168.3.4,192.168.3.1,139.63.77.30,139.63.77.49}

Committed
```



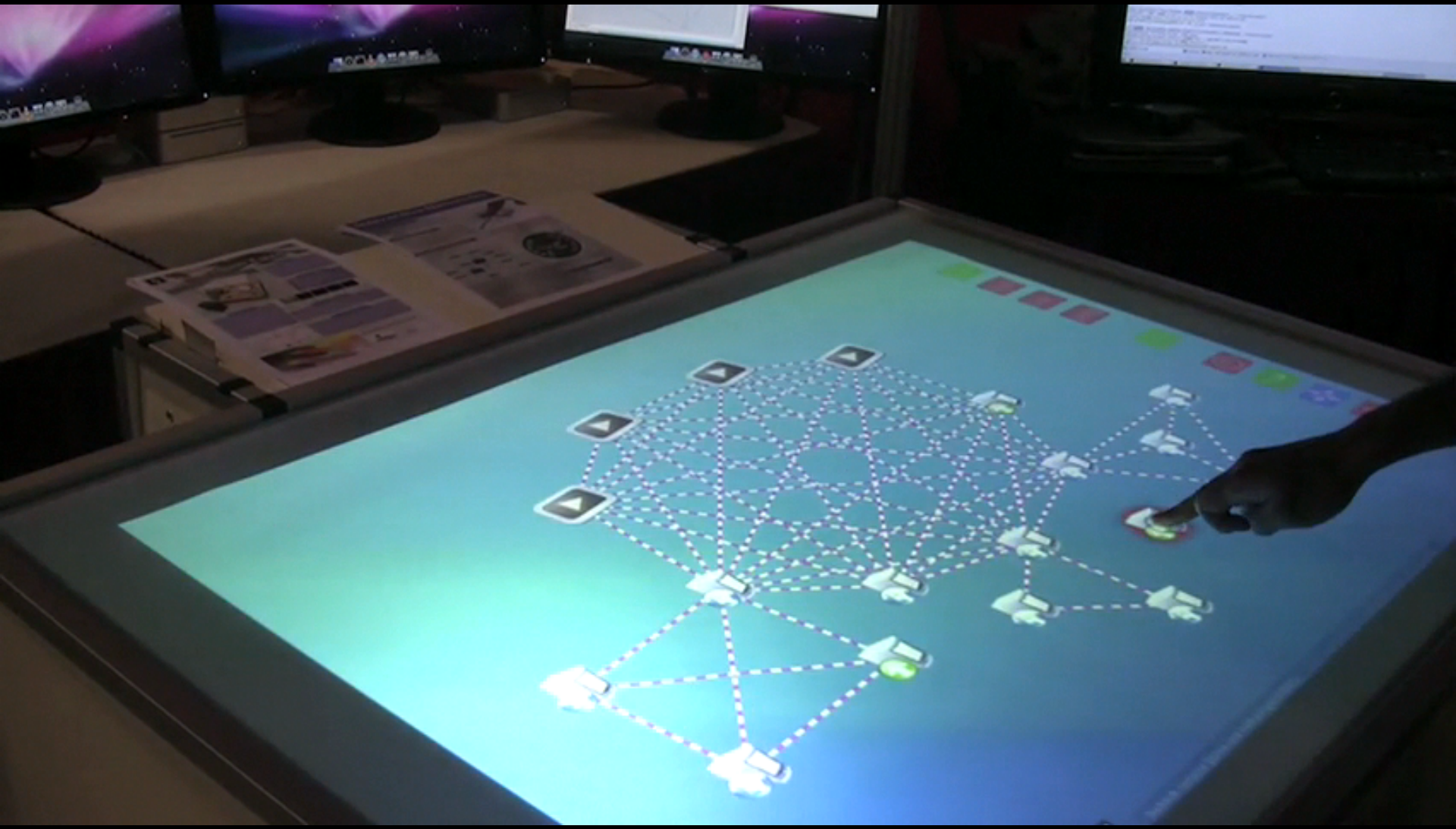
Network flows using real-time bandwidth measurements

ref: Robert J. Meijer, Rudolf J. Strijkers, Leon Gommans, Cees de Laat, User Programmable Virtualiized Networks, accepted for publication to the IEEE e-Science 2006 conference Amsterdam.

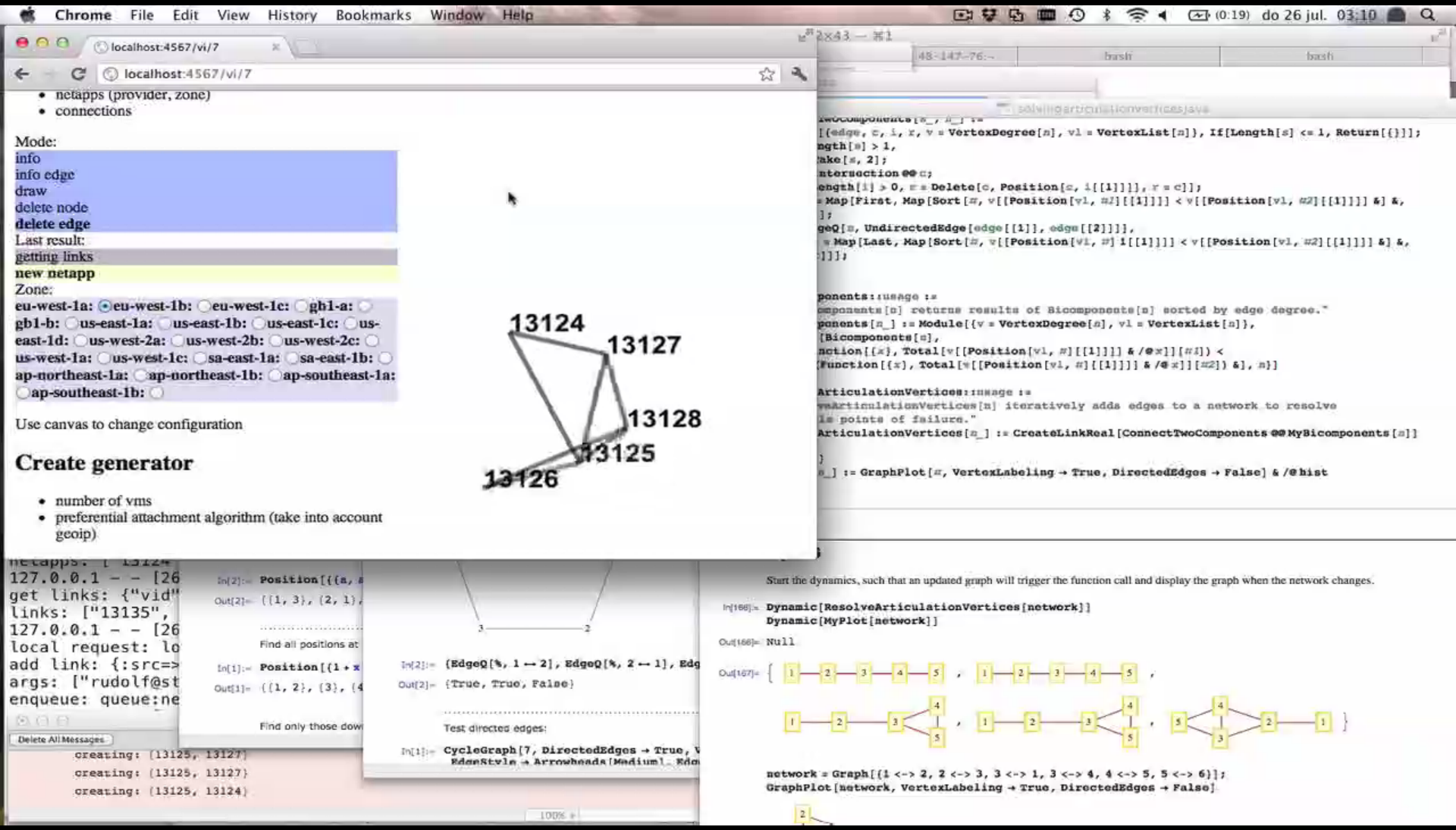
StarPlane

# CDN on Demand in the cloud

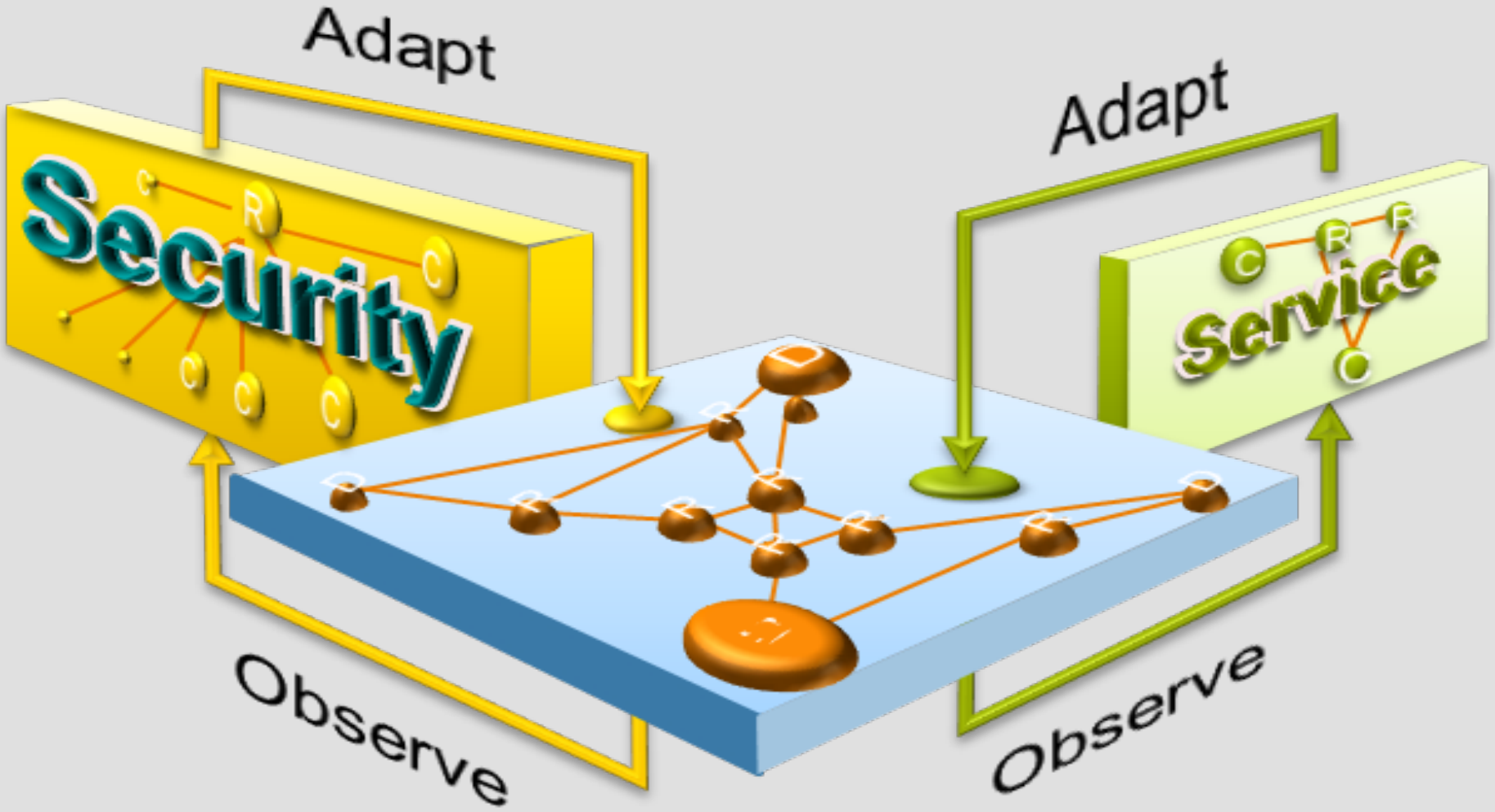
# Interactive programmable networks



# Basic operating system loop



# SMART Infrastructure



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  - *Greening infrastructure, awareness*
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  - *Systems under attack, failures, disasters*

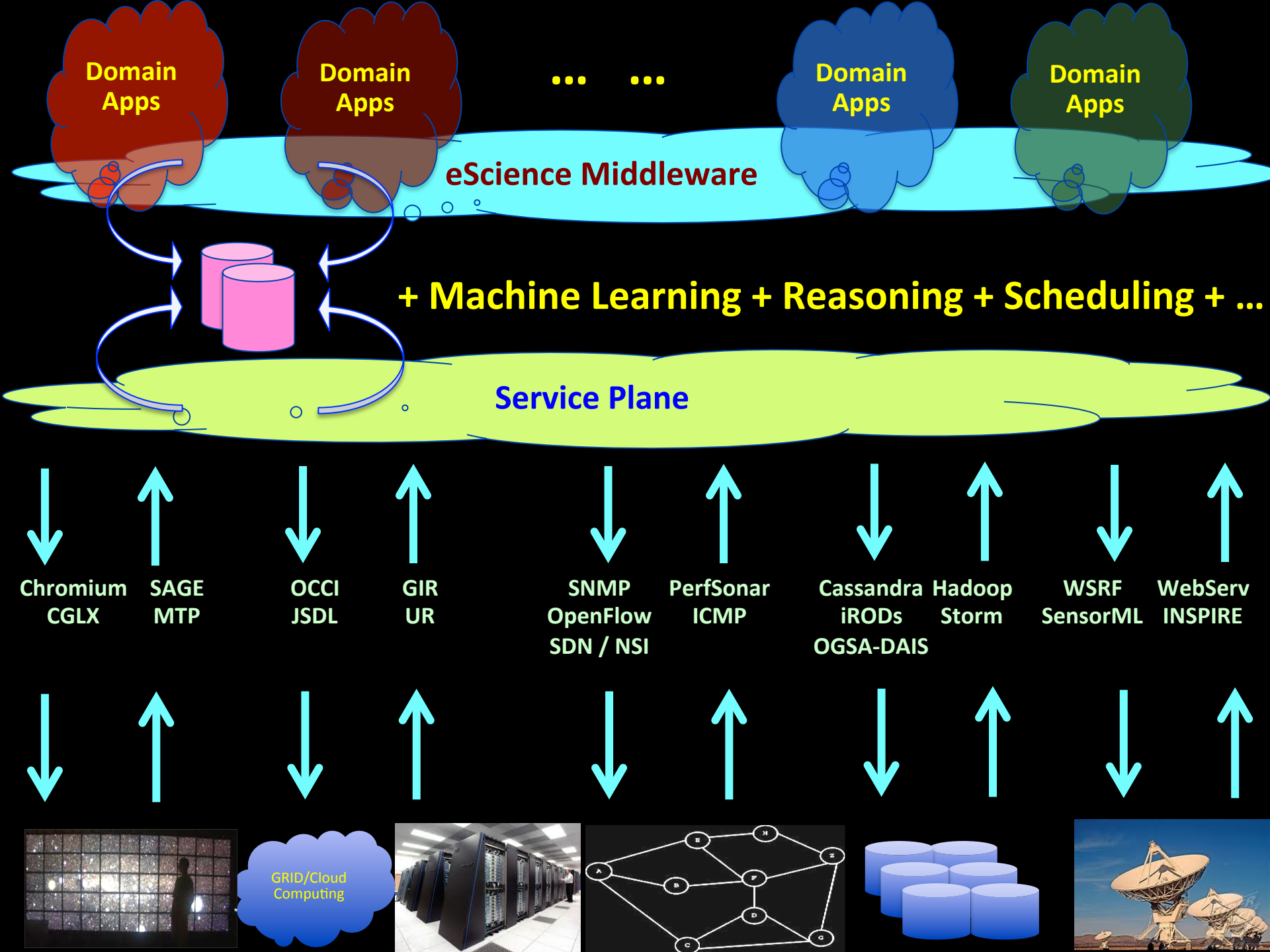
SMART

# 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.

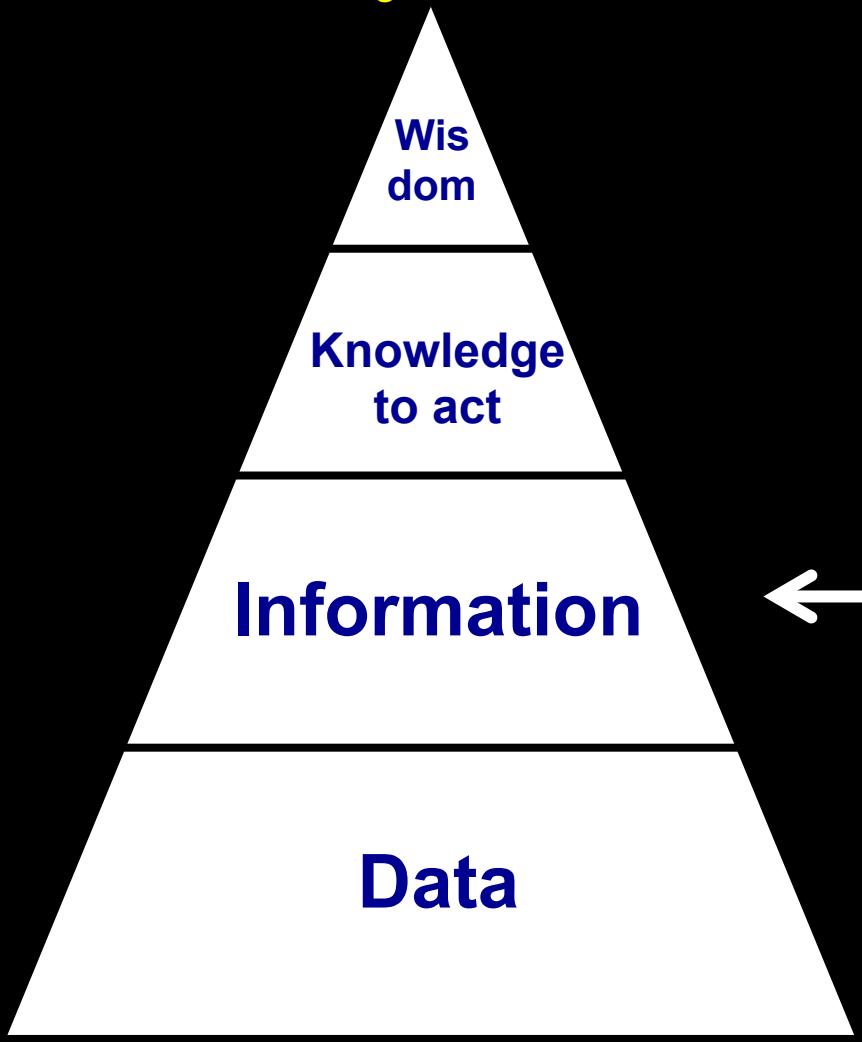
➔ His refrigerator also just works!

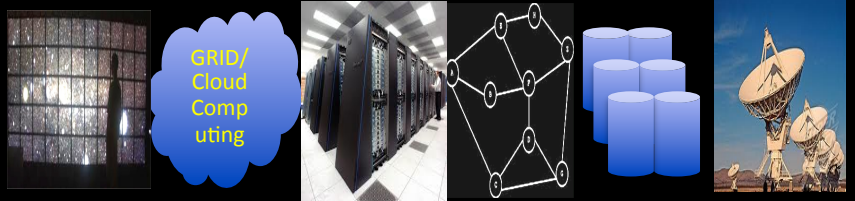

Domain Apps
Domain Apps
... ...
Domain Apps
Domain Apps
eScience Middleware
+ Machine Learning + Reasoning + Scheduling + …
Service Plane
Chromium CGLX
SAGE MTP
OCCI JSDL
GIR UR
SNMP OpenFlow SDN / NSI
PerfSonar ICMP
Cassandra iRODs OGSA-DAIS
Hadoop Storm
WSRF SensorML
WebServ INSPIRE
GRID/Cloud Computing

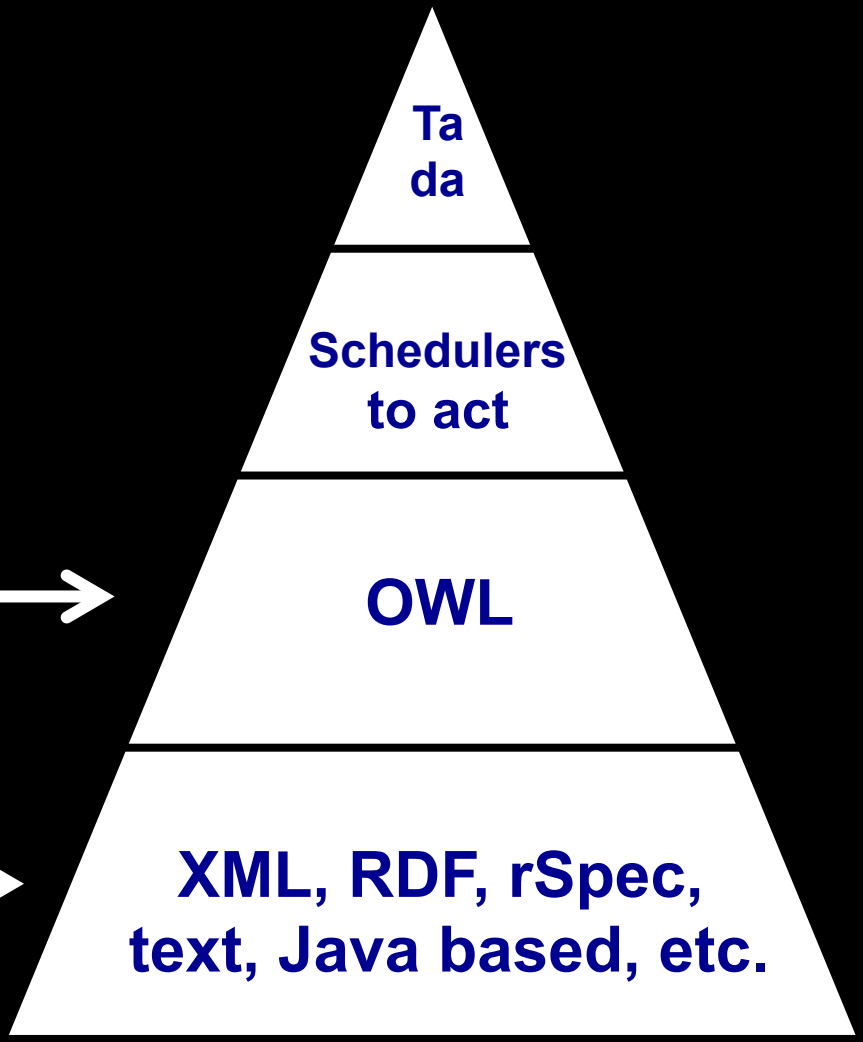
# Layers

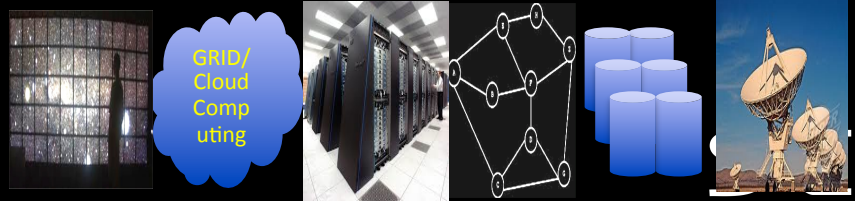
Doing Science

ICT to enable Science



# The Big Data Challenge

Doing Science

ICT to enable Science

Wis
dom

Knowledge

Data

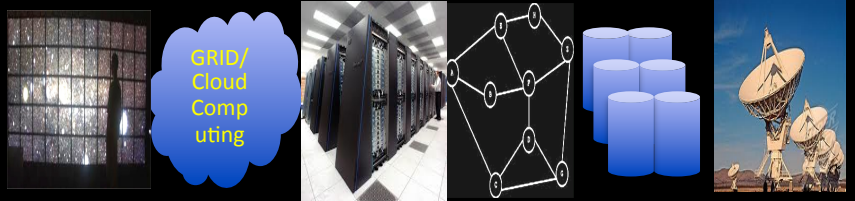
Ta
da

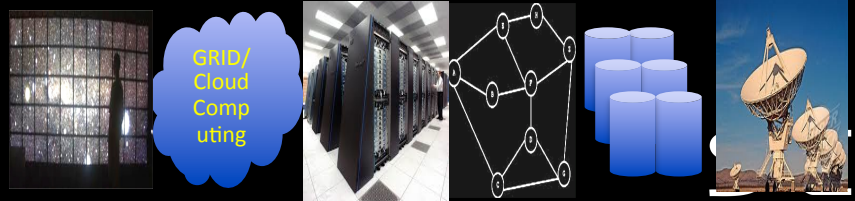
Schedulers

XML, RDF, rSpec,
text, Java based, etc.

MAGIC DATA CARPET

curation – description – security – policy – integrity - storage



If
“out of time”
then
“jump to slide 59”
else
“next slide”

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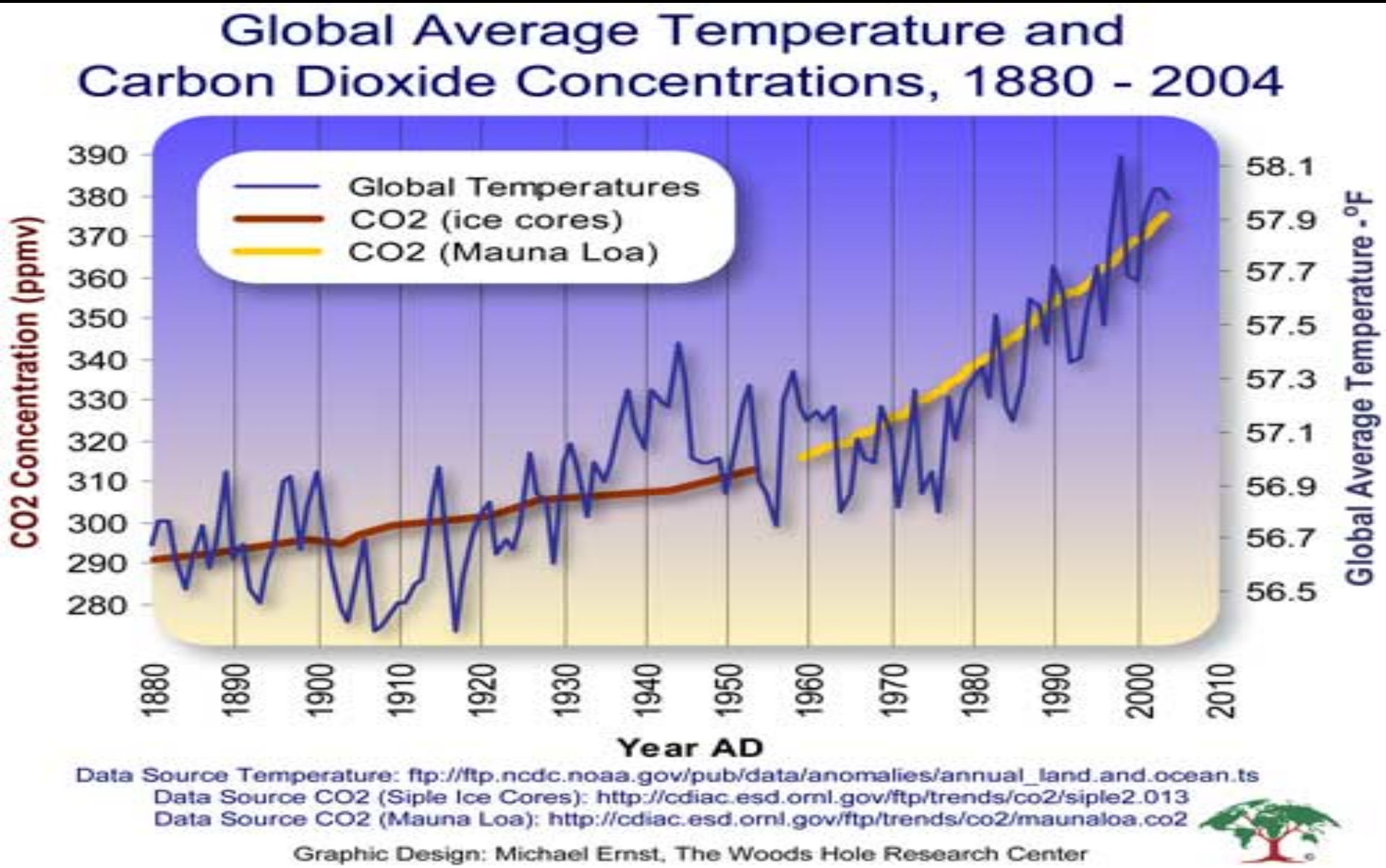
# Need for GreenIT

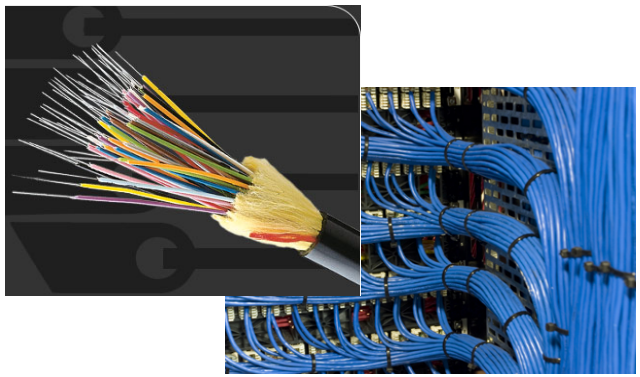


# Greening the Processing

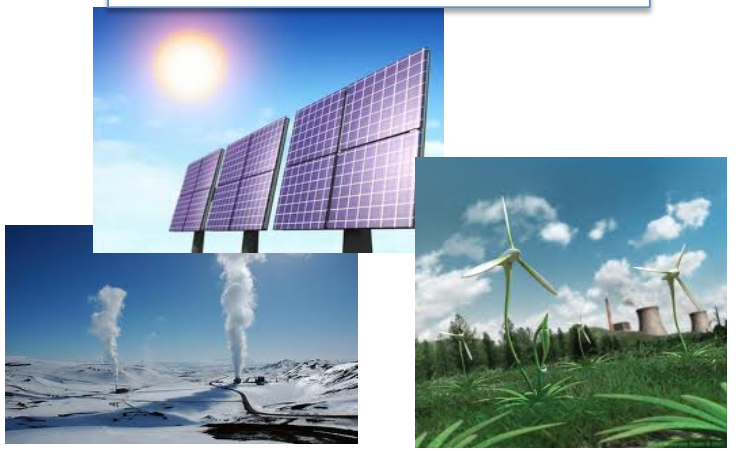
# ECO-Scheduling

# Green scheduling

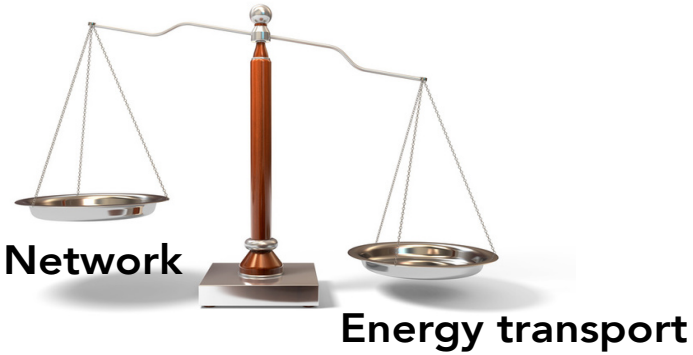
**Network infrastructures**



**Green energy sources**

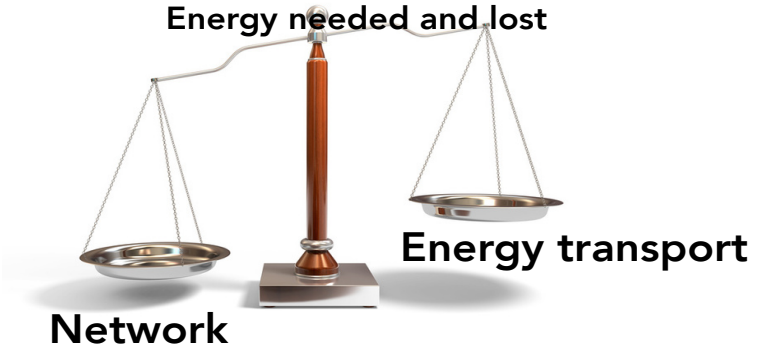


$CO_2$ footprint;
Energy needed and lost



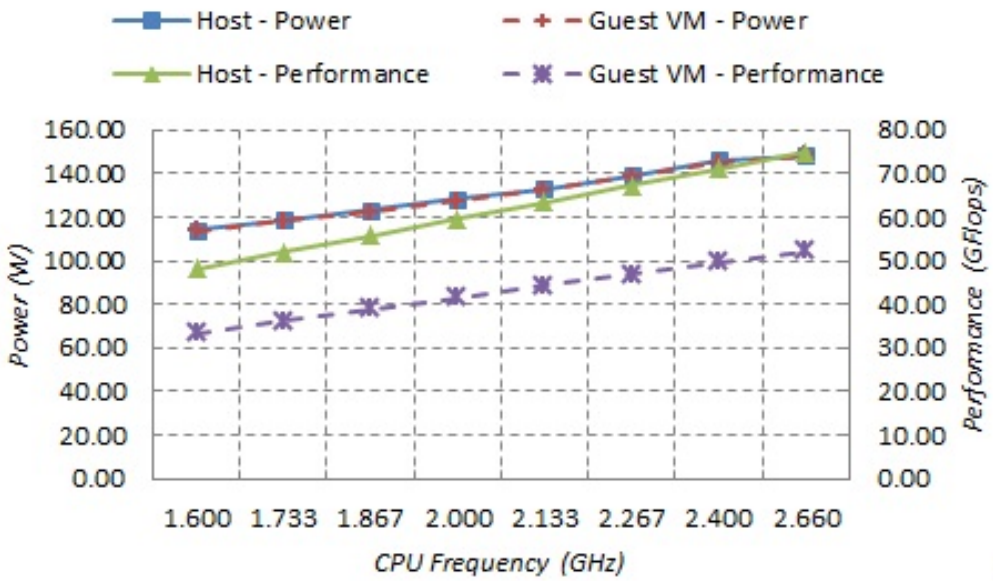

*Bits to energy*

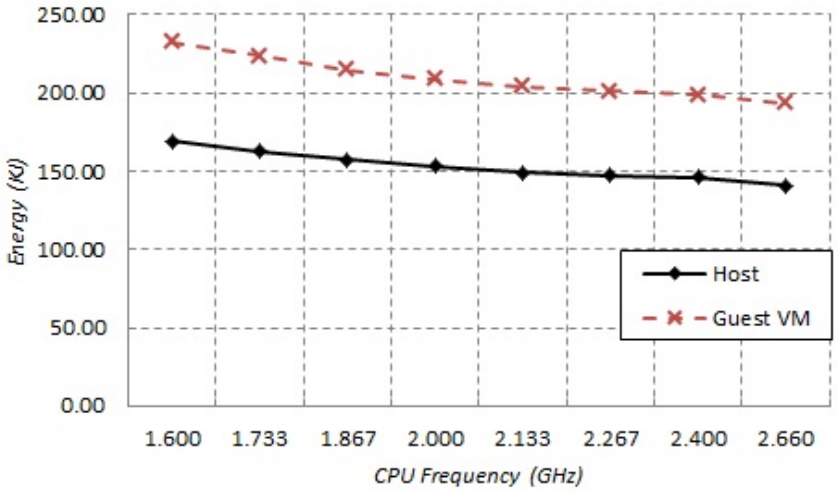
$CO_2$ footprint;
Energy needed and lost



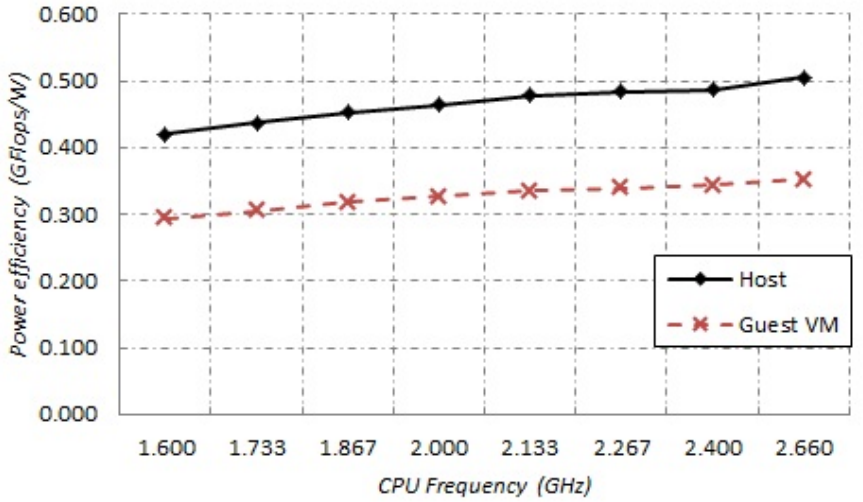

*Energy to bits*

# Energy saving in clouds




Quantifying the energy performance of VMs is the first step toward energy-aware job scheduling.

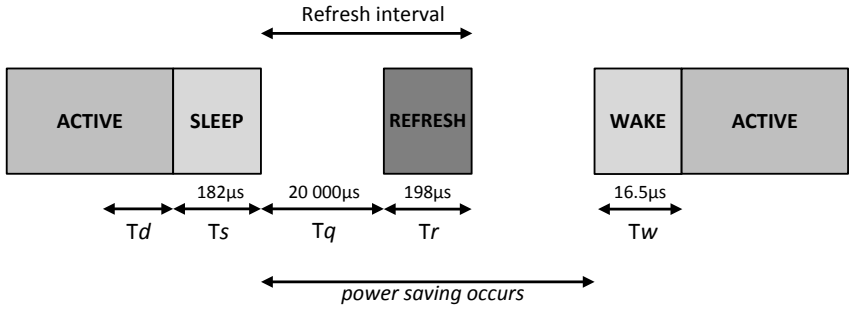


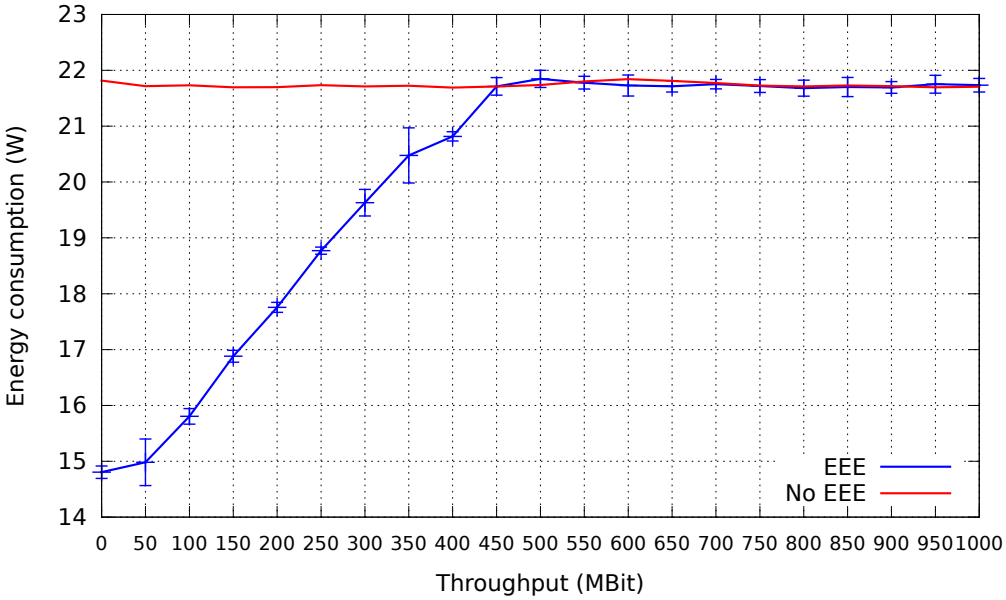


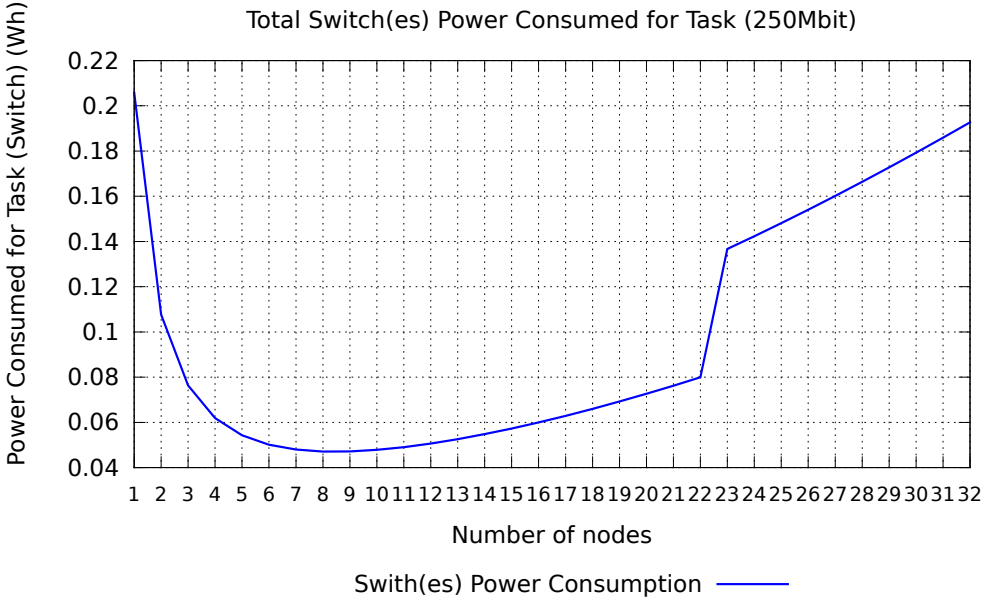
Q. Chen, P. Grosso, K. van der Veldt, C. de Laat, R. Hofman and H.Bal.
*Profiling energy consumption of VMs for green cloud computing*
In: International Conference on Cloud and Green Computing (CGC2011), Sydney December 2011

# Energy Efficient Ethernet (802.3az)

Power savings techniques in hardware can be leveraged in architecturing communication patterns in data centra



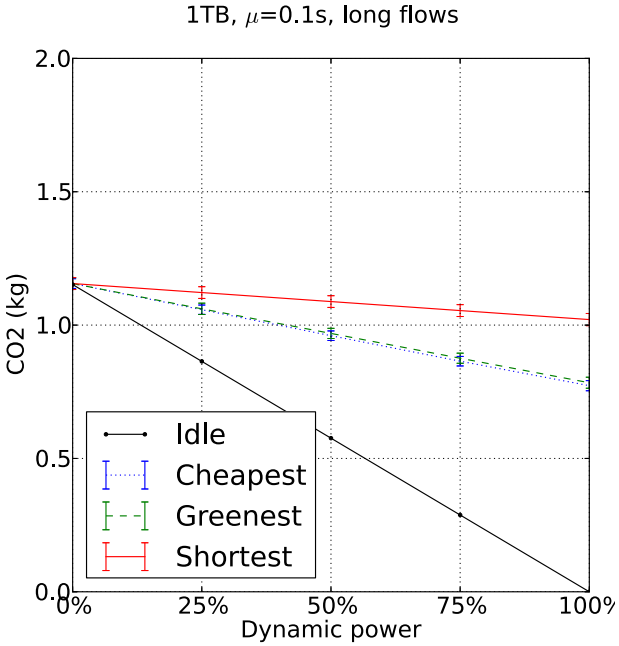



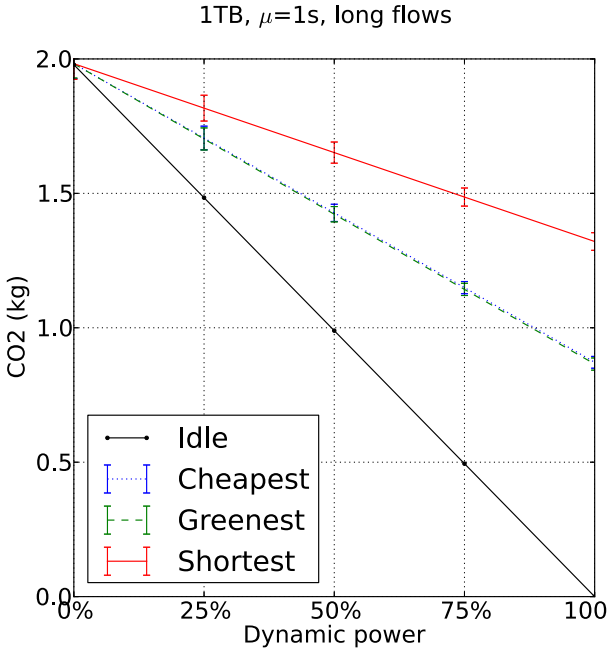



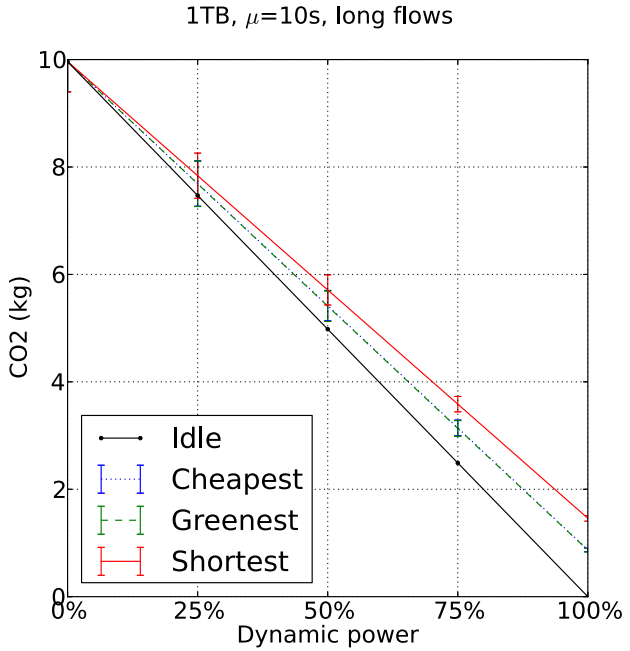

D. Pavlov and J. Soert and P. Grosso and Z. Zhao and K. van der Veldt and H. Zhu and C. de Laat
*Towards energy efficient data intensive computing using IEEE 802.3az*
In: DISCS 2012 workshop - Nov 2012

# Networks and CO2

- Take a network (ESnet, working on using SURFnet data)
- Define the traffic model running on it
- Use the energy monitoring information and energy costs data
- Compare path selection strategies : shortest, cheapest and greenest




*"A motivation for carbon aware path provisioning for NRENs" (submitted to eEnergy2014)*

# The constant factor in our field is Change!

The 50 years it took Physicists to find one particle, the Higgs, we came from:

"Fortran goto", Unix, c, SmallTalk, DECnet, TCP/IP, c++, Internet, WWW, Semantic Web, Photonic networks, Google, grid, cloud, Data^3, App

to:

DDOS attacks destroying Banks and Bitcoins.

Conclusion:

Need for Safe, Smart, Resilient Sustainable Infrastructure.