# System & Network Engineering research UvA

Cees de Laat

EU

COMMIT

UvA

NWO

PID/EFRO

SURFnet

TNO

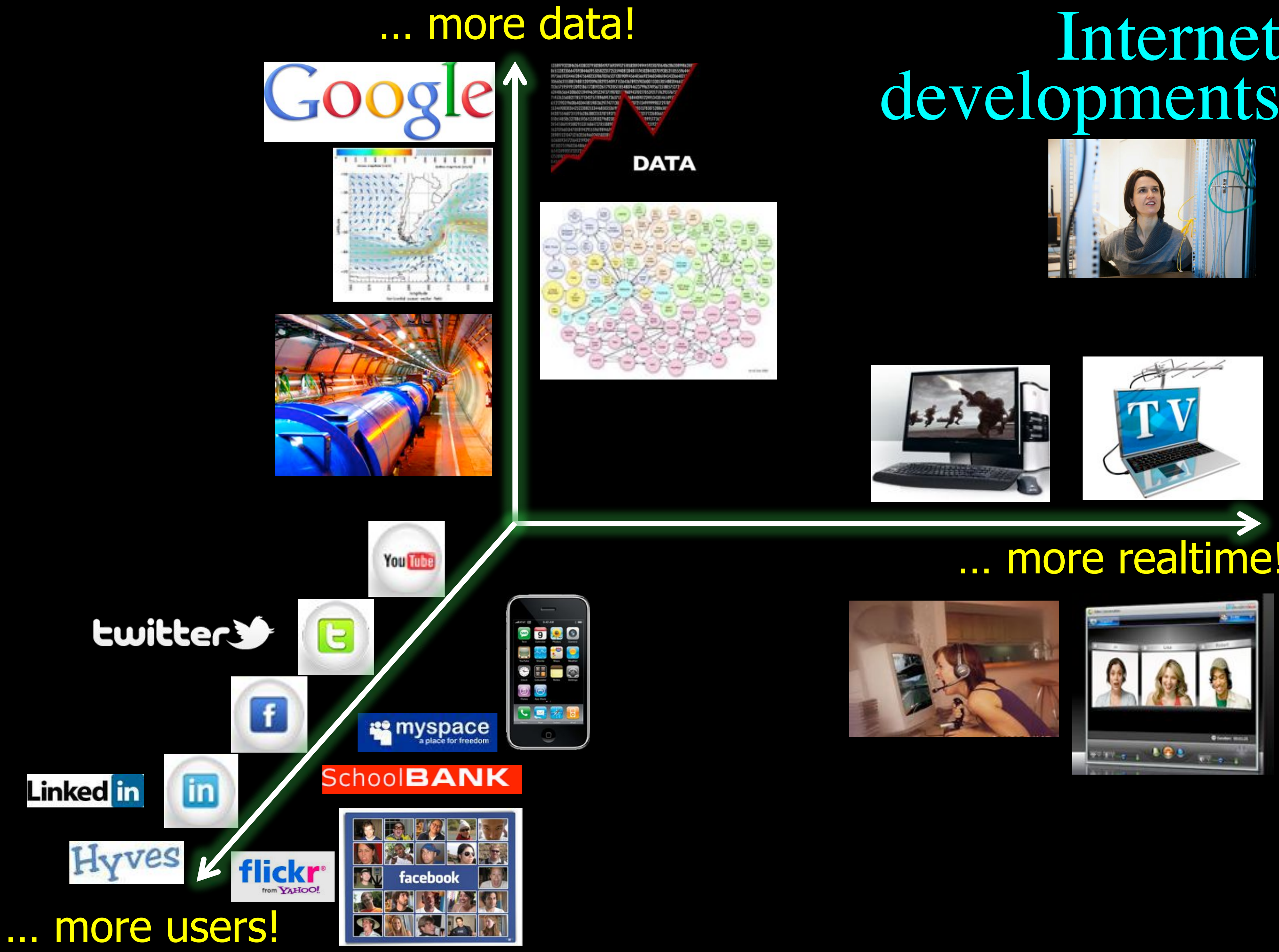
NCF

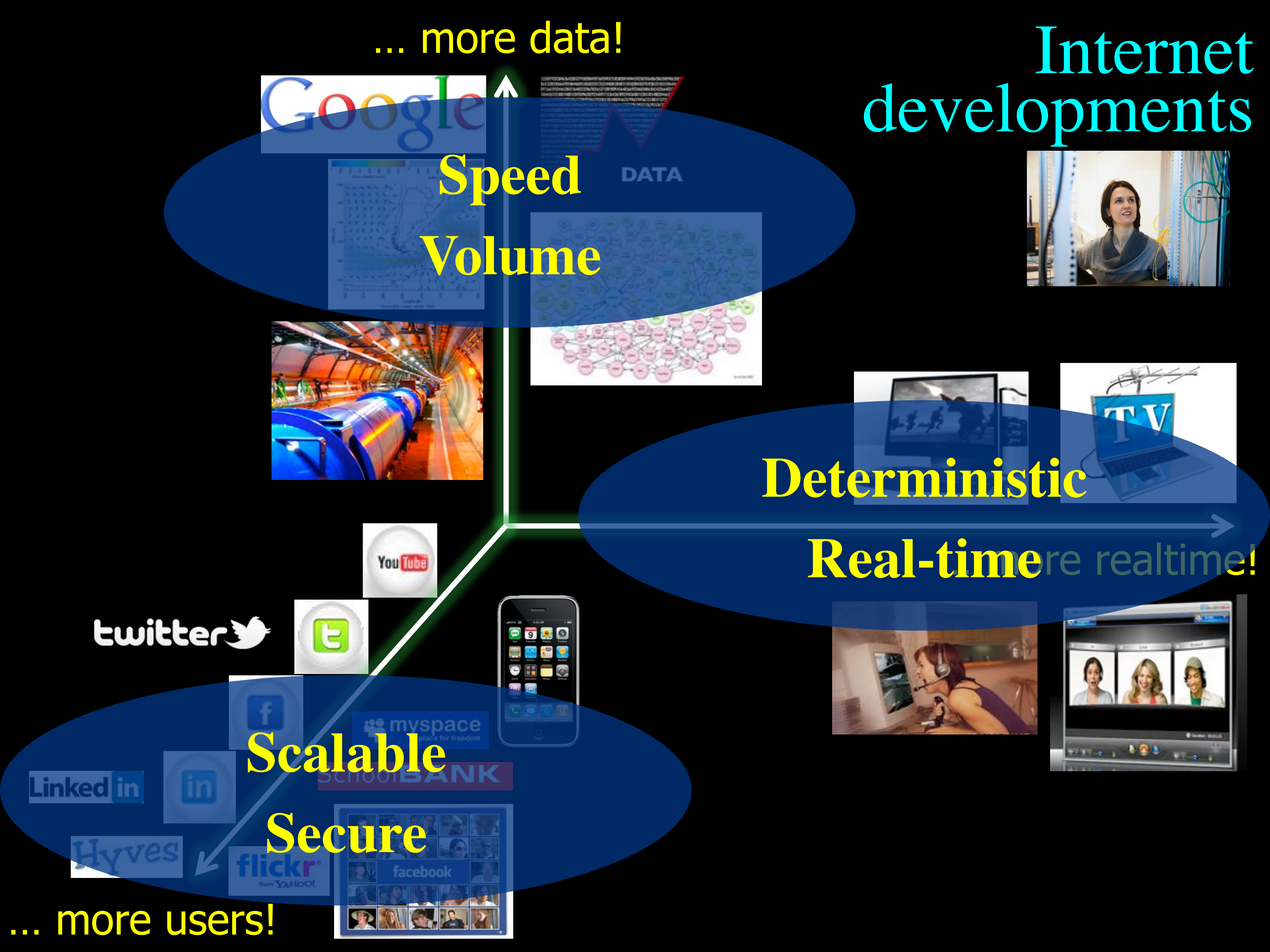
# Science Faculty @ UvA

## Informatics Institute

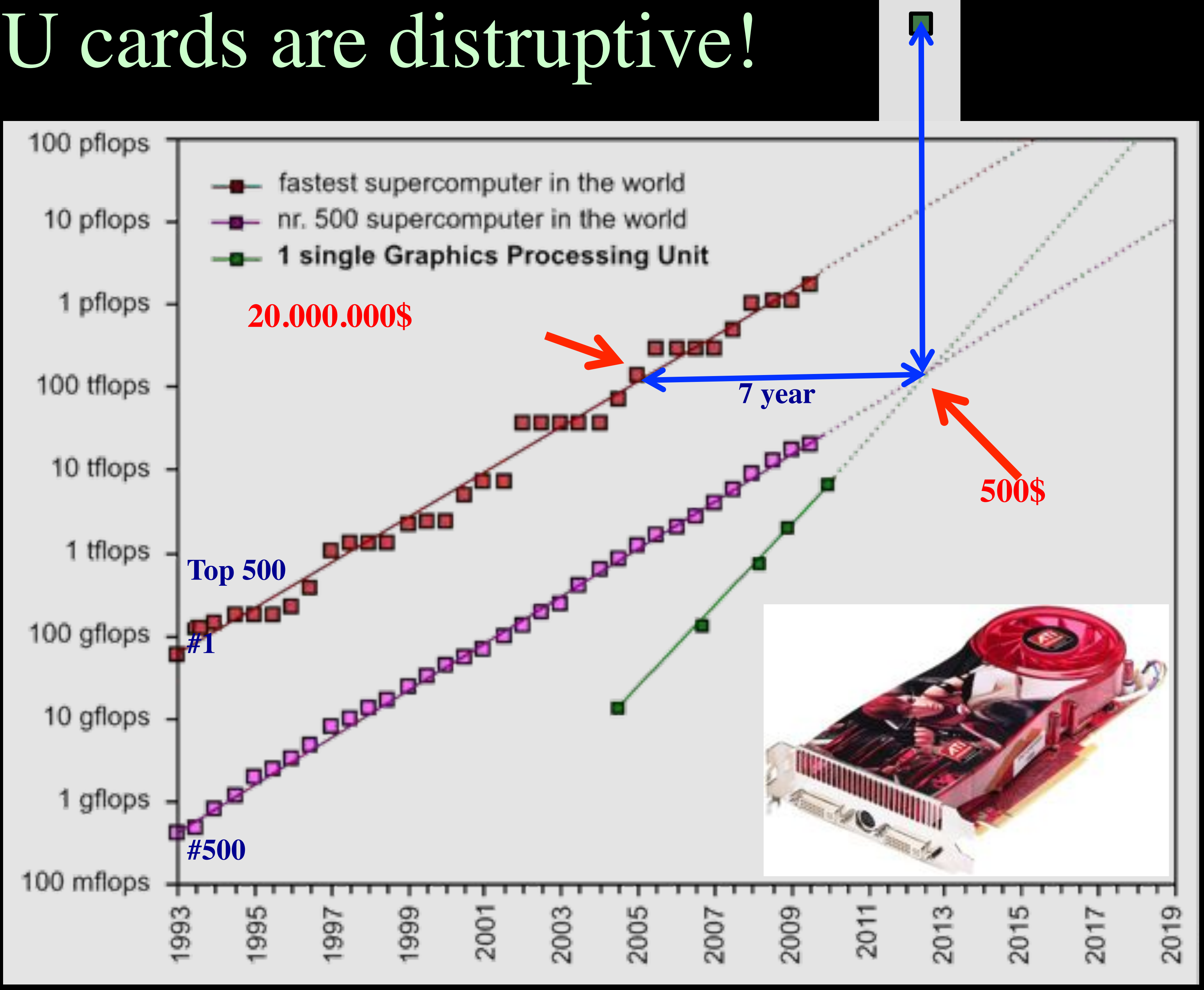
- CSA: Computer Systems Architecture (dr. A.D. Pimentel)
- FCN: Federated Collaborative Networks (Prof. dr. H. Afsarmanesh)
- IAS: Intelligent Autonomous Systems (Prof. dr. ir. F.C.A. Groen)
- ILPS: Information and Language Processing Systems (Prof. dr. M. de Rijke)
- ISIS: Intelligent Sensory Information 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)

# Internet developments

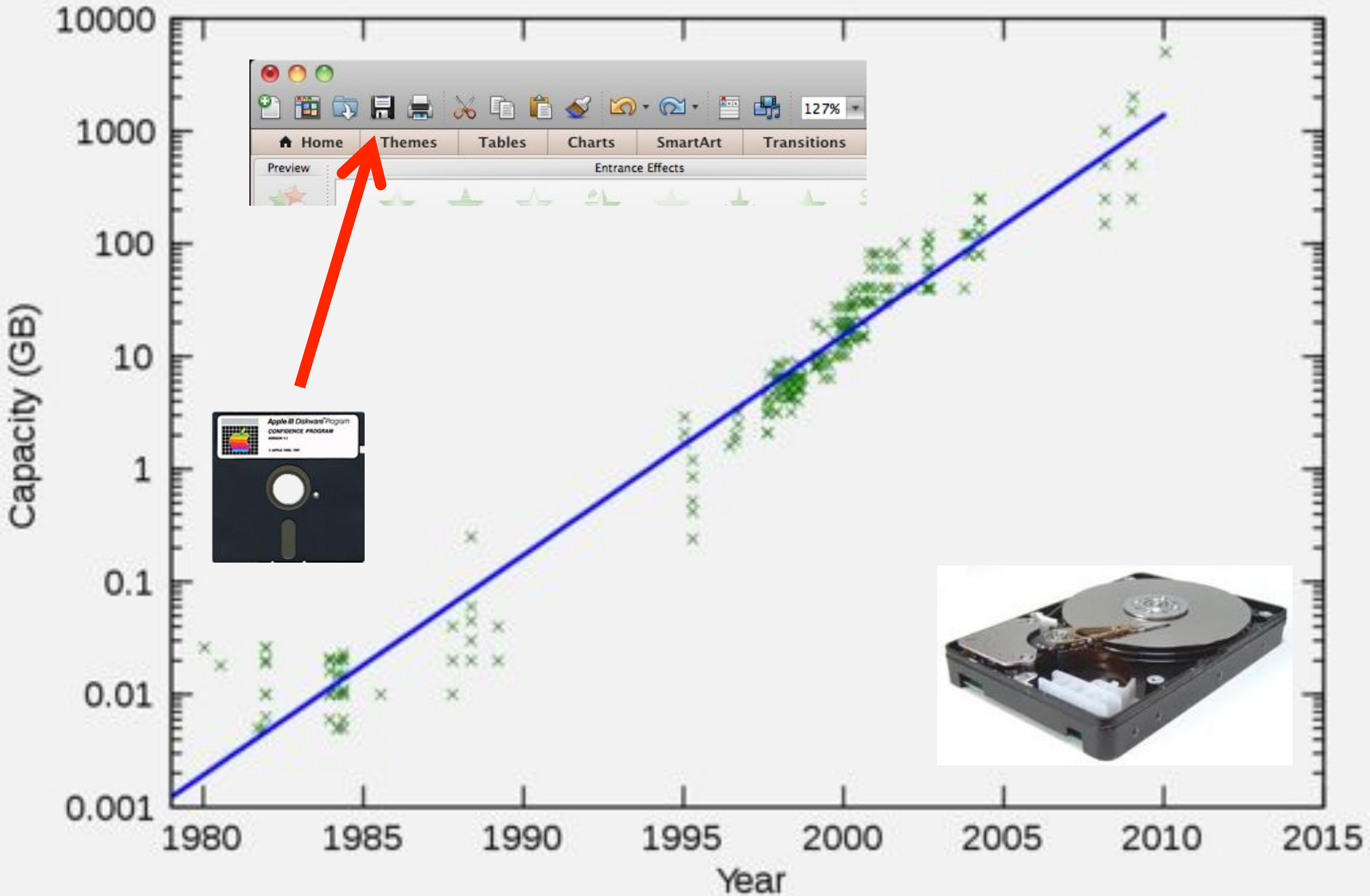



Internet developments
... more data!
Google
Speed
Volume
DATA
TV
Deterministic
Real-time
re realtime!
You Tube
twitter
myspace
Scalable
SchoolBANK
Linked in
Secure
Hyves
flickr from YAHOO!
facebook
... more users!

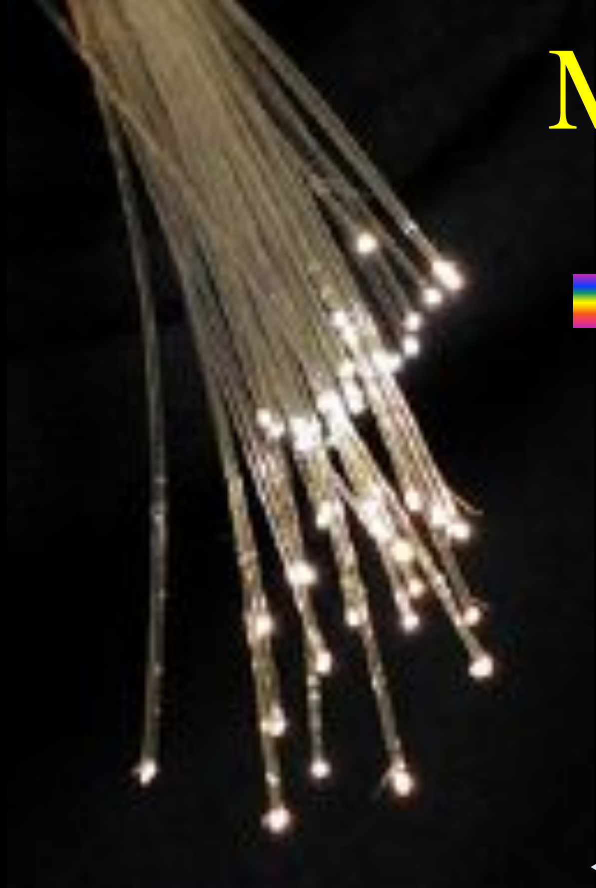
# GPU cards are distruptive!

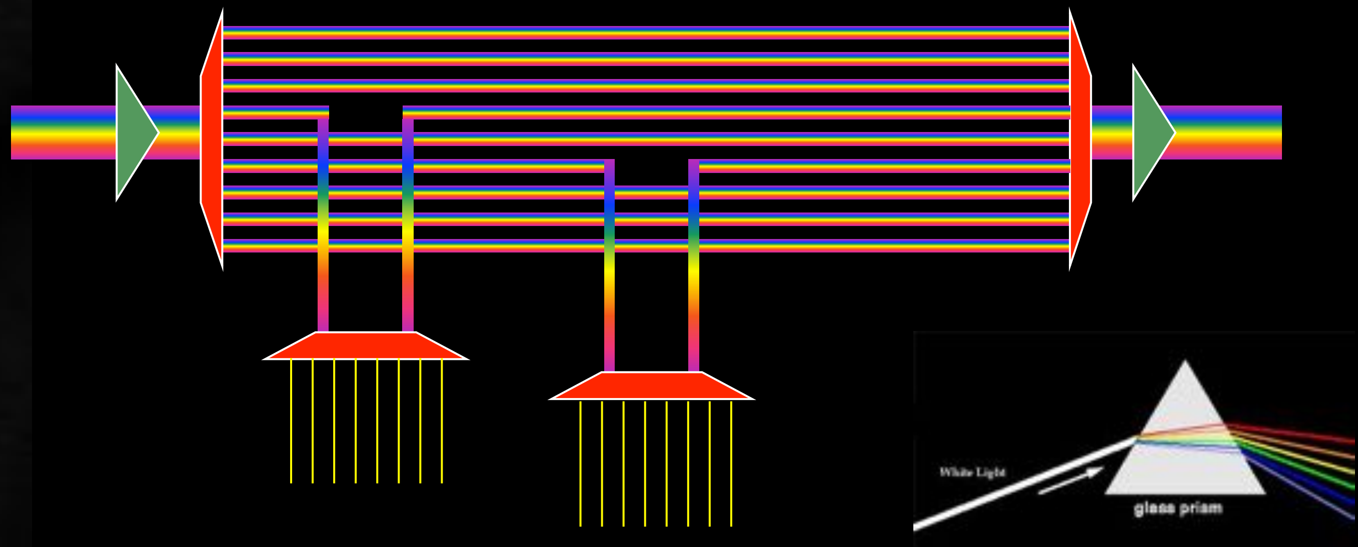


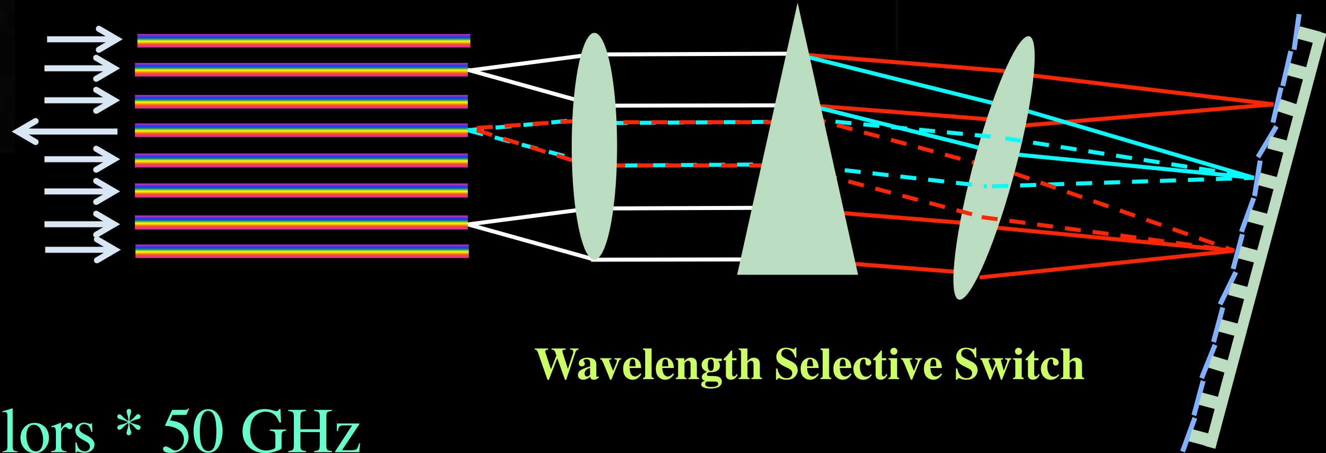
# Data storage: doubling every 1.5 year!



# Multiple colors / Fiber





Wavelength Selective Switch

Per fiber: ~ 80-100 colors * 50 GHz

Per color: 10 – 40 – 100 Gbit/s

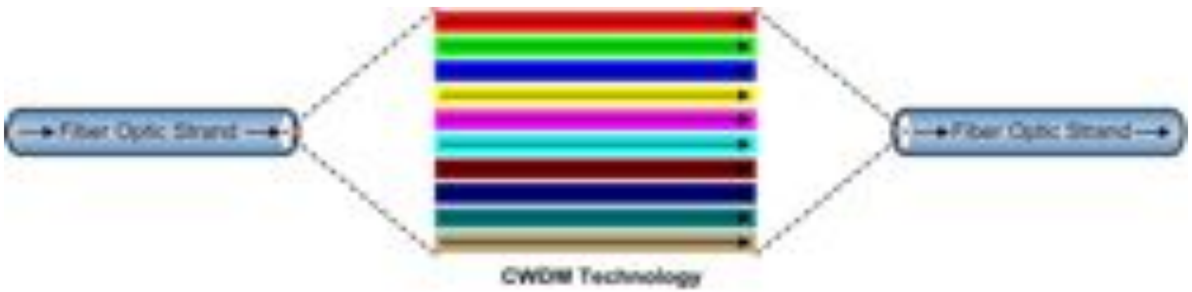
BW * Distance ~ $2*10^{17}$ bm/s

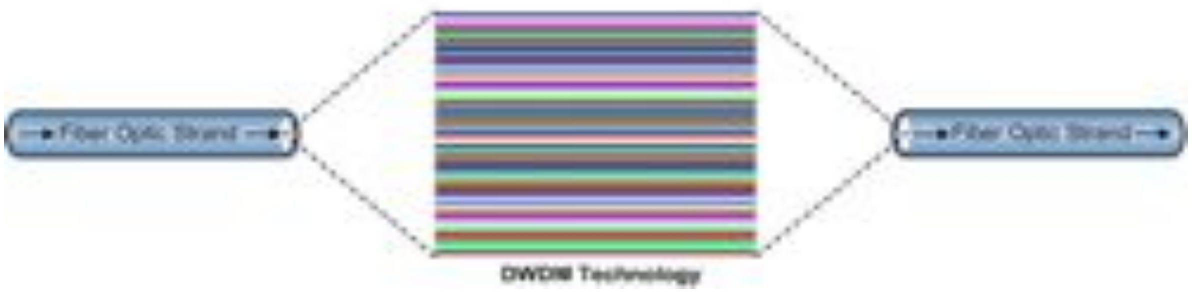
New: Hollow Fiber!

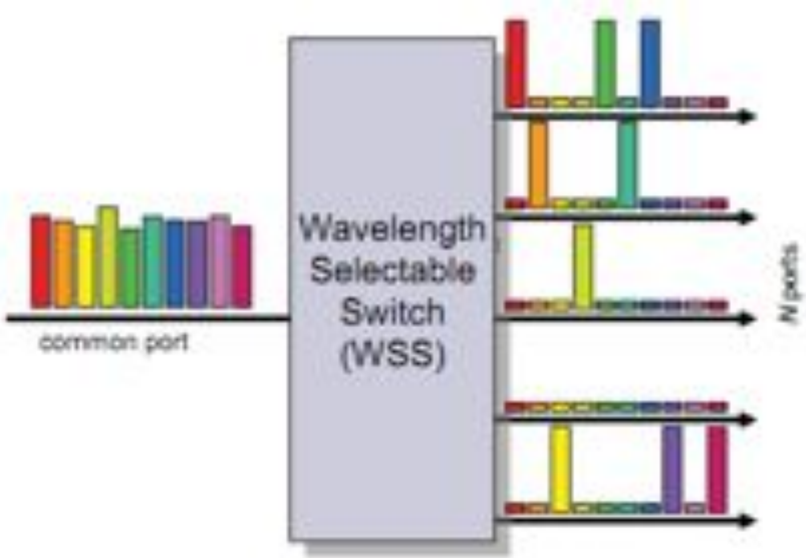
➔ less RTT!

# … more possibilities

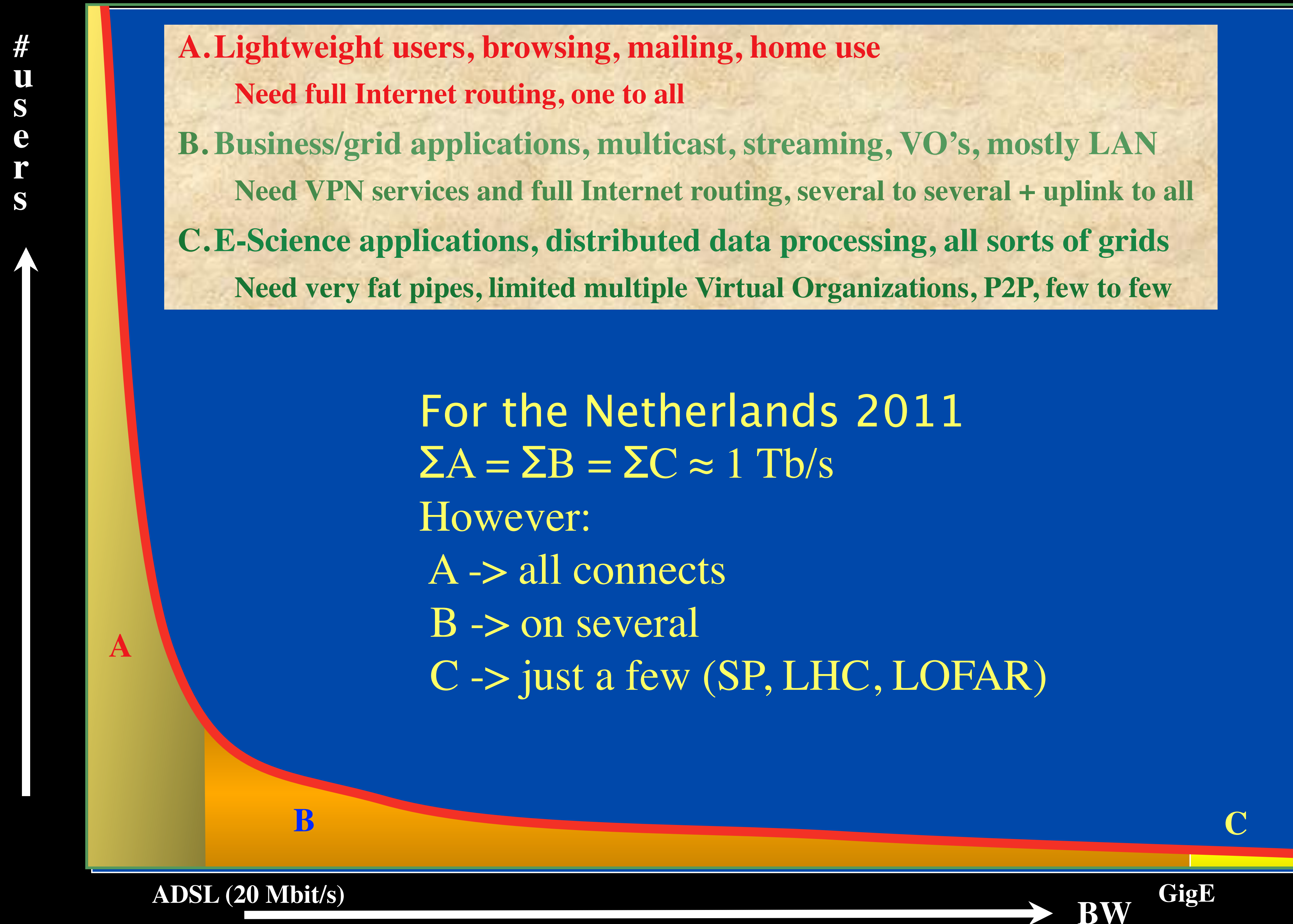
Optical transmission




Virtualization




Ref: Cees de Laat, Erik Radius, Steven Wallace, "The Rationale of the Current Optical Networking Initiatives" iGrid2002 special issue, Future Generation Computer Systems, volume 19 issue 6 (2003)

# Towards Hybrid Networking!

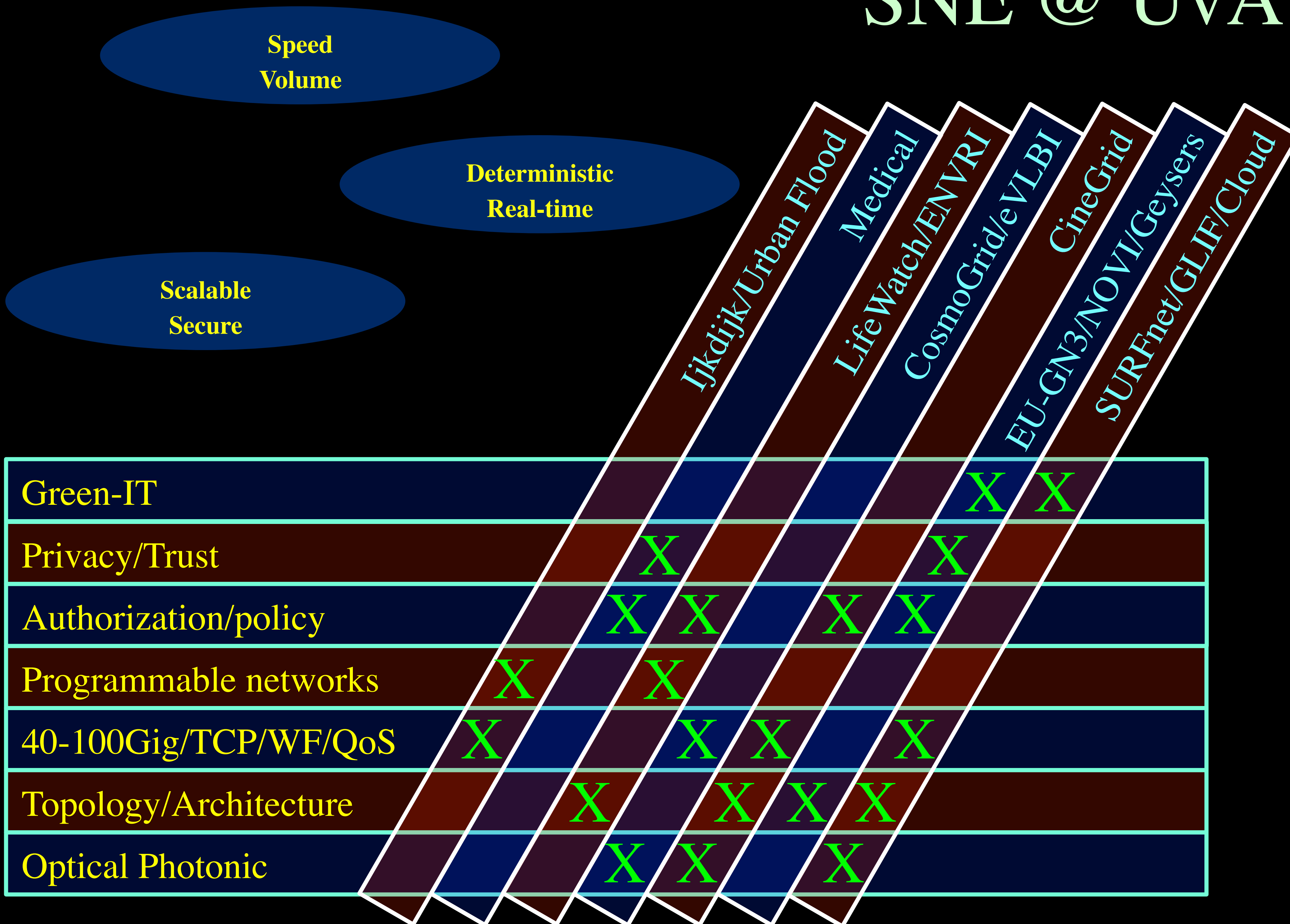
- Costs of photonic equipment 10% of switching 10 % of full routing
  - for same throughput!
  - Photonic vs Optical (optical used for SONET, etc, 10-50 k$/port)
  - DWDM lasers for long reach expensive, 10-50 k$
- Bottom line: look for a hybrid architecture which serves all classes in a cost effective 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

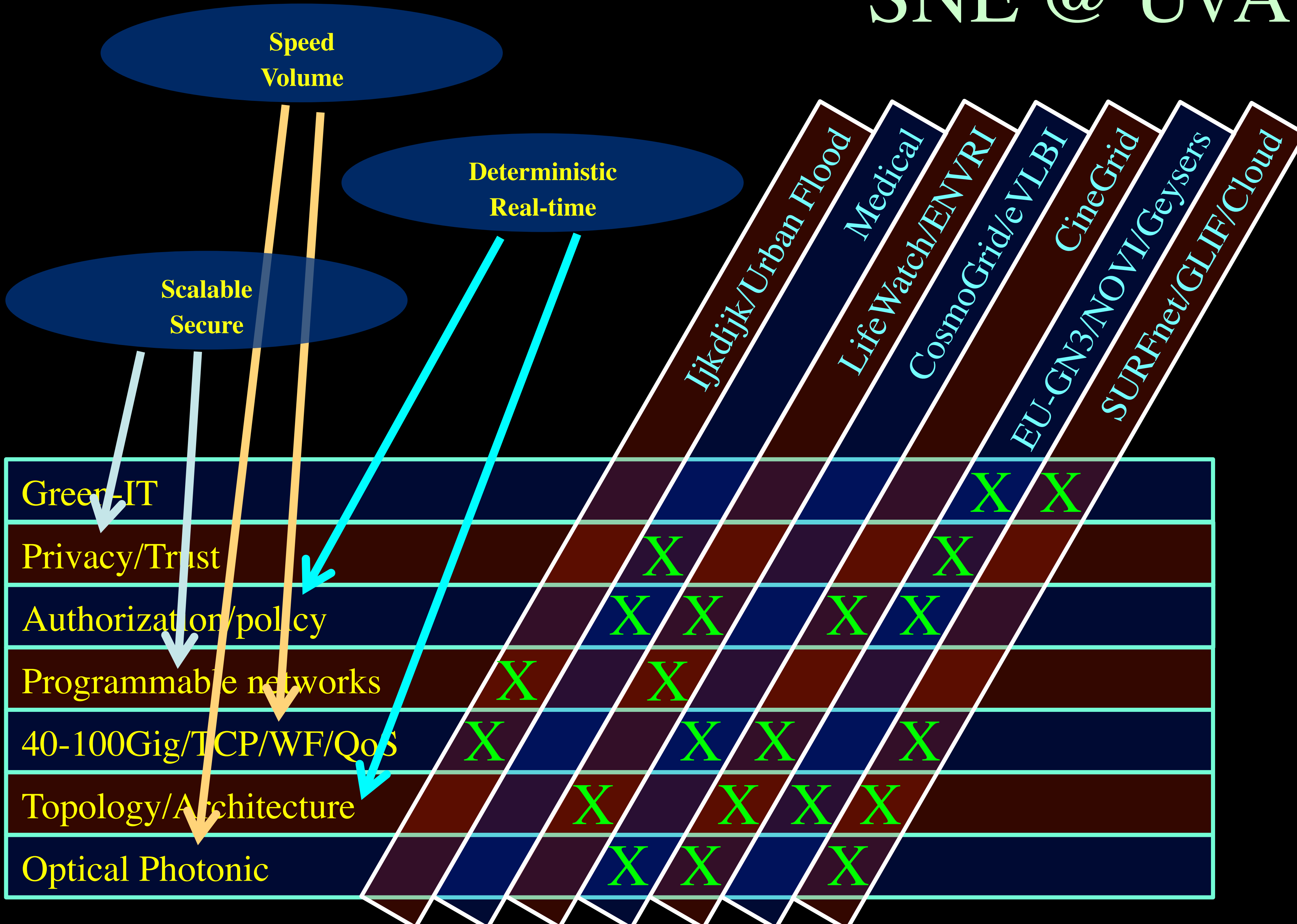
L3 ≈ 75+ k$/port

# SNE @ UvA



Speed
Volume
Deterministic
Real-time
Scalable
Secure
Ijkdijk/Urban Flood
Medical
LifeWatch/ENVRI
CosmoGrid/eVLBI
CineGrid
EU-GN3/NOVI/Geysers
SURFnet/GLIF/Cloud
Green-IT
Privacy/Trust
Authorization/policy
Programmable networks
40-100Gig/TCP/WF/QoS
Topology/Architecture
Optical Photonic

# SNE @ UvA



Speed
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Authorization/policy
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Topology/Architecture
Optical Photonic

# SNE @ UvA


Where when will it happen?


Ijkdijk/Urban Flood
Medical
LifeWatch/ENVRI
CosmoGrid/eVLBI
CineGrid
EU-GN3/NOVI/Geysers
SURFnet/GLIF/Cloud
Green-IT
Privacy/Trust
Authorization/policy
Programmable networks
40-100Gig/TCP/WF/QoS
Topology/Architecture
Optical Photonic

IJKDIJK

**Sensors: 15000km* 800 bps/m ->12 Gbit/s to cover all Dutch dikes**

# Sensor grid: instrument the dikes

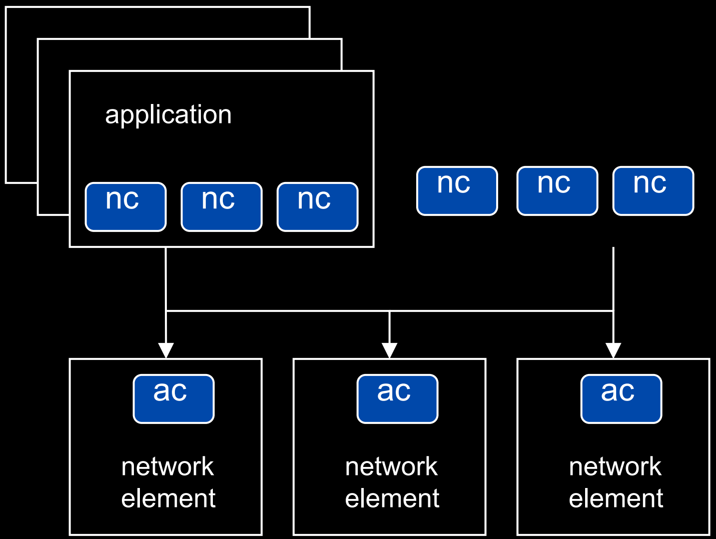
## First controlled breach occurred on sept 27th '08:

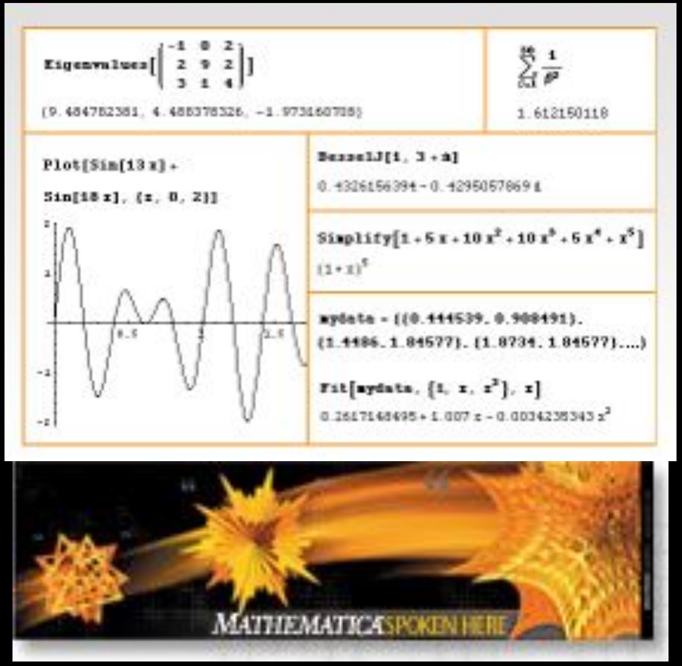
Many Pflops/s

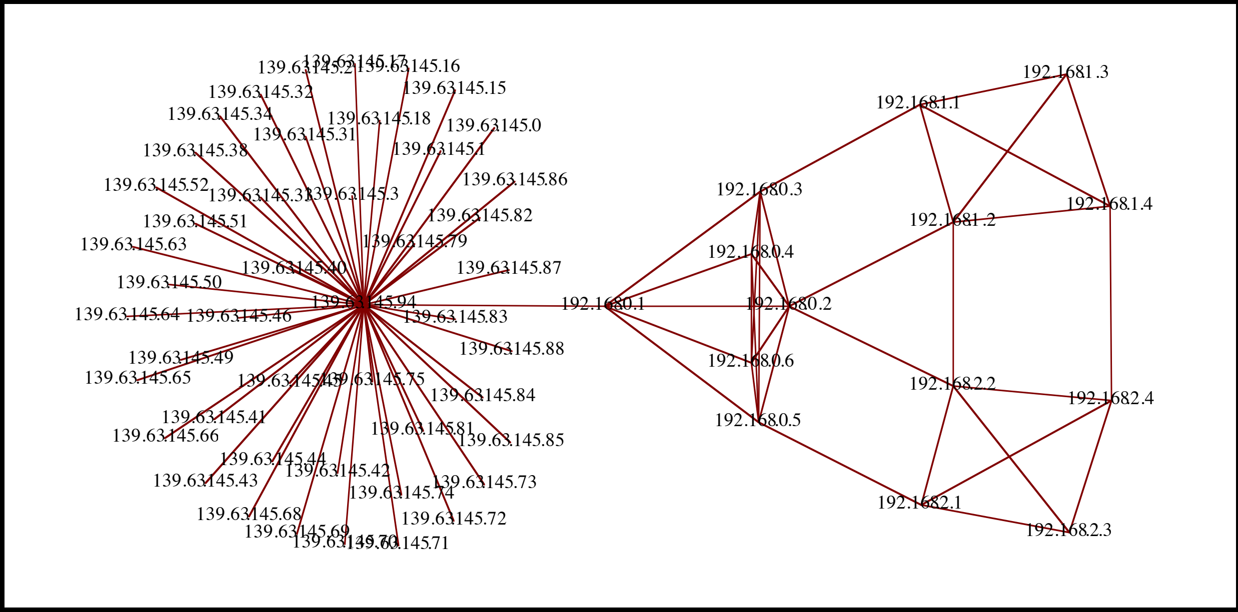
Many small flows -> 12 Gb/s

# User Programmable Virtualized Networks.

- 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



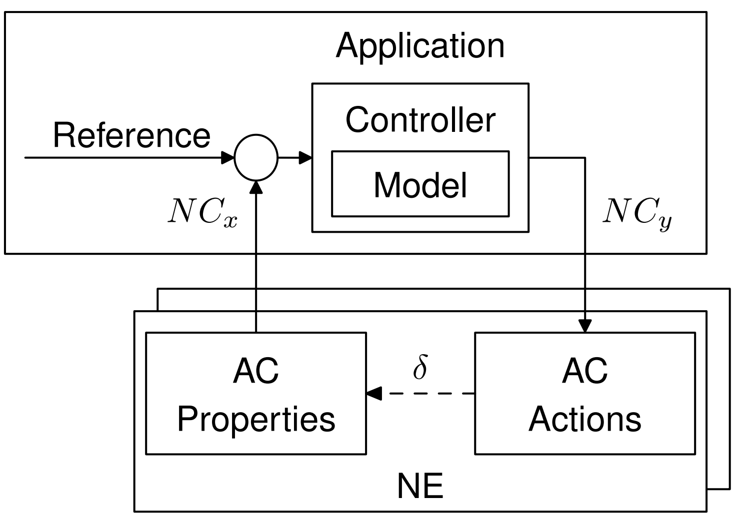





ref: Robert J. Meijer, Rudolf J. Strijkers, Leon Gommans, Cees de Laat, User Programmable Virtualiized Networks, accepted for publication to the IEEE e-Science 2006 conference Amsterdam.

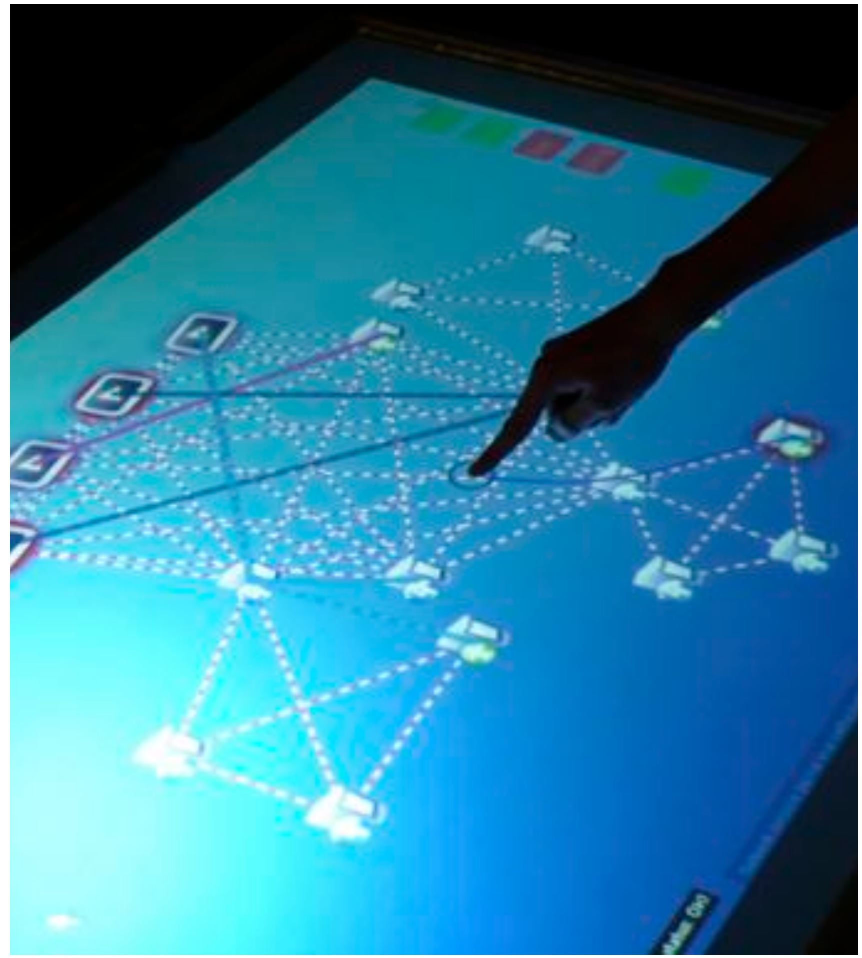
# In the Intercloud virtual servers and networks become software

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




# Interactive Networks

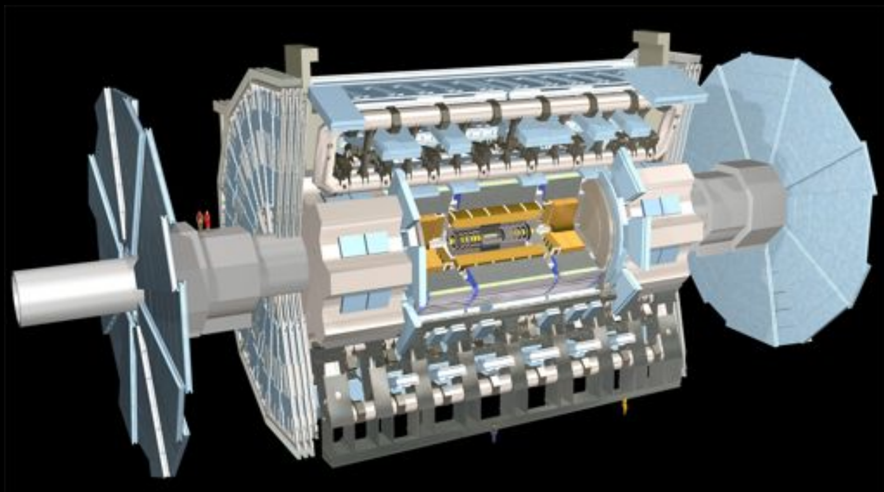
- SuperComputing 2008
- SuperComputing 2009 (in programmable Grid networks demo)
- SuperComputing 2011
- Next Generation Telecom networks workshop 2011
- LHCONE architecture workshop 2011



# Interactive Networks

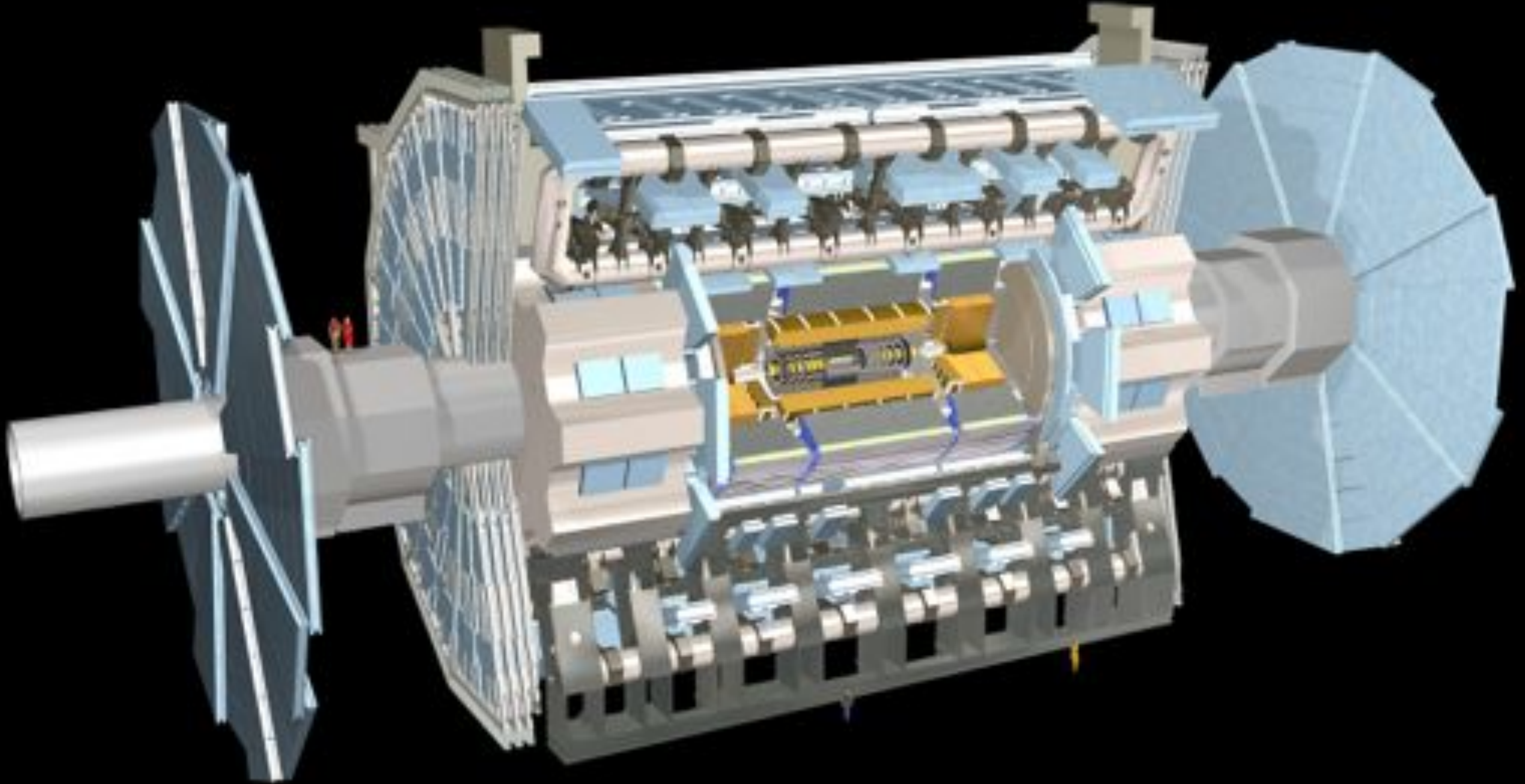
Rudolf Strijkers [1,2]
Marc X. Makkes [1,2]
Mihai Christea 1
Laurence Muller [1]
Robert Belleman [1]
Cees de Laat [1]
Robert Meijer[1,2]
[1] University of Amsterdam, Amsterdam The Netherlands
[2] TNO Information and Communication Technology, Groningen, The Netherlands

# SNE @ UvA



| | Ijkdijk/Urban Flood | Medical | LifeWatch/ENVRI | CosmoGrid/eVLBI | CineGrid | EU-GN3/NOVI/Geysers | SURFnet/GLIF/Cloud |
|---|---|---|---|---|---|---|---|
| Green-IT | | | | | | X | X |
| Privacy/Trust | | X | | | | X | |
| Authorization/policy | | X | X | | X | X | |
| Programmable networks | X | | X | | | | |
| 40-100Gig/TCP/WF/QoS | X | | | X | X | | X |
| Topology/Architecture | | | X | | X | X | X |
| Optical Photonic | | | | X | X | | X |

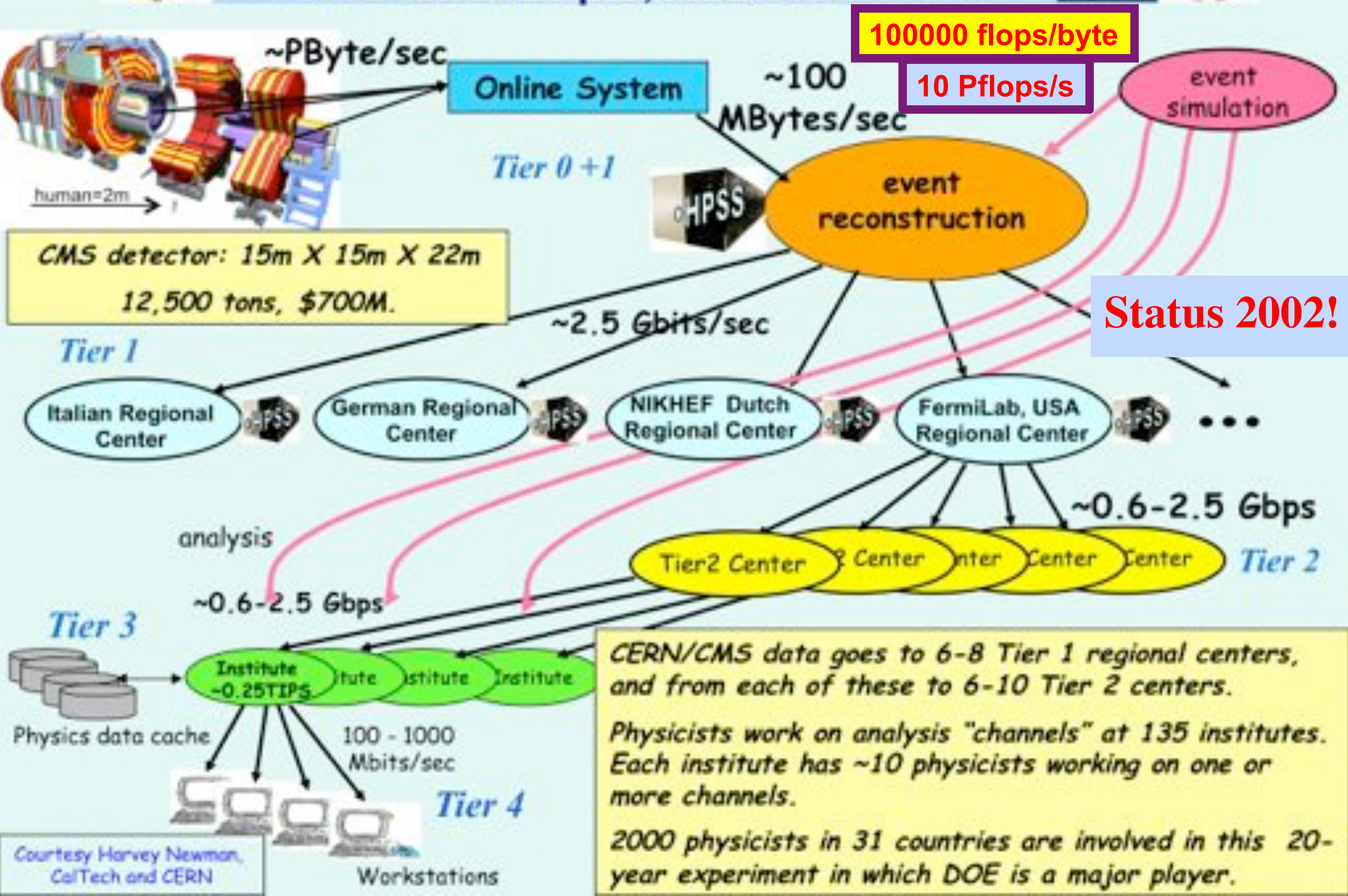
# ATLAS detector @ CERN Geneve



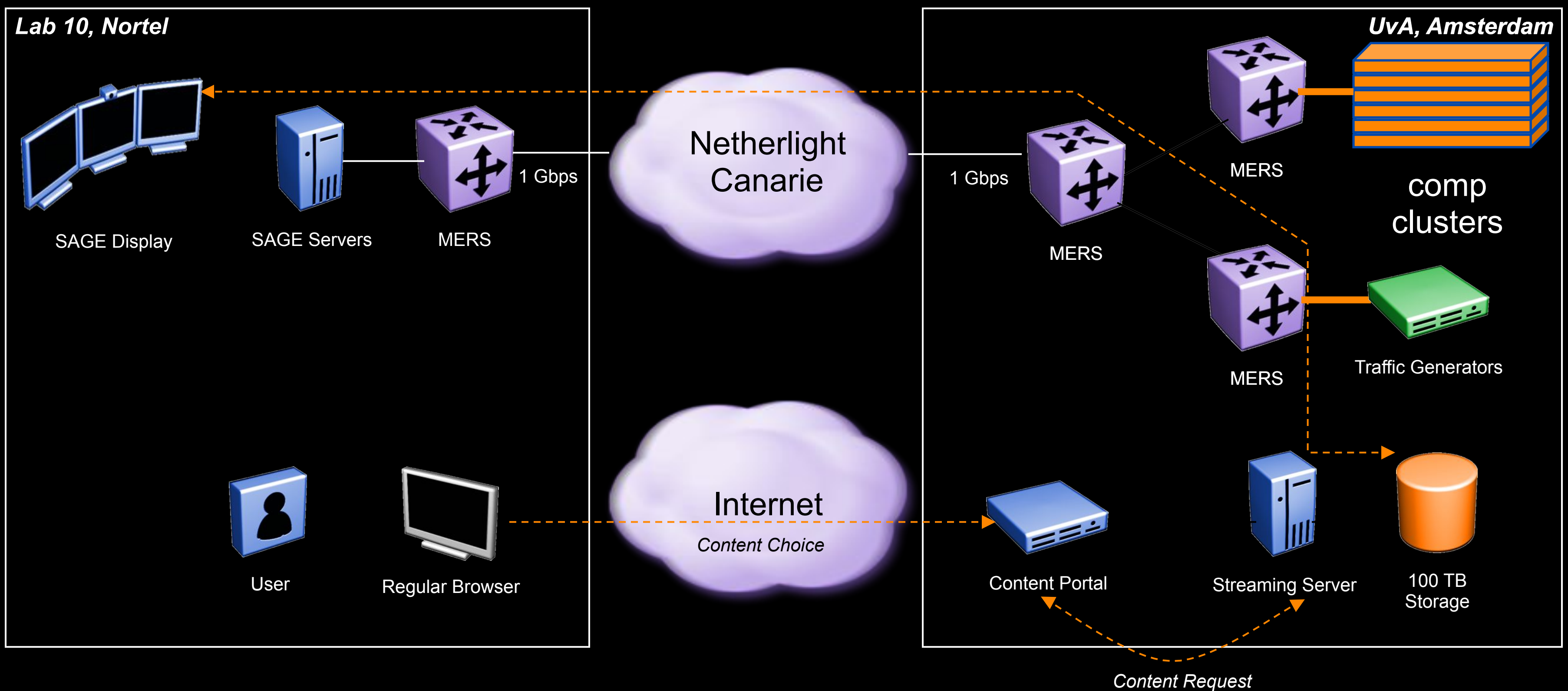
# ATLAS detector @ CERN Geneve

# LHC Data Grid Hierarchy

## CMS as example, Atlas is similar



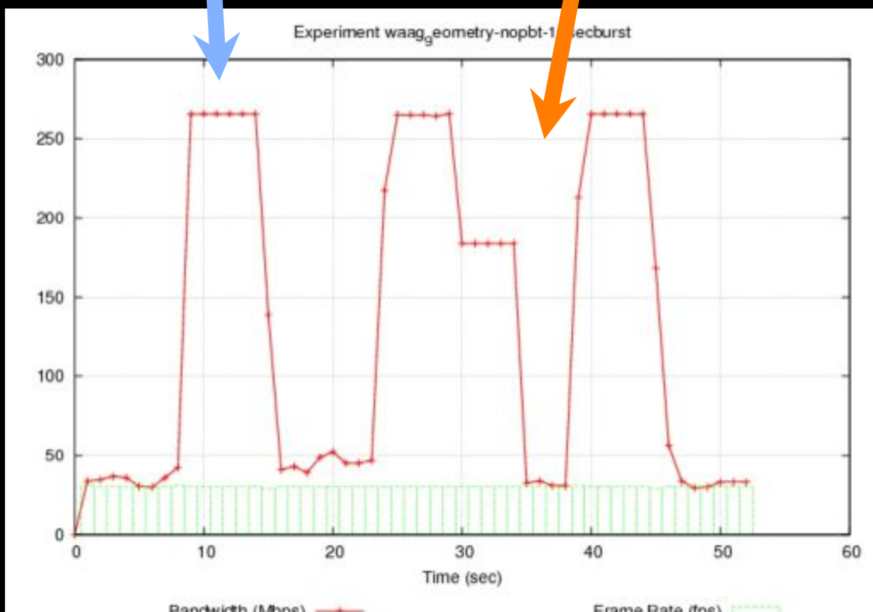
# Diagram for SAGE video streaming to ATS



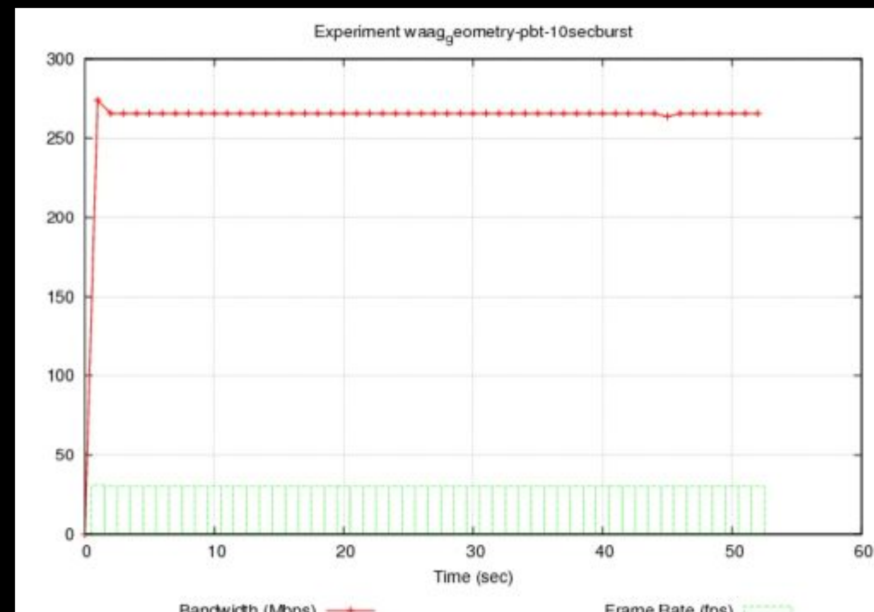
# Experimental Data

Sage without background traffic

Sage with background traffic




10 Second Traffic bursts with No PBT




10 Second Traffic bursts with PBT

PBT is <u>*SIMPLE*</u> and <u>*EFFECTIVE*</u> 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

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.

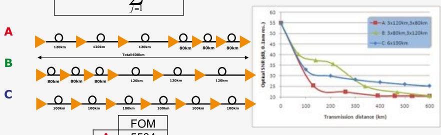
**In this demonstration we will investigate the performance of a 40Gb/s PM-QPSK alien wavelength installed on a 10Gb/s DWDM infrastructure.**

## 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**

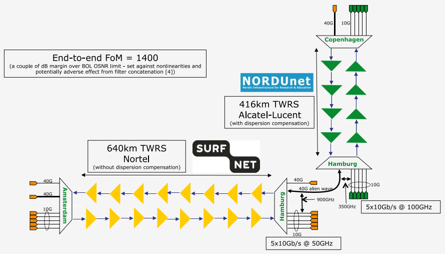



| | FOM |
|---|---|
| A | 5504 |
| B | 5504 |
| C | 1897 |

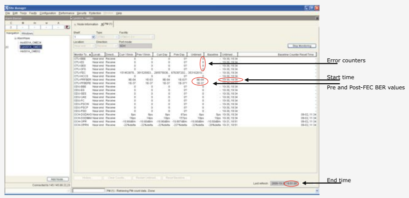
**Easy-to-use formula that accurately quantifies transmission system performance**

## 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 Nordic Infrastructure for Research & Education   telindus belgacom ICT together with ISIT THE STORAGE COMPANY   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 [3] "OPEX SAVINGS OF ALL-OPTICAL CORE NETWORKS", ANDREW LORD AND CARL ENGINEER, ECOC2009 | [4] NORTEL/SURFNET INTERNAL COMMUNICATION
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 TELINDUS AND NORTEL FOR THEIR INTEGRATION WORK AND SIMULATION SUPPORT

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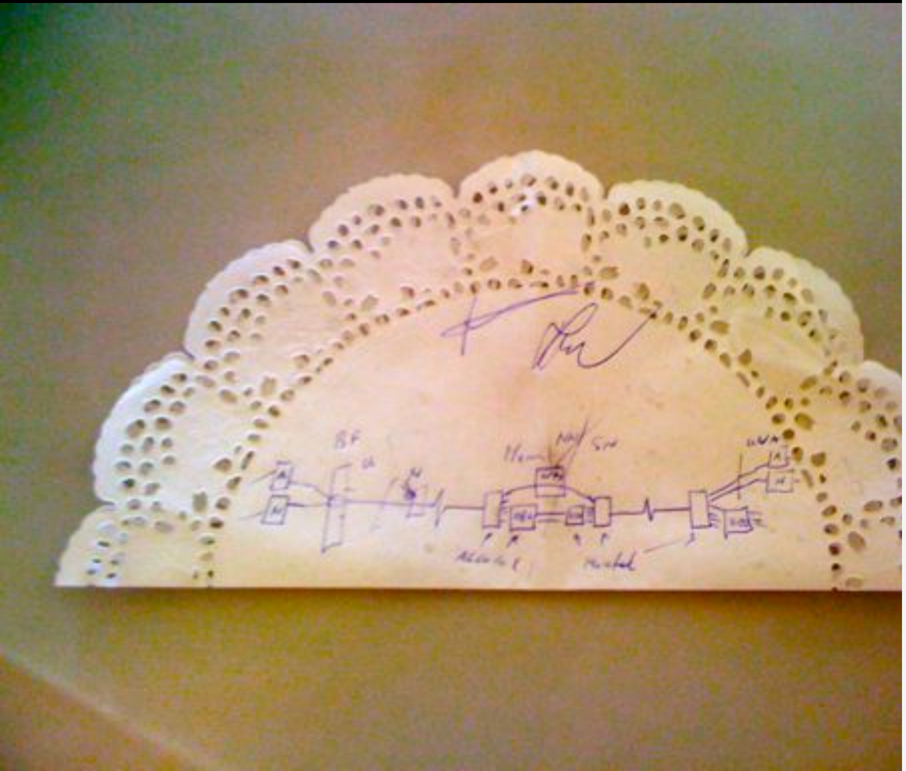

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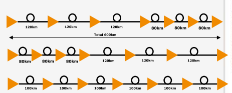


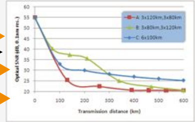


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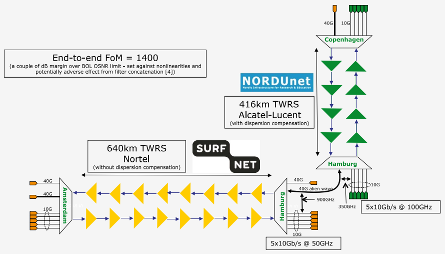


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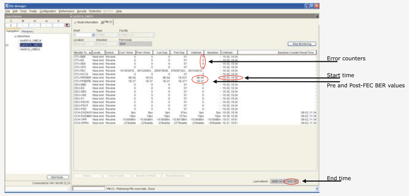


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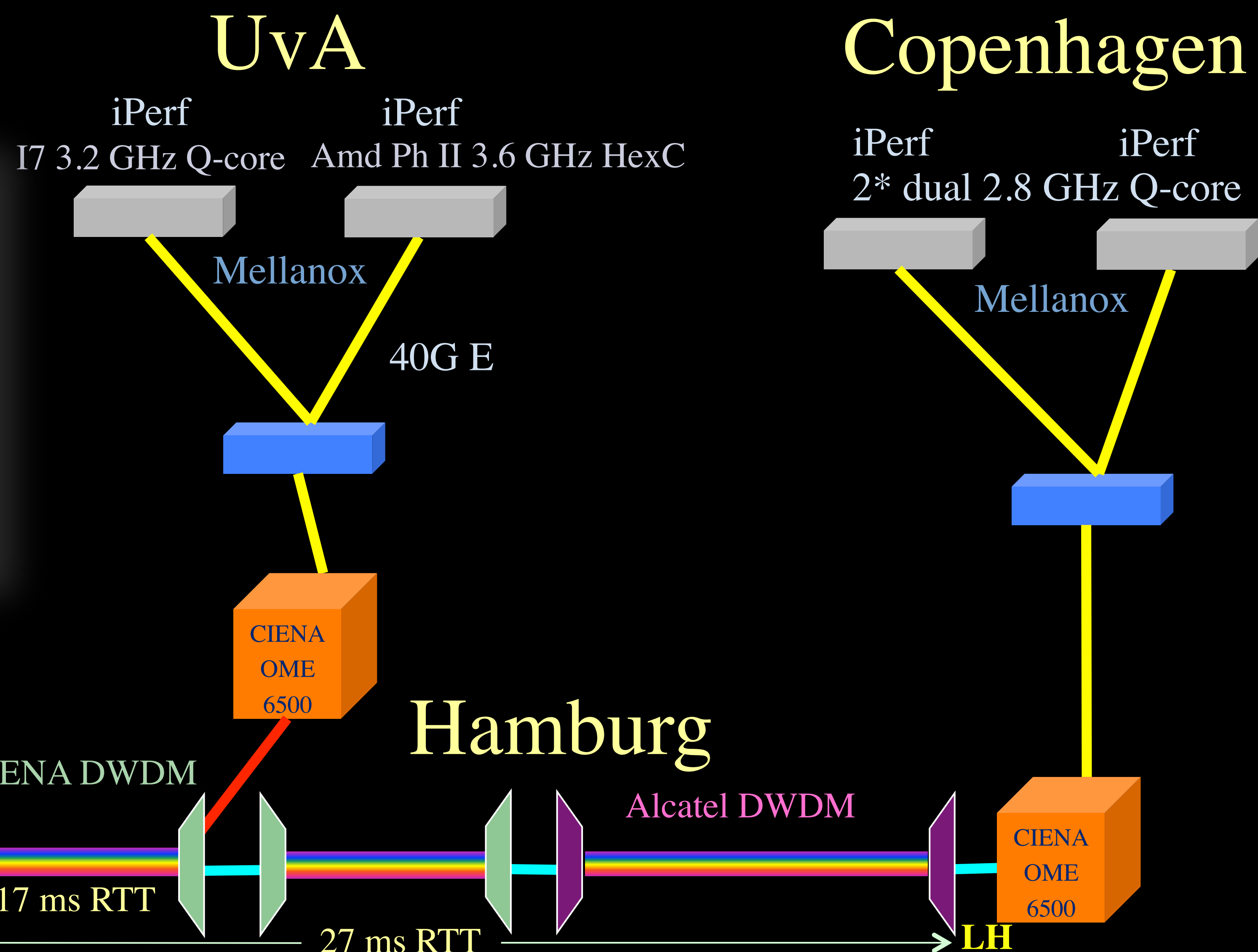
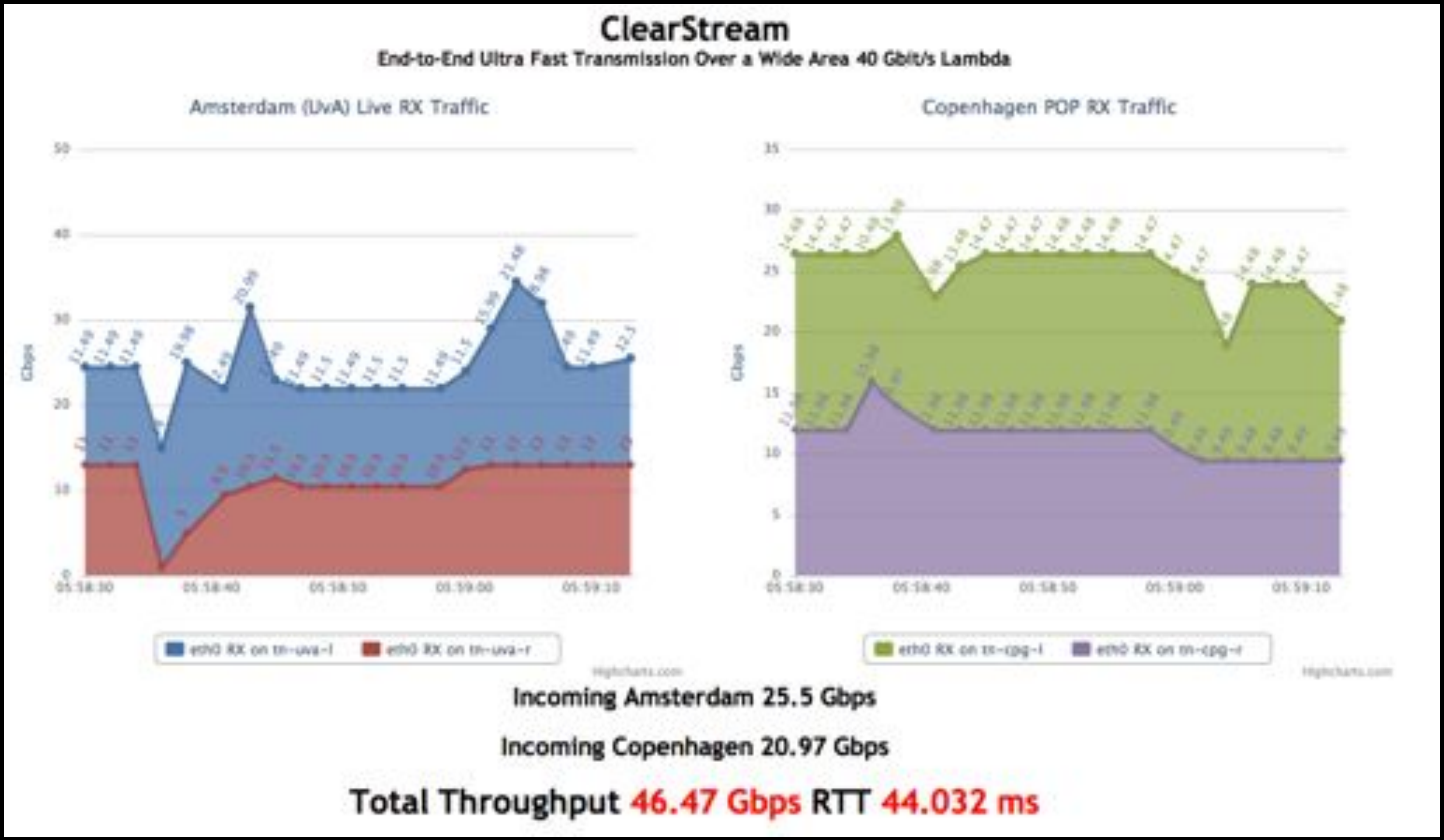
# ClearStream @ TNC2011

Setup codename:
FlightCees




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

# Visit CIENA Booth
# surf to http://tnc11.delaat.net



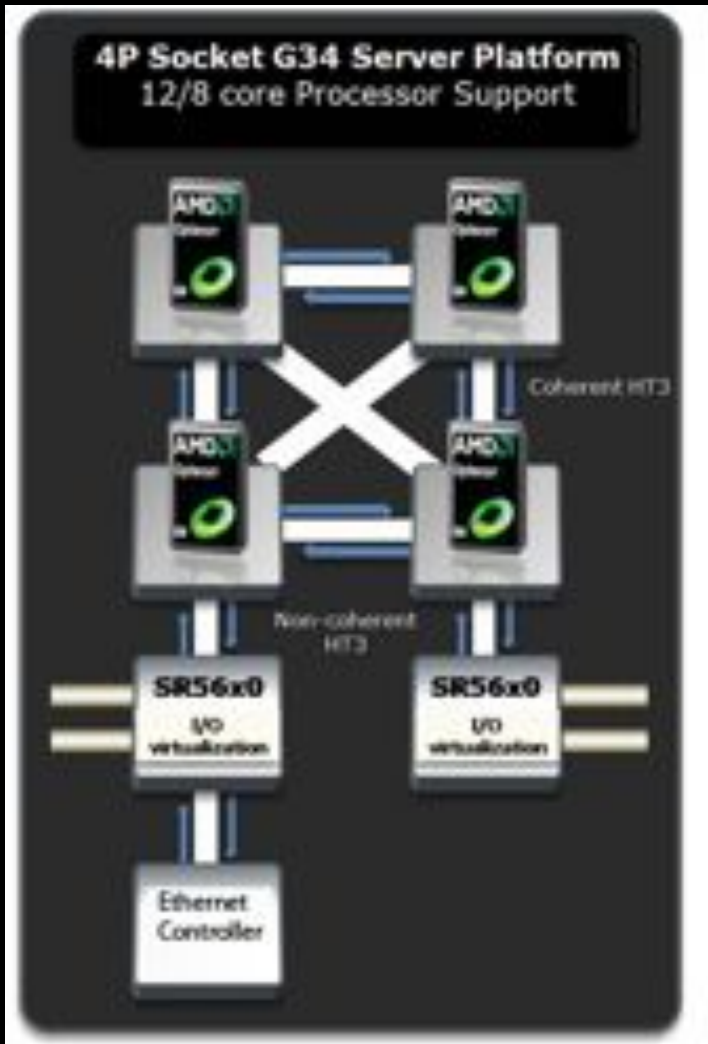
# Results (rtt = 17 ms)

- 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

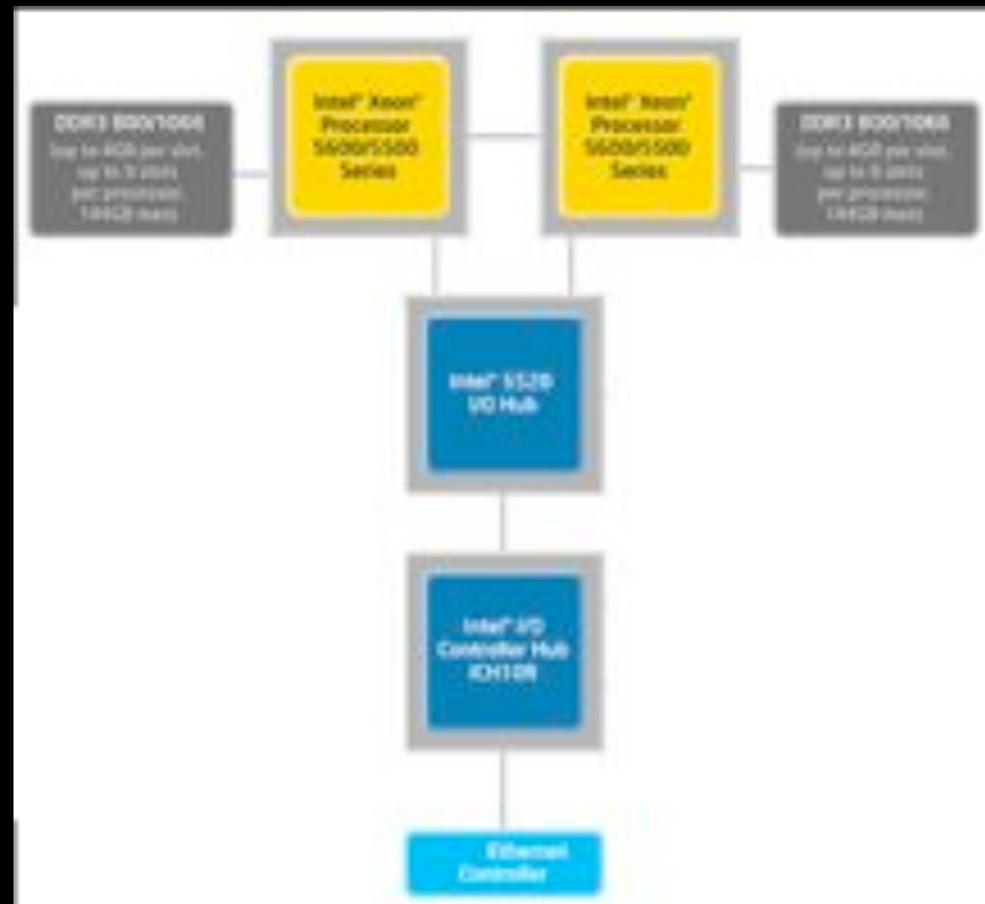
# Performance Explained

- 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

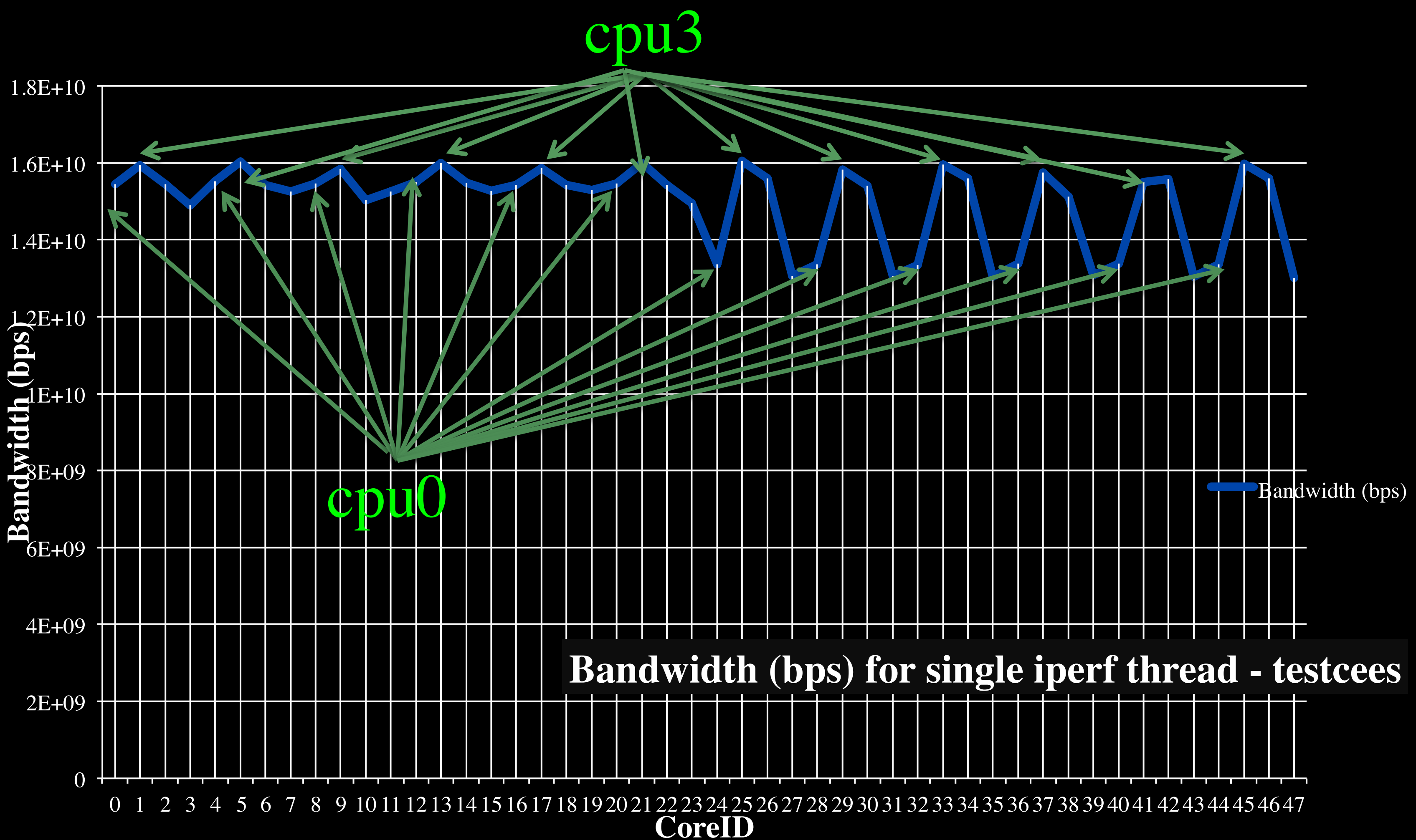



DELL R815
4 x AMD Opteron 6100




Supermicro X8DTT-HIBQF
2 x Intel Xeon

# CPU Topology benchmark



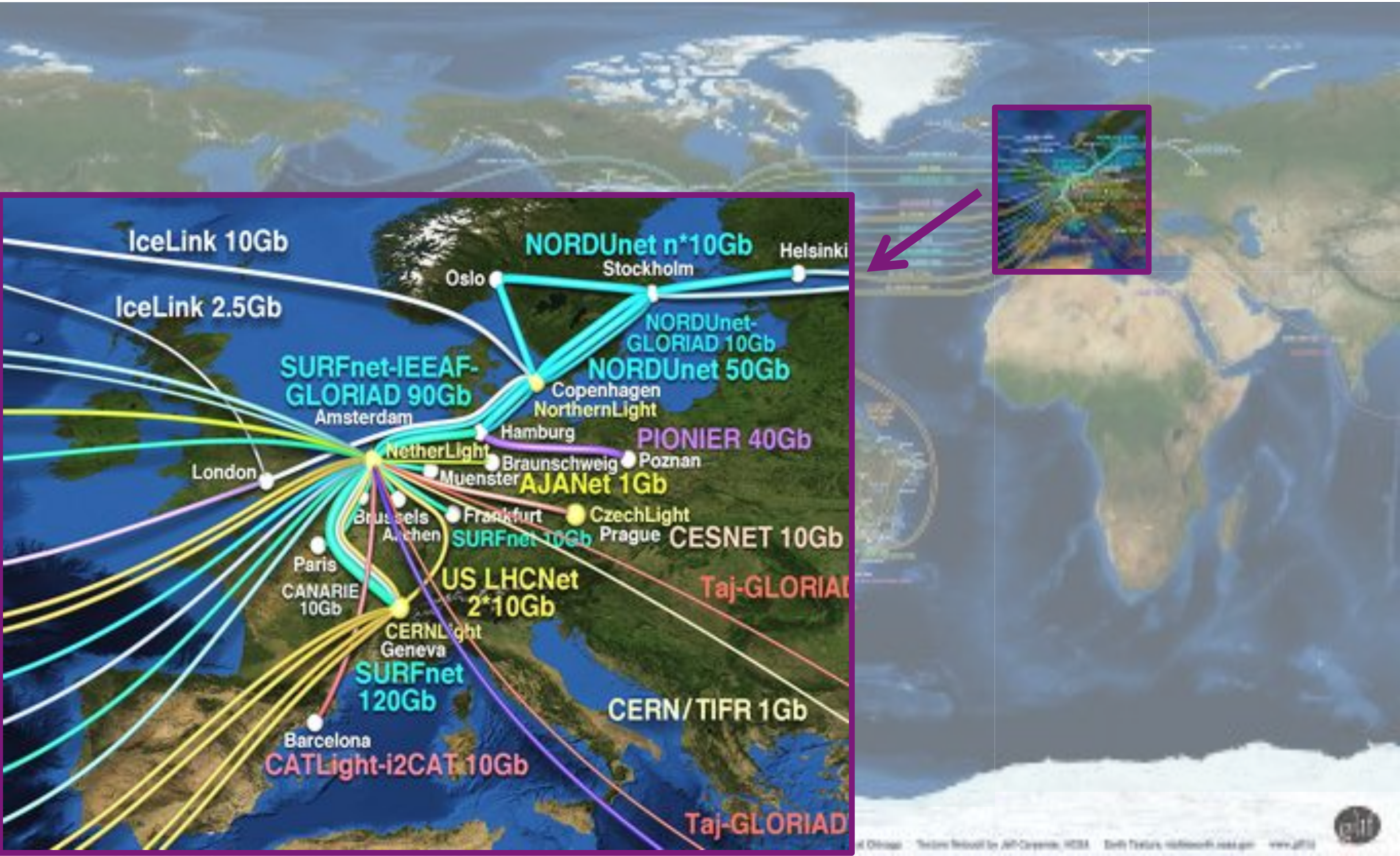

We used numactl to bind iperf to cores

GLIF 2011

**Visualization courtesy of Bob Patterson, NCSA**
**Data collection by Maxine Brown.**

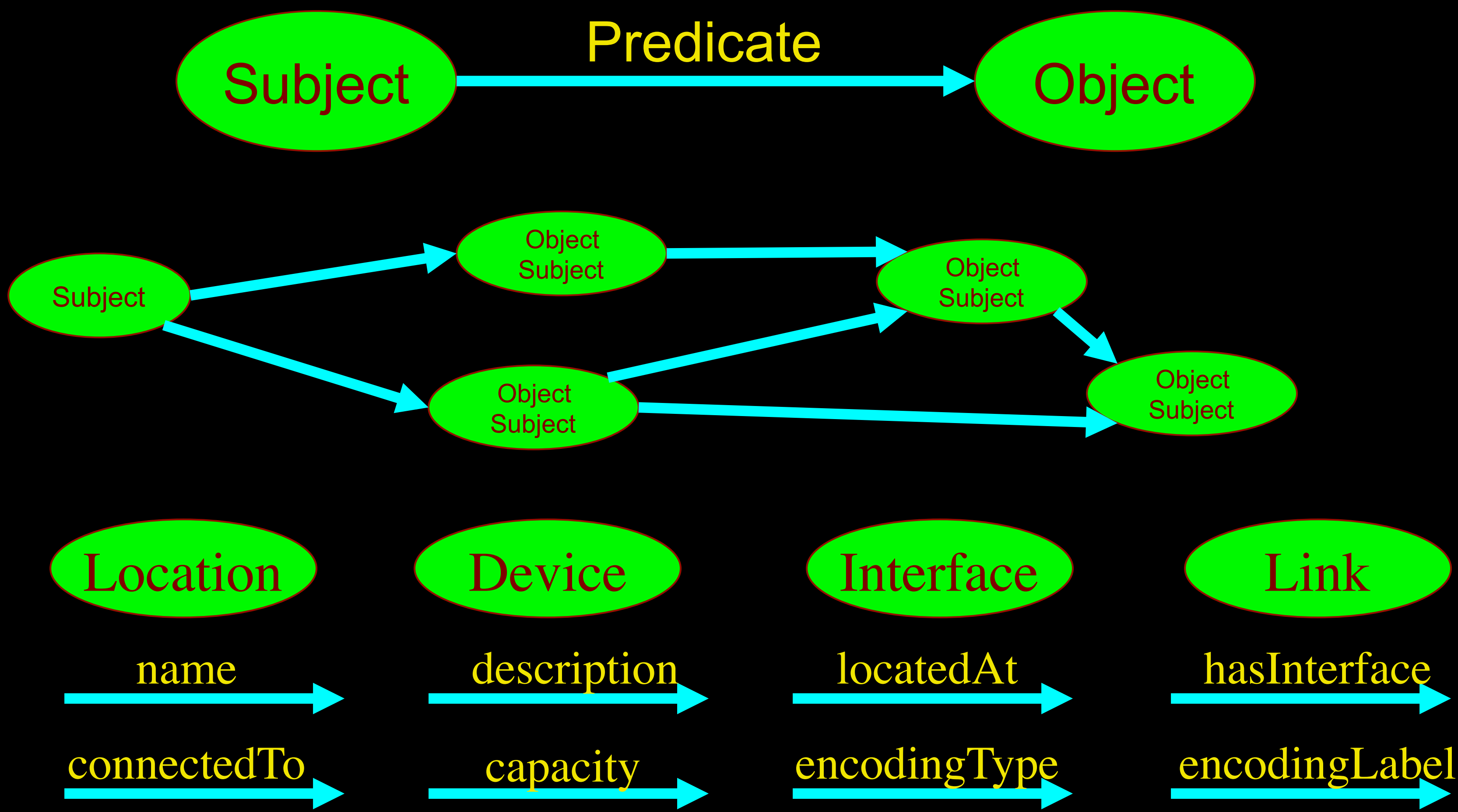
We investigate: TOMTOM for complex networks!

# 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):



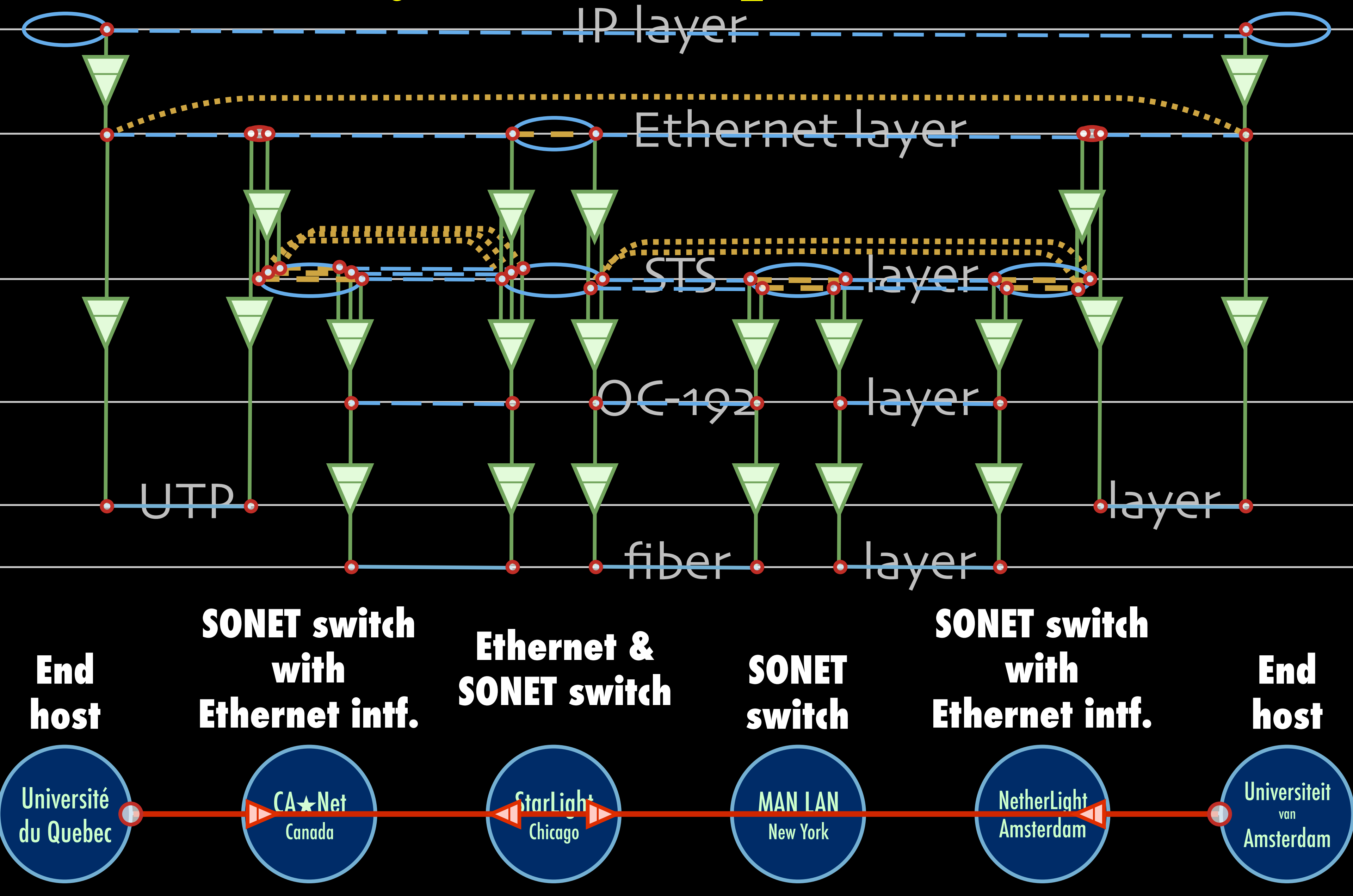
# NetherLight in RDF

```
<?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:501/3"/>
      <ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:501/4"/>
      <ndl:hasInterface rdf:resource="#tdm3.amsterdam1.netherlight.net:503/1"/>
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
      <ndl:hasInterface rdf:resourc
```

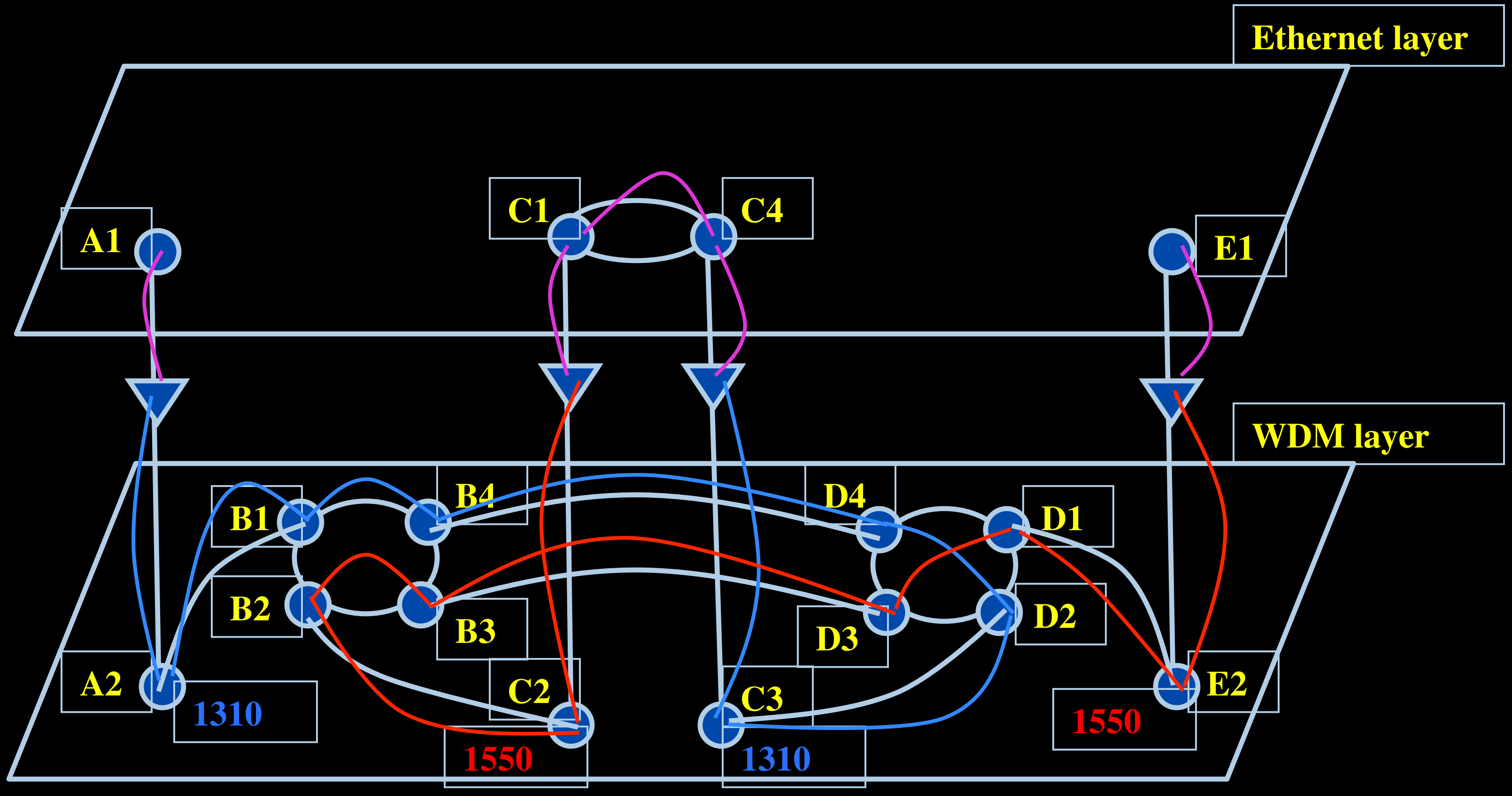
```
<!-- all the interfaces of TDM3.amsterdam1.netherlight.net -->

<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>
```

# Multi-layer descriptions in NDL



# Multi-layer Network PathFinding

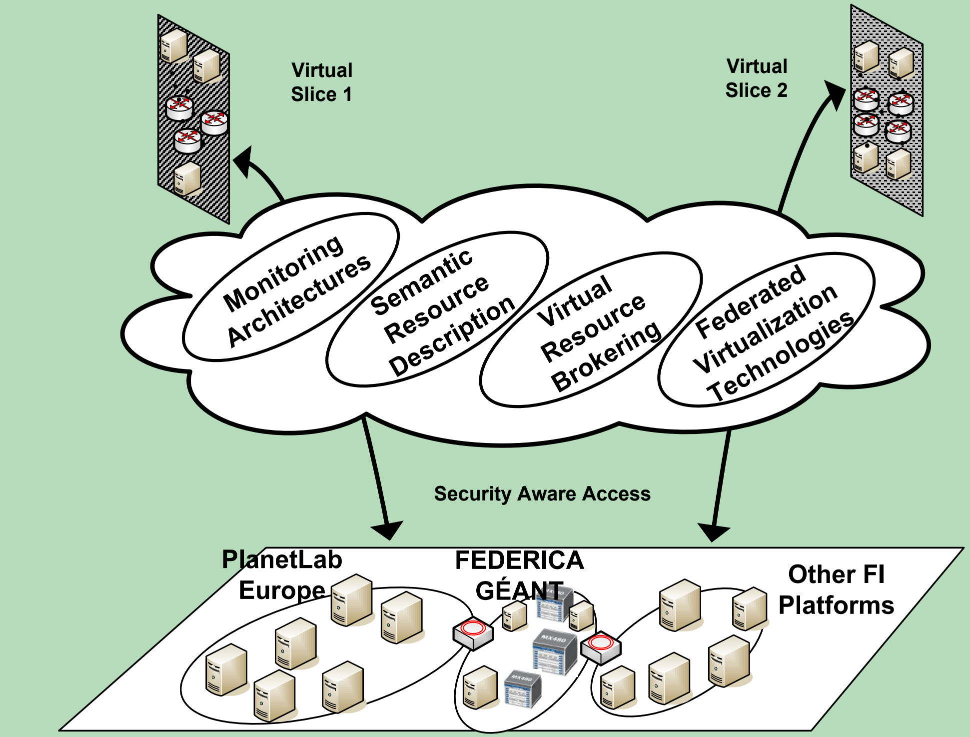


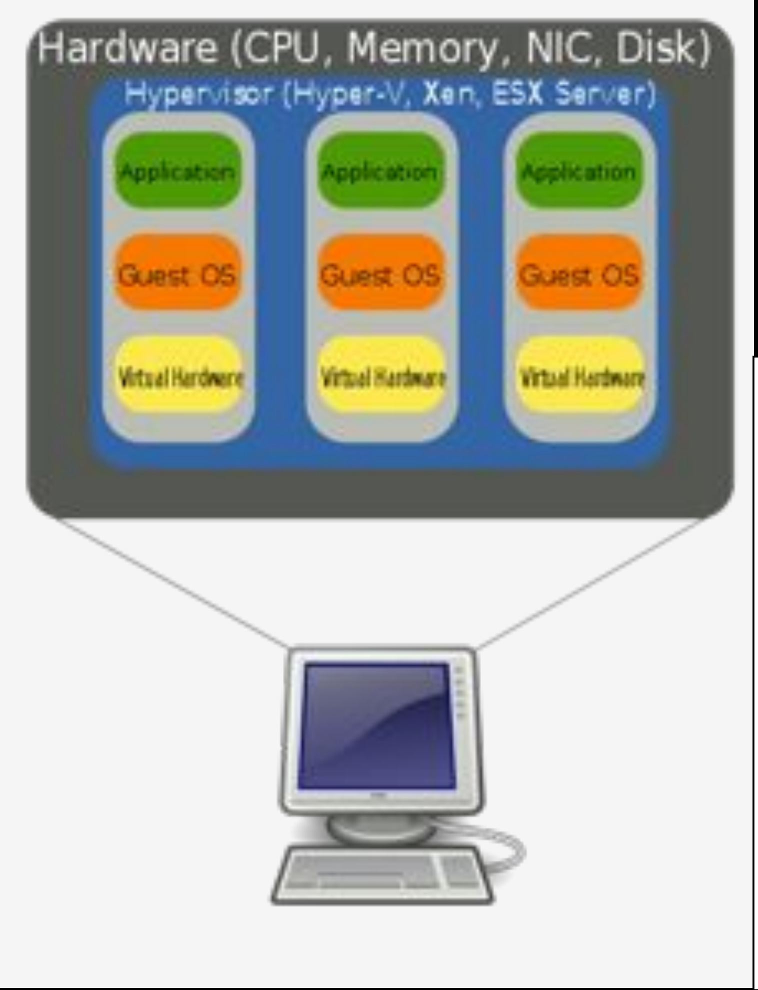

Path between interfaces A1 and E1:

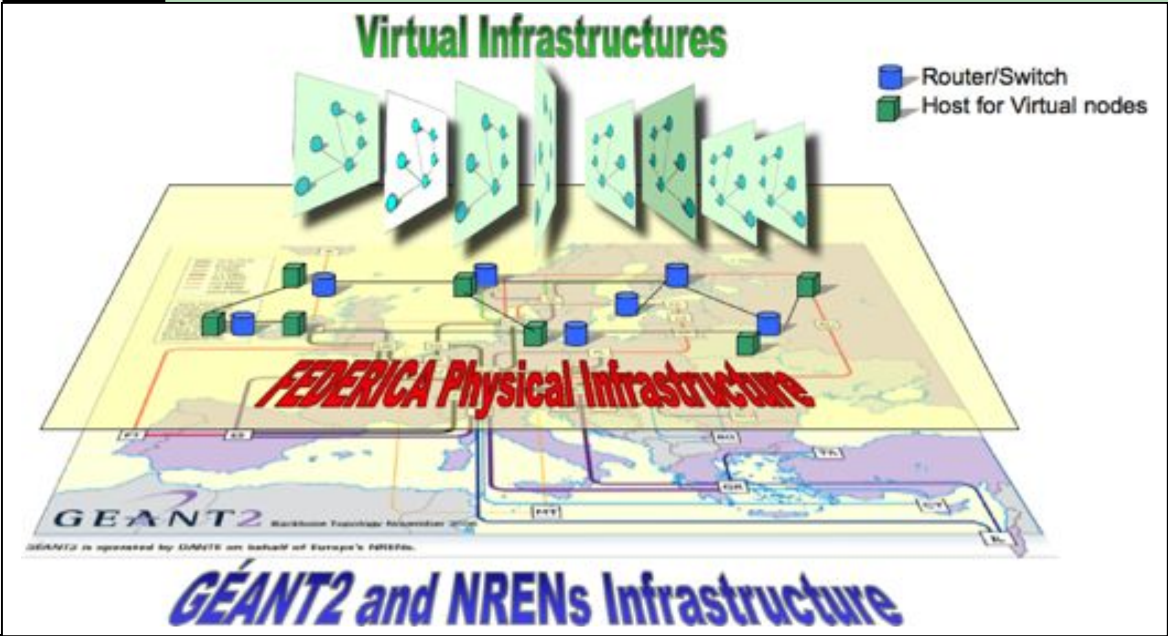
A1-A2-B1-B4-D4-D2-C3-C4-C1-C2-B2-B3-D3-D1-E2-E1

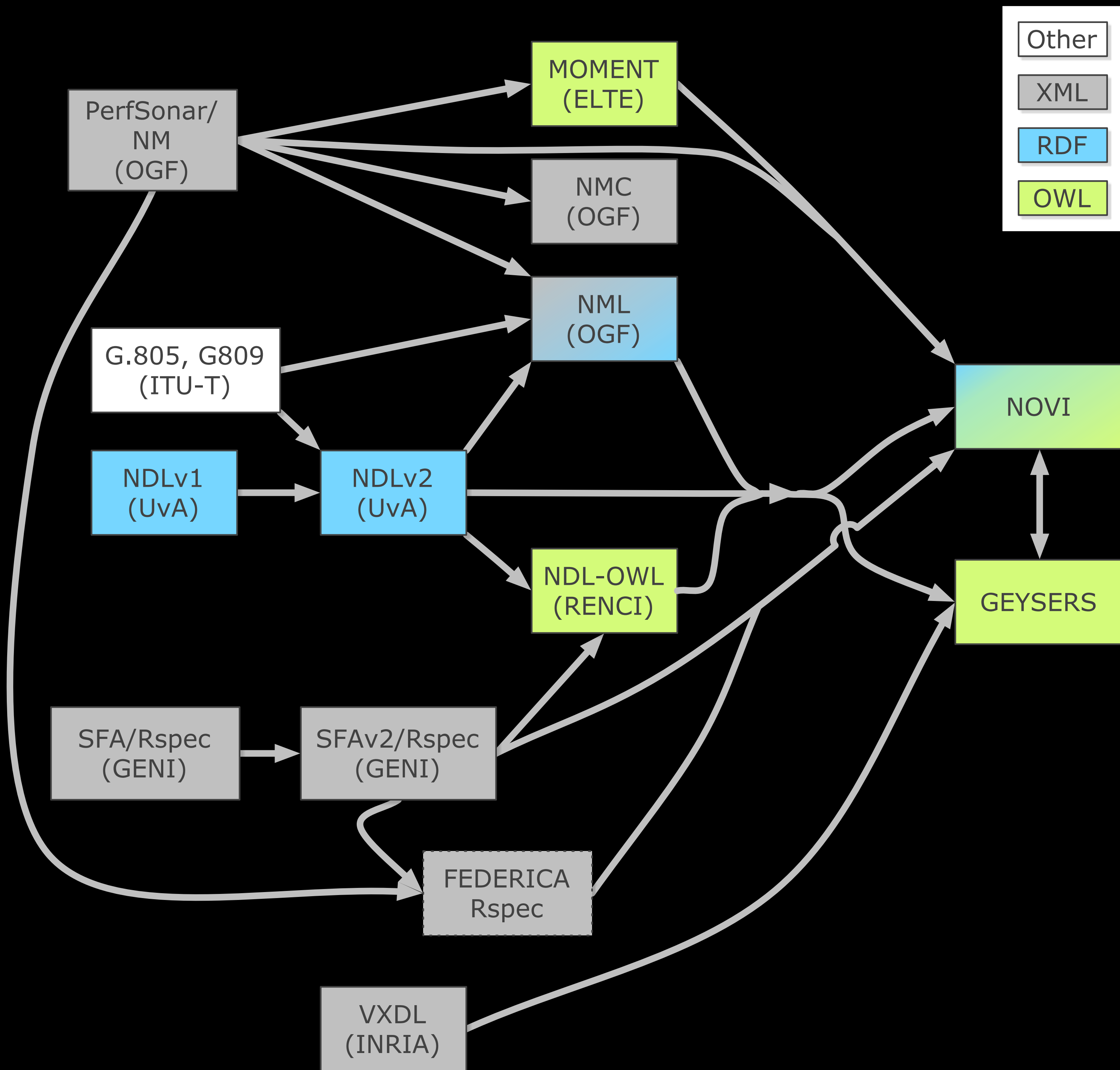
Scaling: Combinatorial problem

# Virtualisatie van infrastructuur & QoS



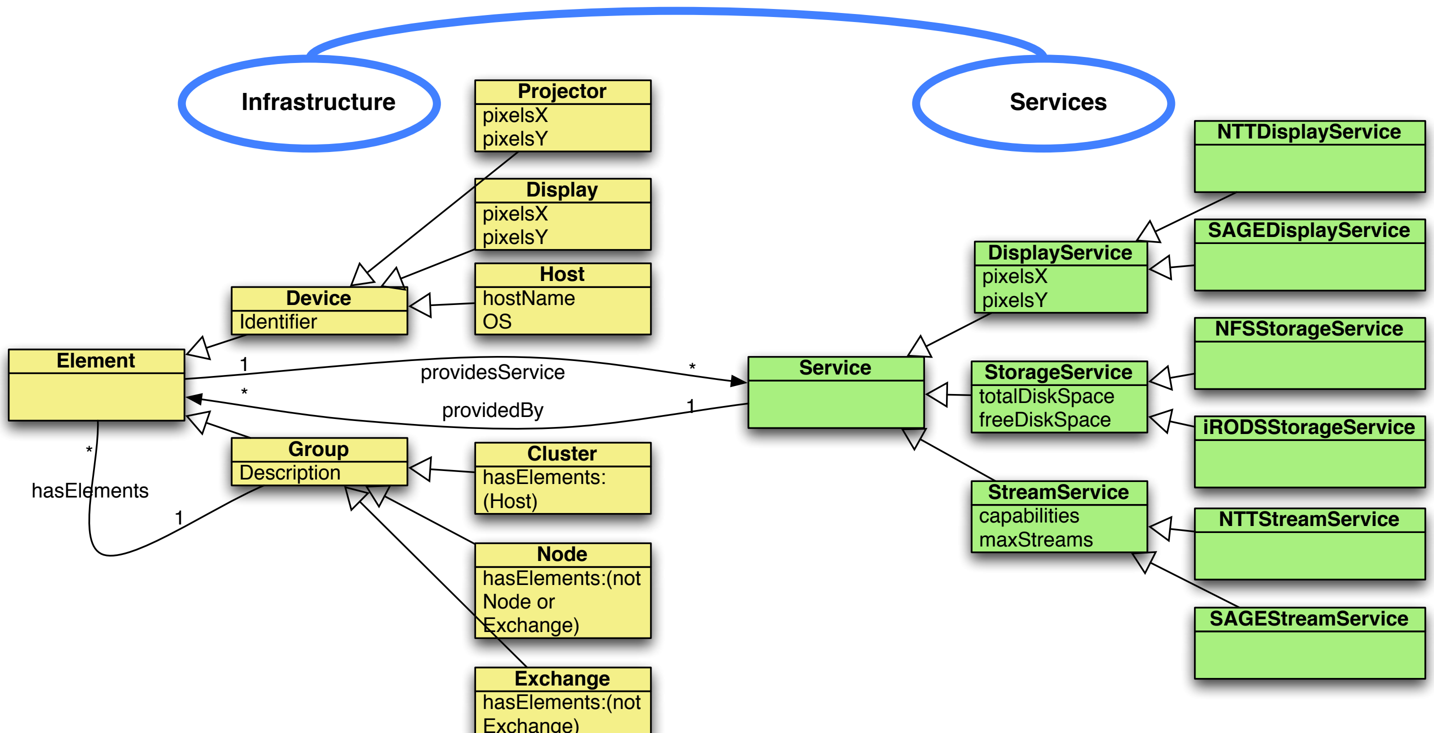




Other
XML
RDF
OWL
PerfSonar/
NM
(OGF)
MOMENT
(ELTE)
NMC
(OGF)
NML
(OGF)
G.805, G809
(ITU-T)
NDLv1
(UvA)
NDLv2
(UvA)
NDL-OWL
(RENCI)
NOVI
GEYSERS
SFA/Rspec
(GENI)
SFAv2/Rspec
(GENI)
FEDERICA
Rspec
VXDL
(INRIA)

# 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

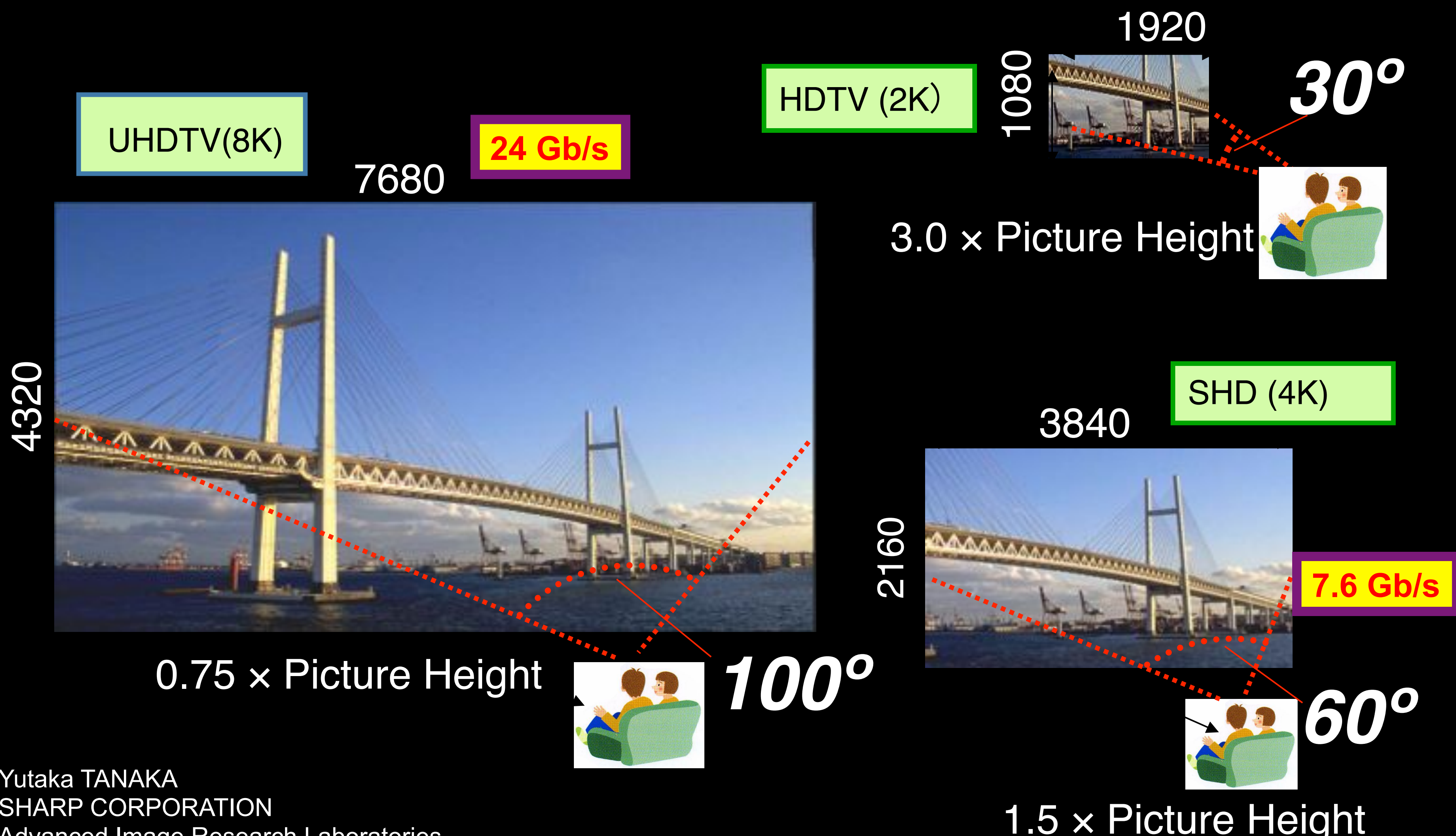
R.Koning, P.Grosso and C.de Laat
*Using ontologies for resource description in the CineGrid Exchange*
In: Future Generation Computer Systems (2010)

# SNE @ UvA

| | Ijkdijk/Urban Flood | Medical | LifeWatch/ENVRI | CosmoGrid/eVLBI | CineGrid | EU-GN3/NOVI/Geysers | SURFnet/GLIF/Cloud |
|---|---|---|---|---|---|---|---|
| Green-IT | | | | | | X | X |
| Privacy/Trust | | X | | | | X | |
| Authorization/policy | | X | X | | X | X | |
| Programmable networks | X | | X | | | | |
| 40-100Gig/TCP/WF/QoS | X | | | X | X | | X |
| Topology/Architecture | | | X | | X | X | X |
| Optical Photonic | | | | X | X | | X |

# Why is more resolution is better?

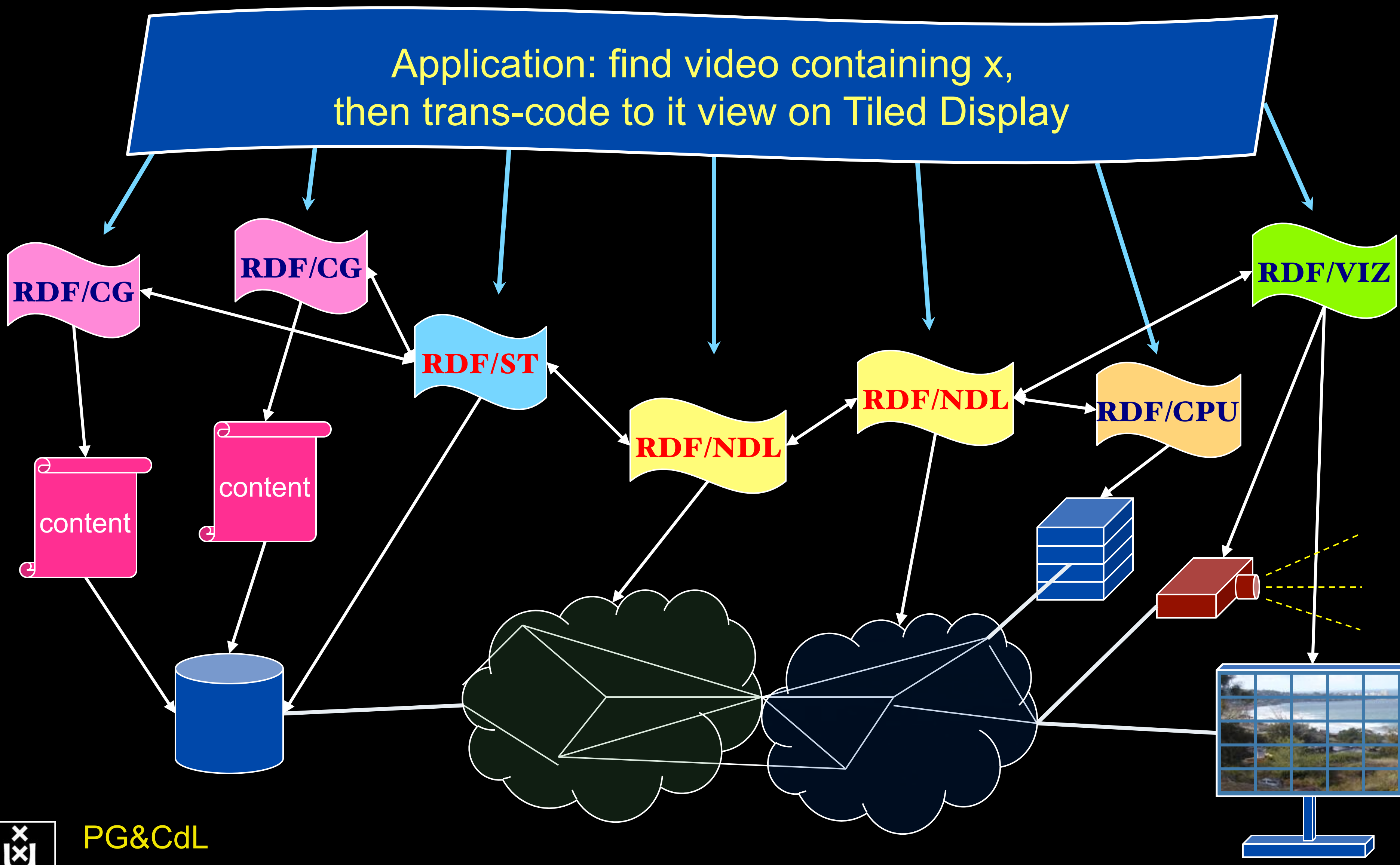
1. More Resolution Allows Closer Viewing of Larger Image
2. Closer Viewing of Larger Image Increases Viewing Angle
3. Increased Viewing Angle Produces Stronger Emotional Response





Yutaka TANAKA
SHARP CORPORATION
Advanced Image Research Laboratories

# RDF describing Infrastructure



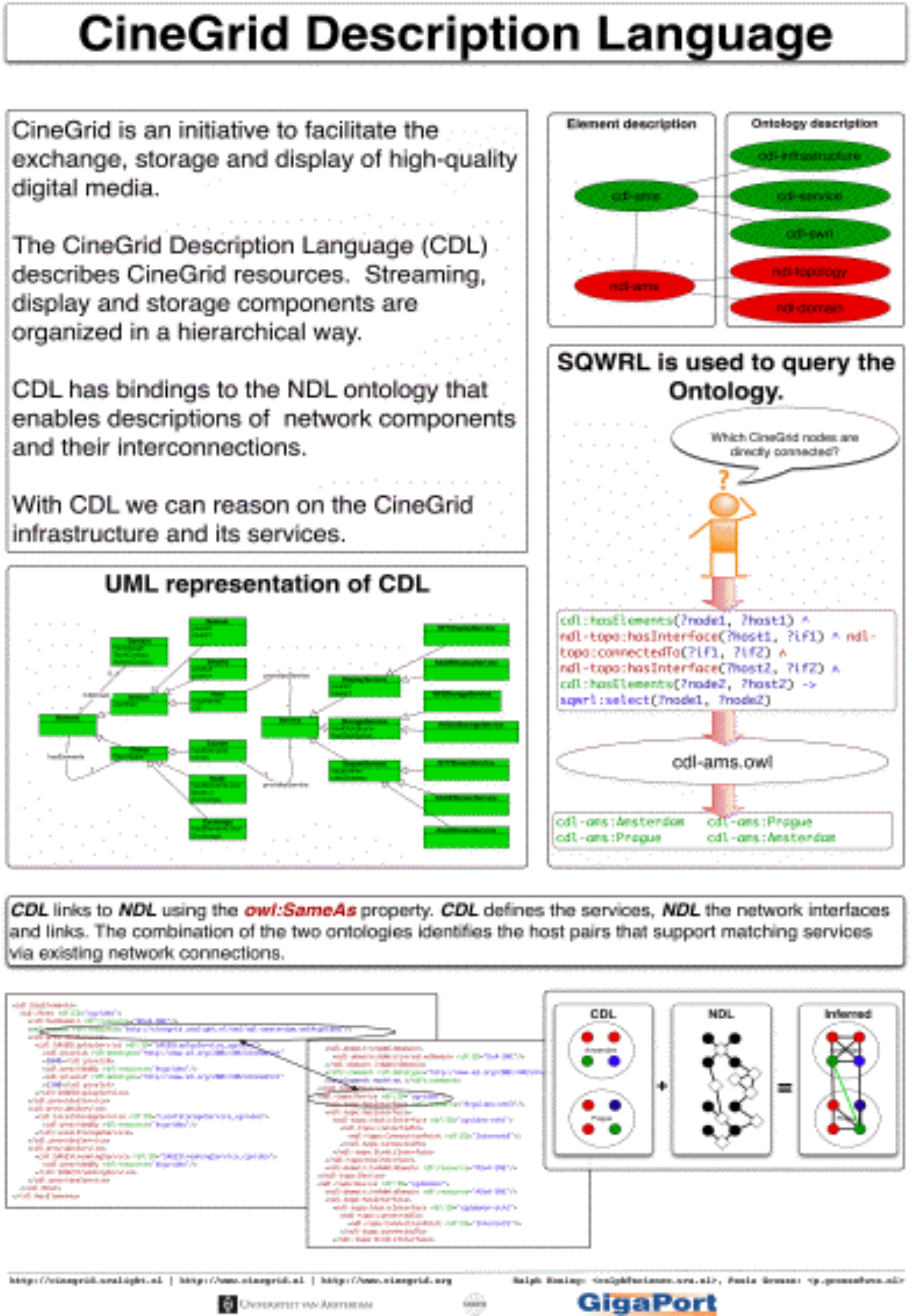
# Why?

## 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

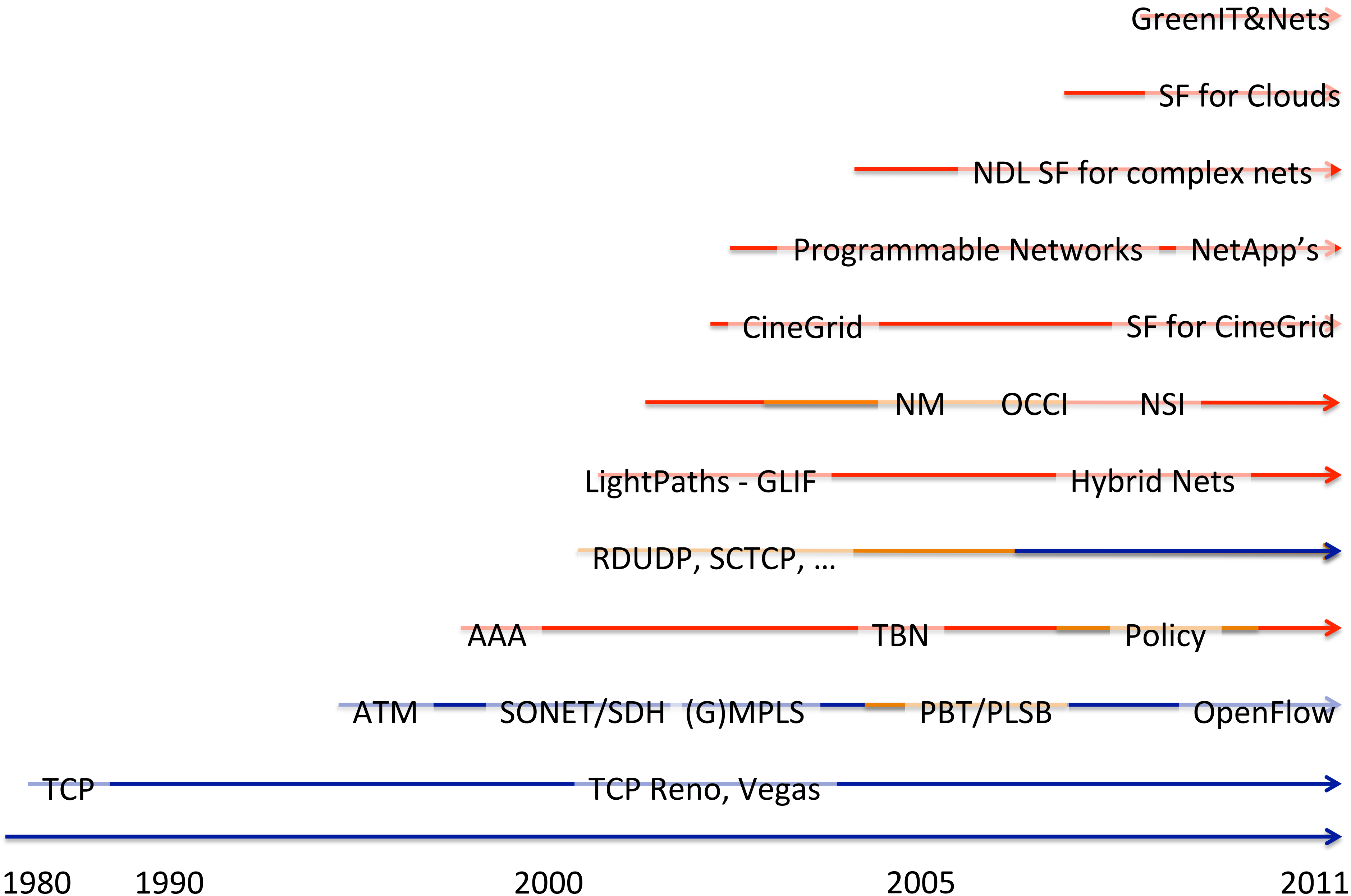
1. **Energy Efficient Communication**
2. Separation of Identity and Address
3. Location Awareness
4. **Explicit Support for Client-Server Traffic and Distributed Services**
5. Person-to-Person Communication
6. Security
7. **Control, Management, and Data Plane separation**
8. **Isolation**
9. Symmetric/Asymmetric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

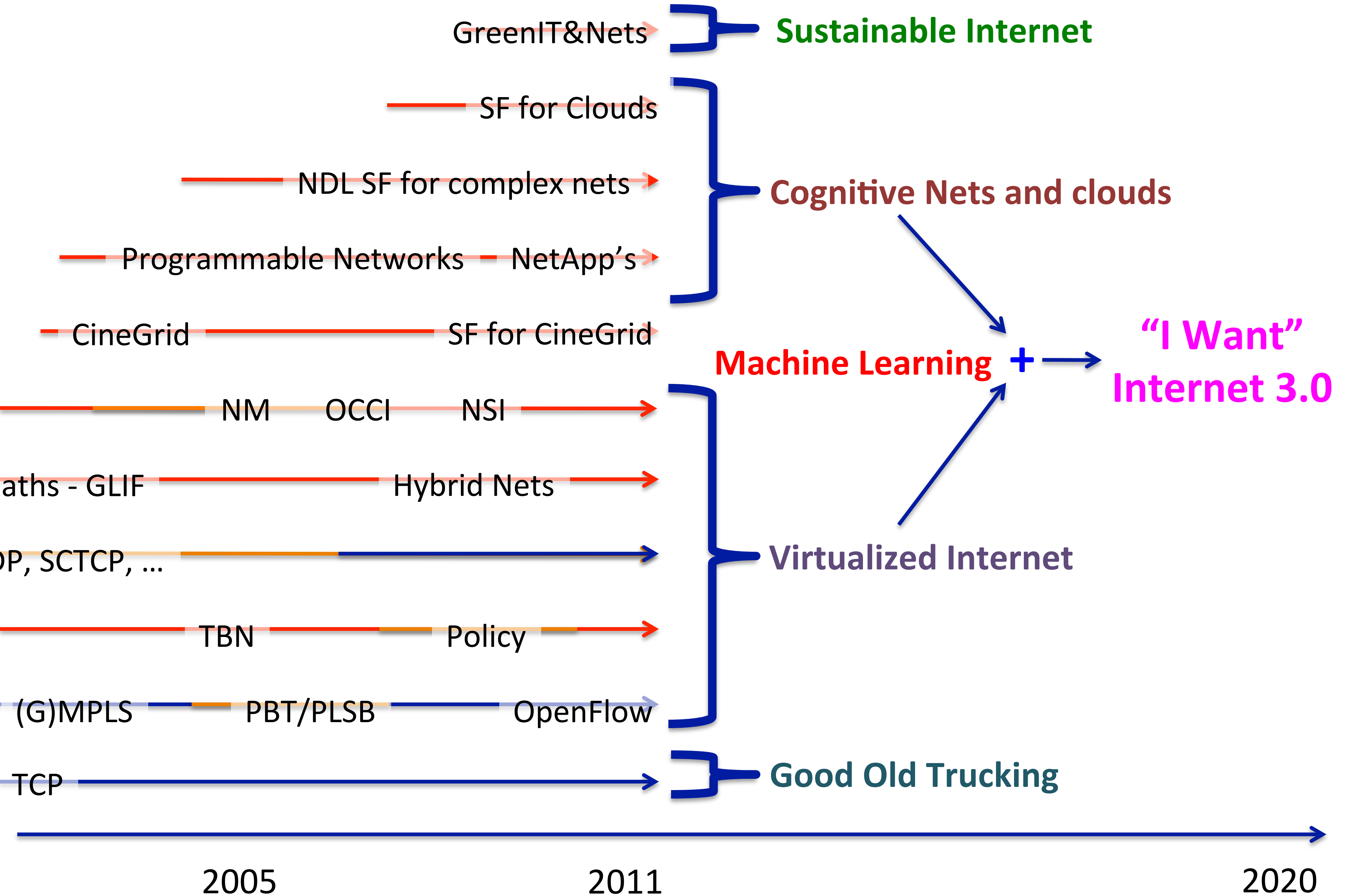
ref: Raj Jain, "Internet 3.0: Ten Problems with Current Internet Architecture and Solutions for the Next Generation", Military Communications Conference, 2006. MILCOM 2006. IEEE

# TimeLine



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
RDUDP, SCTCP, …
AAA
TBN
Policy
ATM
SONET/SDH
(G)MPLS
PBT/PLSB
OpenFlow
TCP
TCP Reno, Vegas
1980
1990
2000
2005
2011

# TimeLine



GreenIT&Nets
Sustainable Internet
SF for Clouds
NDL SF for complex nets
Programmable Networks
NetApp's
Cognitive Nets and clouds
CineGrid
SF for CineGrid
Machine Learning
+
"I Want"
Internet 3.0
NM
OCCI
NSI
aths - GLIF
Hybrid Nets
DP, SCTCP, …
Virtualized Internet
TBN
Policy
(G)MPLS
PBT/PLSB
OpenFlow
TCP
Good Old Trucking
2005
2011
2020

# TimeLine

- Sustainable Internet

- Cognitive Nets and clouds

lachine Learning + → "I Want" Internet 3.0

- Virtualized Internet

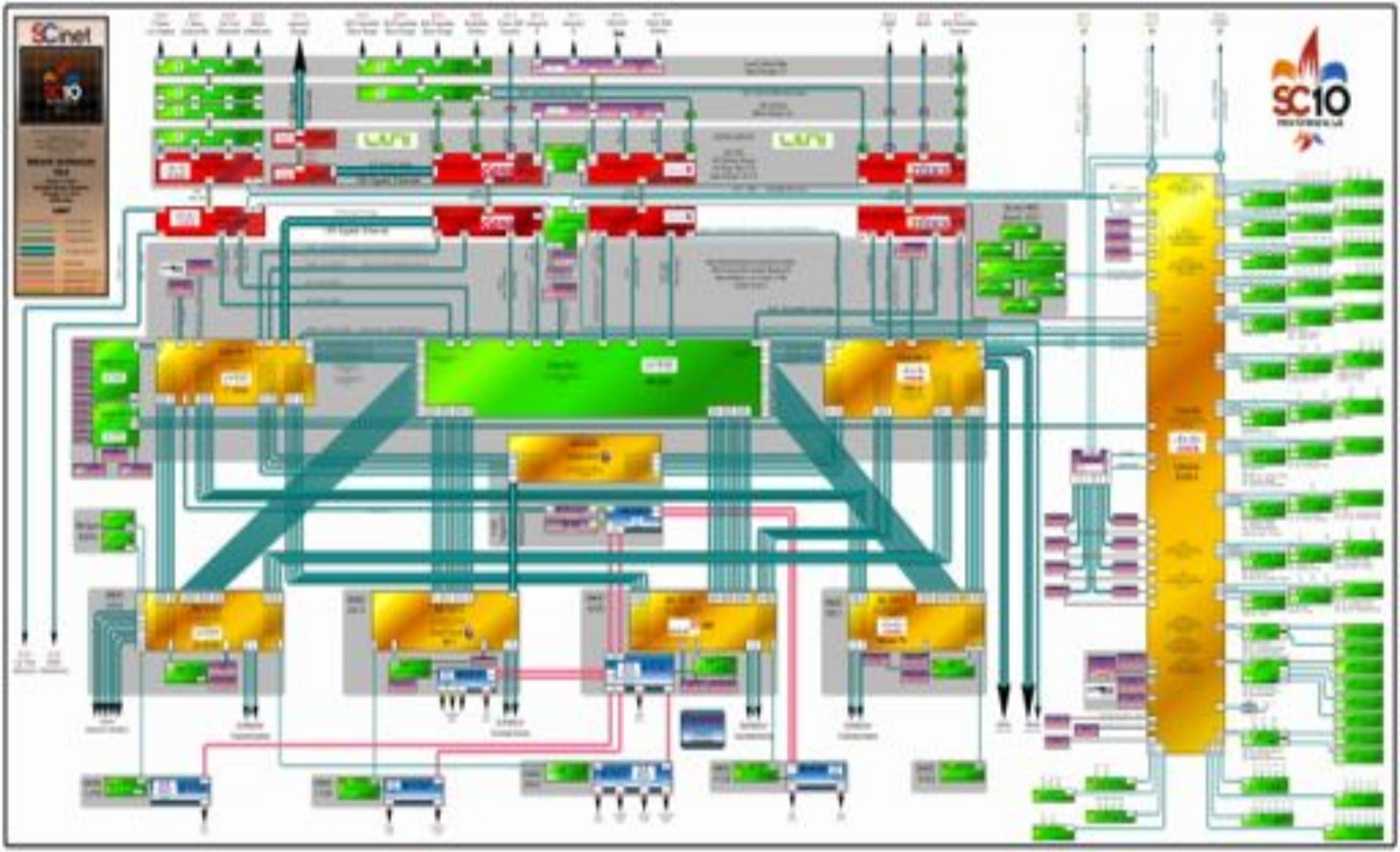
- Good Old Trucking

I retire

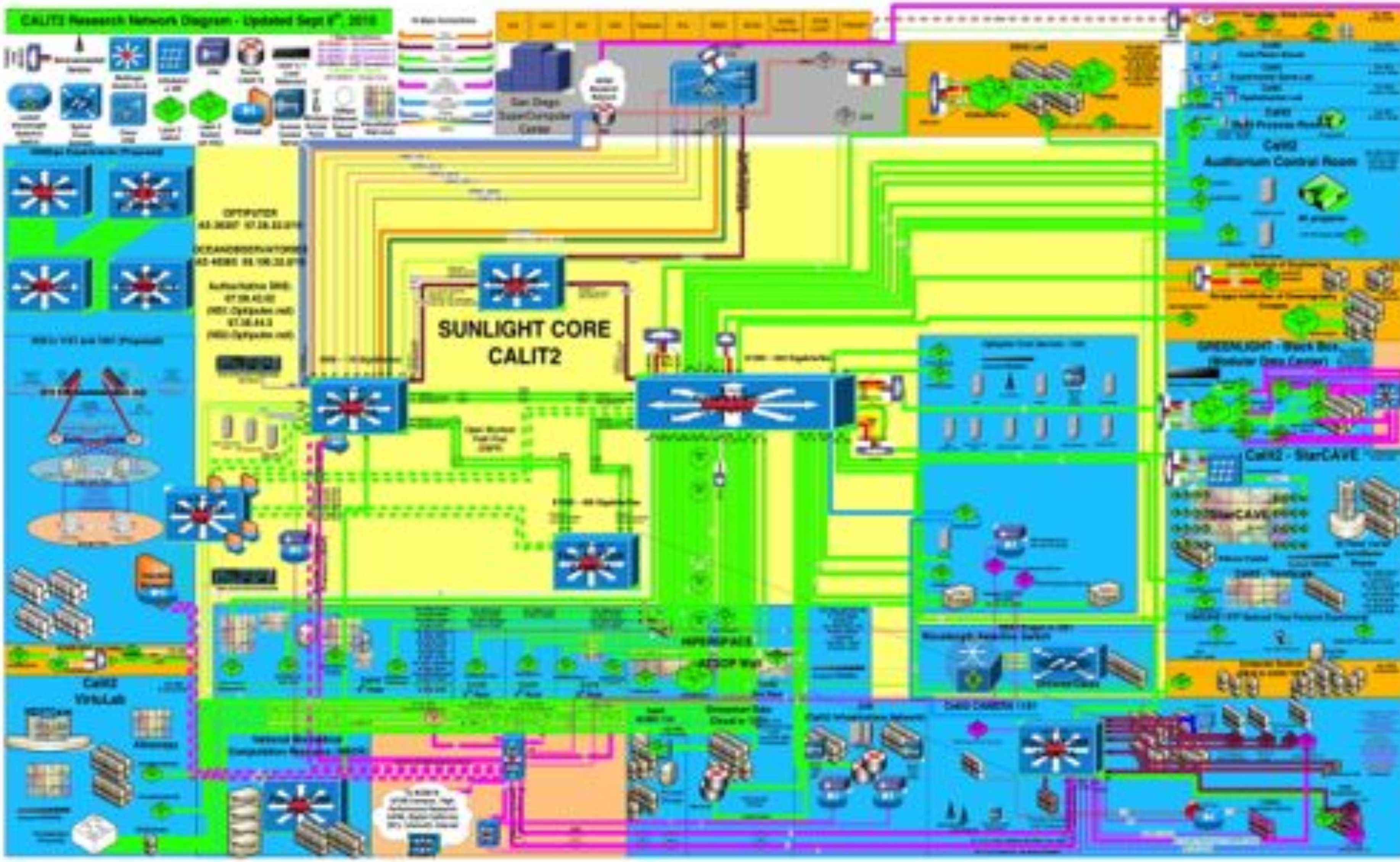
2020

2040

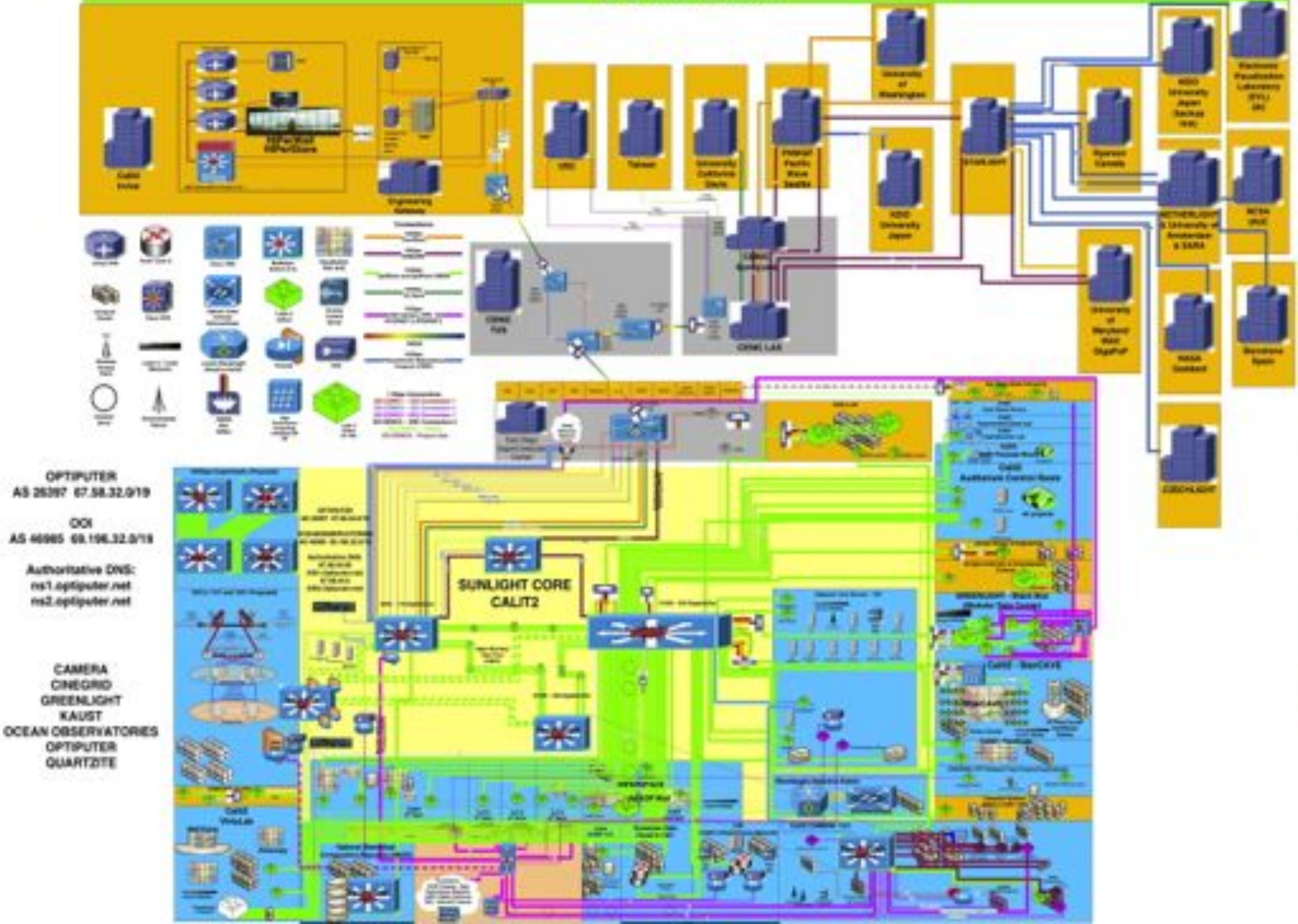
# Complex e-Infrastructure!

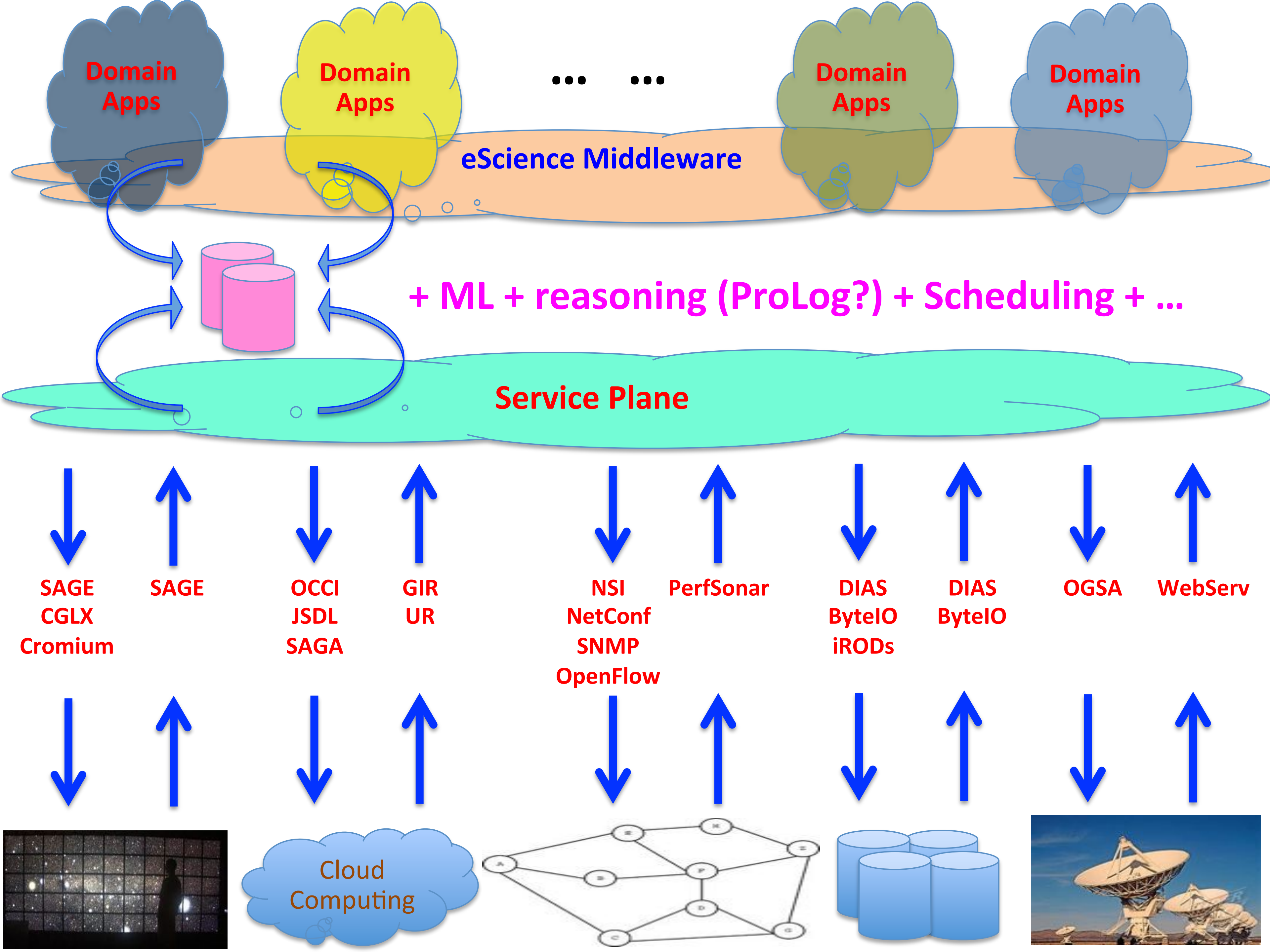


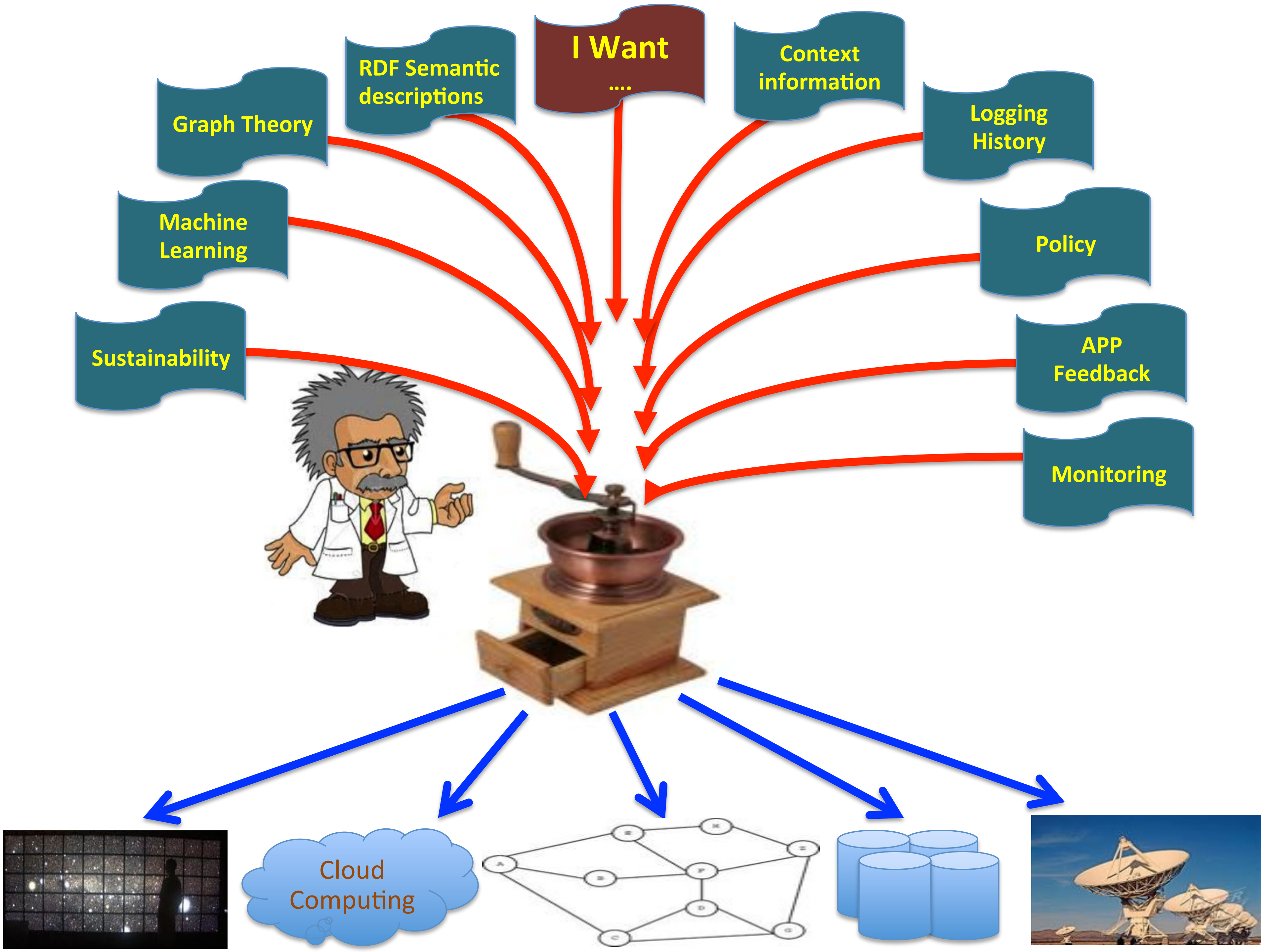
# Complex e-Infrastructure!



# California Institute for Telecommunications and Information Technology (Calit2)
## Wide Area Network




Domain Apps
Domain Apps
... ...
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
Cloud Computing



I Want
....
RDF Semantic descriptions
Context information
Graph Theory
Logging History
Machine Learning
Policy
Sustainability
APP Feedback
Monitoring
Cloud Computing

# 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

- 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

http://ext.delaat.net/

Slides thanks to:

- Paola Grosso
- Sponsors see slide 1. ☺
- SNE Team & friends, see below